The time to act is now

SoCalGas

2022
ANNUAL
REPORT

RESEARCH,
DEVELOPMENT, AND
DEMONSTRATION


“**California** is leading the planet
in building a clean energy future...

...and **SoCalGas®**, the nation's largest natural gas distribution utility, is collaborating with stakeholders to innovate...

...and to deploy new energy technologies so that every Californian can have access to **clean, safe, and reliable energy**."

—MARYAM BROWN
PRESIDENT
SOCALGAS

Contents

Introduction

Atmospheric greenhouse gas (GHG) emissions from human activities are driving climate change and are now at their highest levels in recorded history.[1,2] These GHGs trap heat, melting glaciers, warming the world's oceans, and raising sea levels.[3] A hotter Earth is also associated with more extreme weather-related events, including floods, heat waves, droughts, and hurricanes.[4]

As a result, some of the world's most sensitive ecosystems—from the High Arctic tundra to the ice shelves of Antarctica—are undergoing massive and sometimes irreversible change. The cost of climate change is not limited to the natural world. It affects every country on the Earth, and the poorest and most vulnerable people are often impacted the most.

The time to act is now.

To slow the pace of climate change and avoid its most significant consequences, aggressive action to reduce and ultimately eliminate net GHG emissions is required. One of the most impactful ways to do this is through a massive transformation in how the world produces and consumes energy. Fortunately, there has never been a time in human history when we have had more tools to do just that.

Guided by forward-thinking energy and environmental policy, countries around the world are developing scalable, effective, and increasingly affordable clean energy and clean transportation solutions. More and more people, businesses, and governments are adopting these technologies, driving down costs and increasing confidence in the new technologies. These efforts are paying off. In the last 10 years, the price of solar electricity has dropped by 89% and the price of wind electricity by 70%.[5]

Businesses are on board. Nearly half of the largest companies in the U.S. now recognize that they have a responsibility to tackle climate change and help preserve the planet for future generations.[6]

SoCalGas is a leader among those companies.

"We've already waited too long to deal with this climate crisis. We can't wait any longer. We see it with our own eyes, we feel it. We know it in our bones. And it's time to act."

—PRESIDENT JOE BIDEN

SoCalGas RD&D Pursues Innovation and Decarbonization

With more than 21 million customers and one of the nation's largest gas distribution systems, consisting of pipeline and storage facilities, SoCalGas is playing 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 clean fuels, such as renewable natural gas (RNG) and, potentially, green hydrogen. 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.

SoCalGas Research, Development, and Demonstration (RD&D)—a department within SoCalGas—is tasked with identifying and supporting projects and technologies with the potential to save energy, reduce GHG emissions, improve air quality, and increase the safety, reliability, and affordability of energy.

In 2022 alone, RD&D staff invested $13,430,264 in hundreds of energy technology and clean fuels projects—from technology that converts carbon dioxide (CO_2) from industrial sources into consumer products to fuel-flexible power generators or innovative hydrogen fuel cell yard trucks for demanding port operations.

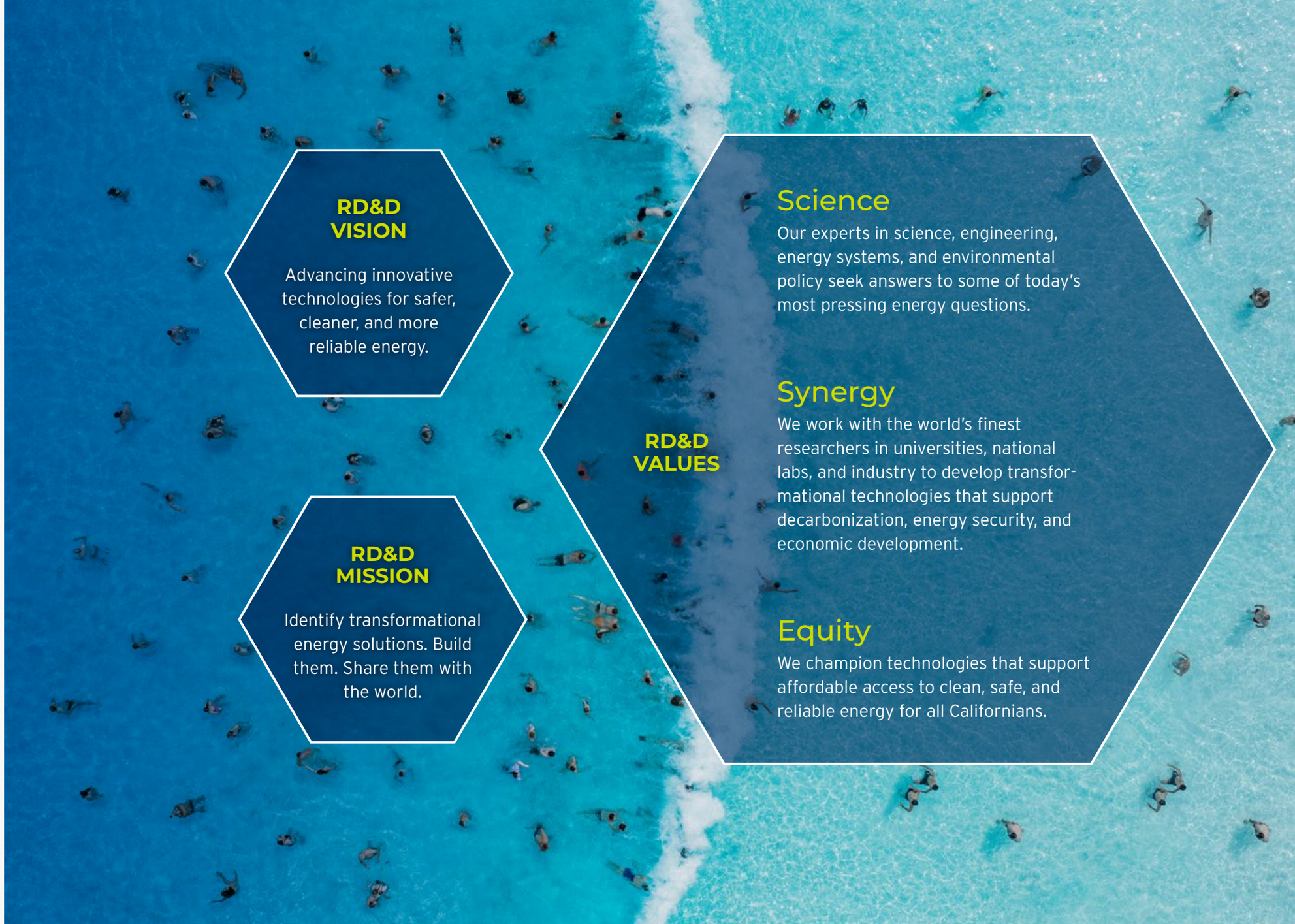
Driven by scientific research and collaboration with subject matter experts from universities, national labs, public agencies, private industry, and research consortia, RD&D staff are committed to accelerating the energy transition to clean fuels and to educating policymakers, industry, and the public about the many opportunities and technology pathways to achieve that goal.

"We are seeing exciting progress in making hydrogen cleaner, more affordable, and more available for use across different sectors of the economy."

—FATIH BIROL
EXECUTIVE DIRECTOR
INTERNATIONAL ENERGY AGENCY

Vision, Mission, & Values

The vision, mission, and values of SoCalGas RD&D align with SoCalGas' mission to build the cleanest, safest, and most innovative energy infrastructure company in America.



RD&D VISION

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

RD&D MISSION

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

RD&D 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, SoCalGas RD&D 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.

2022
IN REVIEW

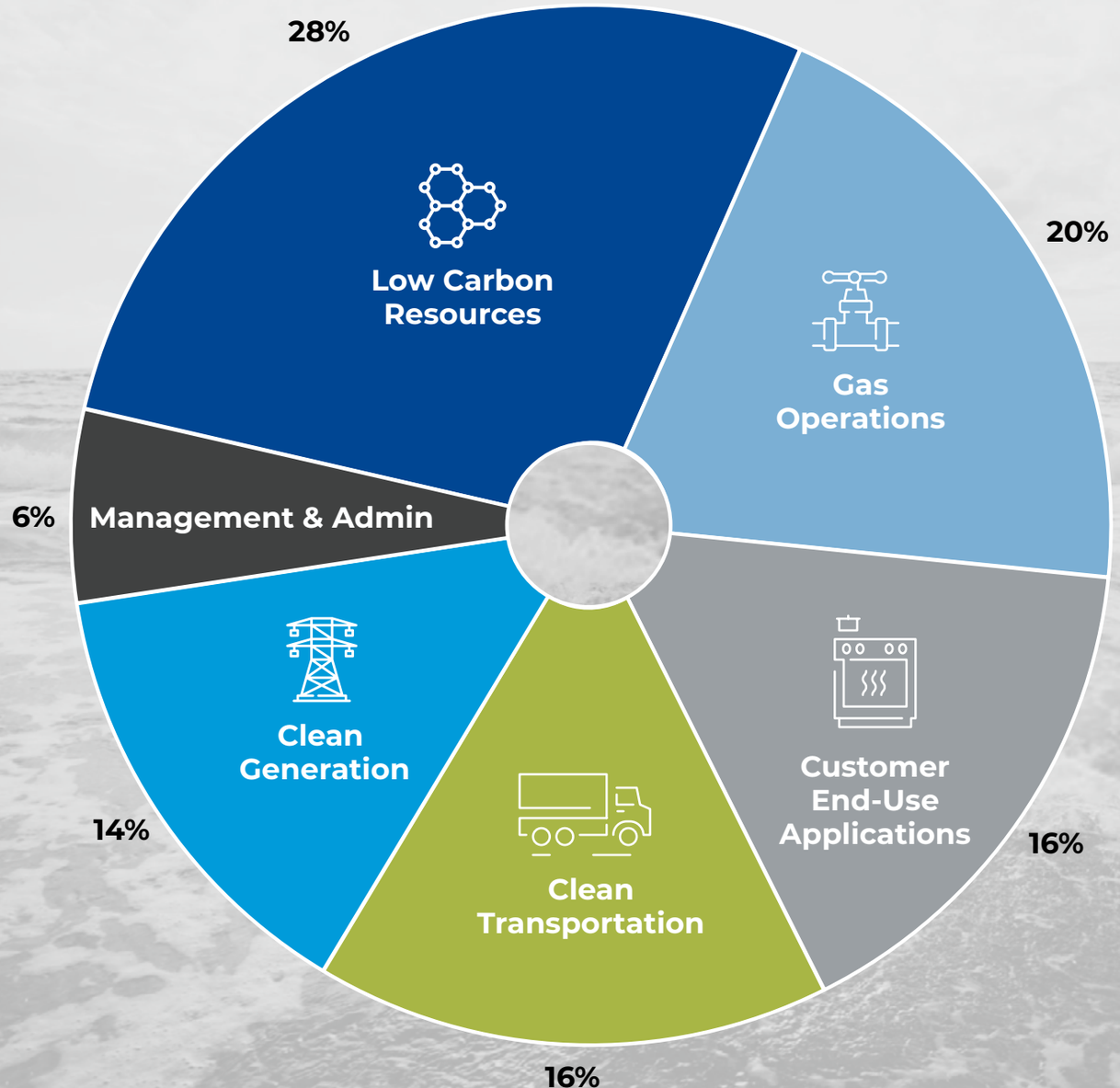
"Developing a source of safe, affordable green hydrogen is key to achieving our clean energy future by 2035, while ensuring the reliability we all need and depend on."

—MARTY ADAMS
CHIEF ENGINEER AND GENERAL MANAGER, LOS ANGELES DEPARTMENT OF WATER AND POWER

Financial Highlights

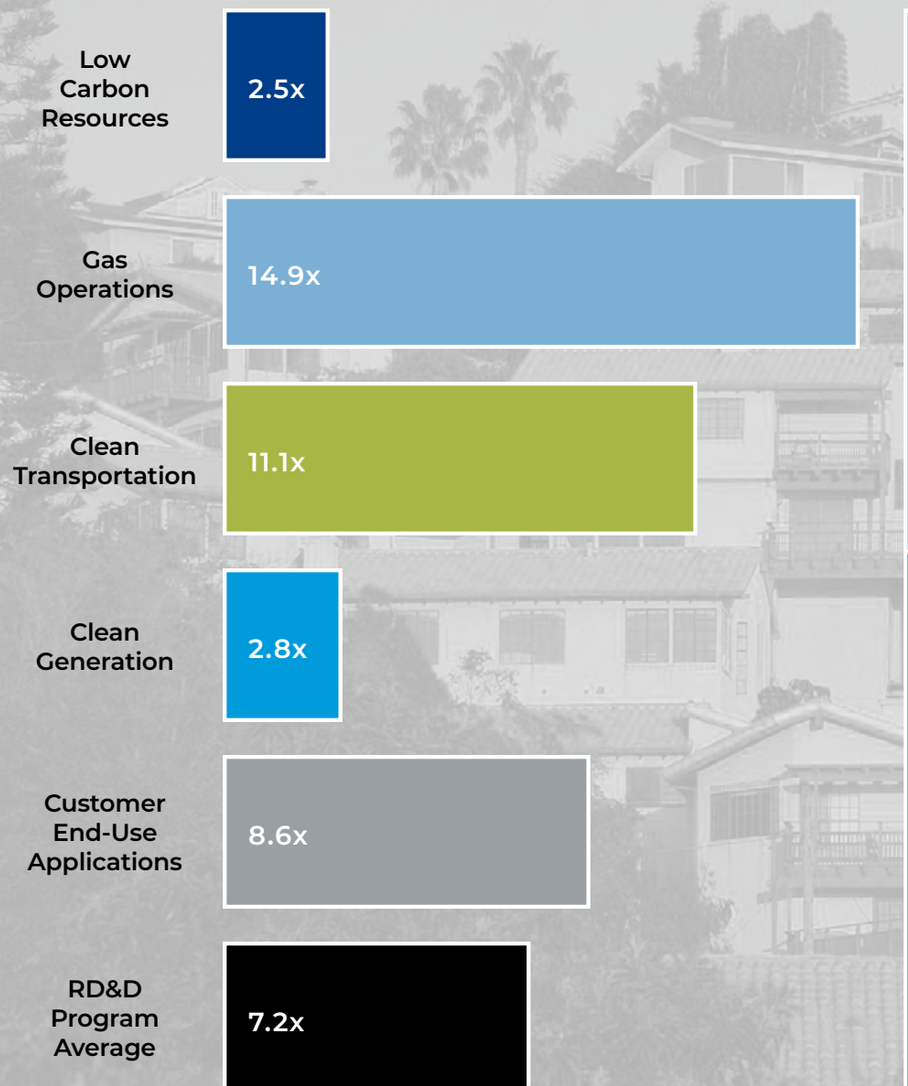
In 2022, SoCalGas RD&D supported 339 RD&D projects and distributed $13,430,264 to projects across the entire gas value chain in California. In executing these projects, SoCalGas collaborated with many of the most forward-thinking research consortia, universities, national labs, public agencies, and entrepreneurs in the nation and the world. Collectively, these organizations provided significant leveraged funding as well as invaluable guidance, review, technical expertise, and access to resources and infrastructure.

2022 ACTUAL FUNDING BY PROGRAM AREA AND ADMINISTRATIVE COSTS



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

RATIO OF OUTSIDE FUNDING TO SOCALGAS FUNDING



2022 Funds Expended

In 2022, SoCalGas RD&D invested $13,430,264 in hundreds of projects across the gas value chain, with an additional $1,567,990 going to program management and administration. SoCalGas RD&D allocated funding across the five program areas and multiple subprograms. Collectively, these projects leveraged significant co-funding from businesses, research consortia, the California Energy Commission (CEC), the U.S. Department of Energy (DOE), and other participating organizations. On average, every dollar of RD&D funds expended was matched by approximately $7.20 of funding from other sources in 2022.

PROGRAM	2022 ACTUALS
Low Carbon Resources	$4,952,553
Gas Operations	$3,228,435
Clean Transportation	$1,778,809
Clean Generation	$1,697,347
Customer End-Use Applications	$1,773,120
SUBTOTAL	**$13,430,264**
Management & Administration	$1,567,990
TOTAL	**$14,998,254**

Significant 2022 Milestones

2022 ANNUAL STAKEHOLDER WORKSHOP

On April 27, 2022, SoCalGas RD&D hosted an online workshop attended by 402 individuals from a variety of organizations, including the Electric Power Research Institute (EPRI), Pacific Northwest National Laboratory, Southern California Edison, the National Renewable Energy Laboratory, Regional CAL Black Chamber SFV, Hermandad Mexicana Nacional, the California Institute of Technology, and the University of California. RD&D staff incorporated input received at the workshop into the 2023 RD&D SoCalGas Research Plan.

402

PEOPLE ATTENDED THE 2022 ANNUAL STAKEHOLDER WORKSHOP

RESEARCH WEBINARS

In 2022, SoCalGas presented quarterly research webinars discussing four projects supported by SoCalGas RD&D.

612

PEOPLE ATTENDED SOCALGAS RD&D RESEARCH WEBINARS IN 2022

» **Thermal Particle Fluid for Commercial and Industrial Emissions Reductions**
February 25, 2022: This webinar was with GTI Energy, discussing an innovative thermal particle fluid (TPF) that can recover, store, and transport heat for large commercial and industrial processes. By recovering and reusing waste heat, TPFs can reduce fuel demand for large process heat systems, resulting in lower combustion emissions and decreased customer costs.

» **Gas Mapping LiDAR™ Airborne Methane Leak Detection and Emissions Monitoring**
May 20, 2022: During this program, Mike Thorpe, CTO of Bridger Photonics, Inc., spoke about Gas Mapping LiDARTM (GML), an airborne methane emission monitoring technology that detects, localizes, and quantifies methane emissions from all segments of the natural gas value chain. Thorpe provided an overview of the GML technology, discussed results from performance validation testing, and described how it's being used for emissions monitoring surveys in the SoCalGas service area.

» **An Inflection Point for Global Pipeline Safety and Integrity**
August 15, 2022: In this webinar, Cliff Johnson, President of Pipeline Research Council International (PRCI), introduced his organization's drive for lower emissions and a lower carbon future. This session explained the multifaceted strategy that PRCI is taking to enable the safe transport and storage of hydrogen and renewable natural gas.

» **Metal Supported Solid Oxide Fuel Cells: The Key to Efficient, Fast Start Backup Power Generation**
October 27, 2022: In this webinar, SoCalGas RD&D and Lawrence Berkeley National Laboratory (LBNL) discussed an innovative metal-supported solid oxide fuel cell (MS-SOFC) that can be used for clean power generation and electrolytic hydrogen production.

Significant 2022 Milestones

TOTAL FOLLOW-ON FUNDING

$513M+

IN 2022

FOLLOW-ON FUNDING

Numerous companies that received early support from SoCalGas RD&D have received significant follow-on investment, demonstrating the program's ability to not only identify promising, early-stage technologies, but also to advance them toward commercialization. In 2022, 14 companies received follow-on funding:

» AVNOS
In addition to a $650,000 investment from SoCalGas in 2021, Avnos raised $3.2 million in funding to advance research and development of a carbon capture technology called Isothermal Water Vapor and CO_2 Capture. This includes partial funding from the DOE.

» BLUE FRONTIER
Blue Frontier raised a $20 million Series A equity investment in 2022 from its commercialization partner Modern Niagara as well as through Breakthrough Energy Ventures, 2150 Urban Tech Sustainability Fund, and VoLo Earth Ventures.

» BRIDGER PHOTONICS
Bridger Photonics raised a $55 million investment in 2022 from Beaverhead Partners LLC—a syndicate including Madison Valley Partners, Carica Sustainable Investments, and Next Frontier Capital—to support the company's growth and the continued development of methane detection technology.

» BRIMSTONE
In April 2022, Breakthrough Energy Ventures and DCVC co-led a $55-million funding round in Brimstone to further the commercialization of carbon-negative cement.

» CAPTURA
Captura raised $500,000 from the Advanced Research Projects Agency-Energy through the Supporting Entrepreneurial Energy Discoveries program in 2022 for the development of thin film composite hollow-fiber membranes for direct ocean capture of carbon dioxide.

» C-ZERO
C-Zero secured $34 million through a financing round led by SK Gas, Engie New Ventures, and Trafigura, in addition to participation from existing investors Breakthrough Energy Ventures, Eni Next, Mitsubishi Heavy Industries, and AP Ventures.

» ELECTROCHAEA
Electrochaea completed its fifth round of funding in January 2022, raising $41 million from investors including Baker Hughes Co. and Engie SA to advance commercialization efforts.

Significant 2022 Milestones

TOTAL **ACTIVE PROJECTS** IN 2022

339

TOTAL **PROJECTS INITIATED** IN 2022

57

TOTAL **PROJECTS COMPLETED** IN 2022

90

FOLLOW-ON FUNDING

(continued)

» **H2U**
In addition to raising $7 million in Series A financing in 2021, H2U raised $11 million in Series A funding in 2022 from investors including Jericho Energy Ventures, Freeflow Ventures, VoLo Earth Ventures, and Hess Corporation.

» **KEVALA**
Kevala raised $12.1 million in Series A funding in 2022, led by Cercano Management and with participation from existing investors Costanoa Ventures, High Alpha, and PSL Ventures.

» **MAINSPRING**
Led by global growth equity investor Lightrock, Mainspring's first stage of Series E funding in 2022 raised over $150 million. Additional investors include Khosla Ventures, Bill Gates, Fine Structure Ventures, Princeville Capital, and Lineage Ventures. The funding will contribute to the development of new linear generator models and the acceleration of zero-carbon electricity production.

» **STARS**
Fuse Fund led a $500,000 funding round for STARS for the deployment of a commercial hydrogen generator. Fuse invested $150,000 and collaborated with other investors to raise a total of $500,000.

» **SUSTAERA**
Sustaera raised $500,000 from the Advanced Research Projects Agency-Energy through the Supporting Entrepreneurial Energy Discoveries program in 2022 for development of a novel direct air capture demonstration unit.

» **SUSTEON**
After early support from SoCalGas, Susteon received $1 million from the DOE in 2022 to investigate a CO_2 carbon capture solvent.

» **TWELVE**
Following support from SoCalGas RD&D, this electrochemical carbon dioxide reduction startup raised $130 million in Series B funding, with participation from Series A lead investors Capricorn Technology Impact Fund and Carbon Direct Capital Management. Twelve has also secured a Series B and strategic program investment from the Chan Zuckerberg Initiative.

Significant 2022 Milestones

PUBLICATIONS

In 2022, 37 projects co-funded or otherwise supported by SoCalGas RD&D were featured in articles, reports, and technology briefs. Additionally, three technologies supported by RD&D received patents from the U.S. Patent and Trademark Office.

See Appendix for more information.

PUBLIC FUNDING

In 2022, RD&D staff supported eight winning proposals applying for public funding. These projects were awarded $18,305,406 in research funding from the California Energy Commission (CEC) and Department of Energy (DOE).

8 PROJECTS WON A TOTAL OF **$18,305,406** FROM THE CEC AND DOE

DEPLOYED TECHNOLOGIES

A major goal of SoCalGas RD&D is to bring technology from the lab to market. In 2022, 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 SoCalGas RD&D. Examples from 2022 include:

- Blending Modeling (Hydrogen)
- Center for Hydrogen Safety
- Common RNG Interconnection Skid Development for Utilities (T-789)
- Computed Tomography (CT) Fundamentals with Calibration and Reference Standards for Pipeline Anomaly Detection (NDE-2-12)
- Expansion of NYSEARCH Range Model (M2018-008) Phase II-a
- Gas Composition and Quality
- GIS Portal Data Quality Improvement
- Hydrogen Blend into Natural Gas - Phase 2 - Metallic Materials (6.14.b.2)
- LDC Focused Gap Analysis & SOTA Study on Decarbonization (M2021-010)
- Modeling and Assessing PE Assets with 3D Scanning Technology
- OIML Test Data Summary for New Generation Ultra Sonic Meters (MEAS-6-21)
- Remaining Life Model and Assessment Tool for Dents and Gouges (MD-4 16)
- Steel Transmission Pipeline System Analysis
- Uniform Frequency Code (5.18.m)
- Update ASTM Standard on Soil Compaction Using the DCP (5.20.o)
- Update of PRCI Pipeline Repair Manual (MATR-3-1A)

2022 Equity Activities

THE RD&D PROGRAM SUPPORTED

61

PROJECTS LOCATED IN ESJ **COMMUNITIES** IN 2022

SOCALGAS SPENT

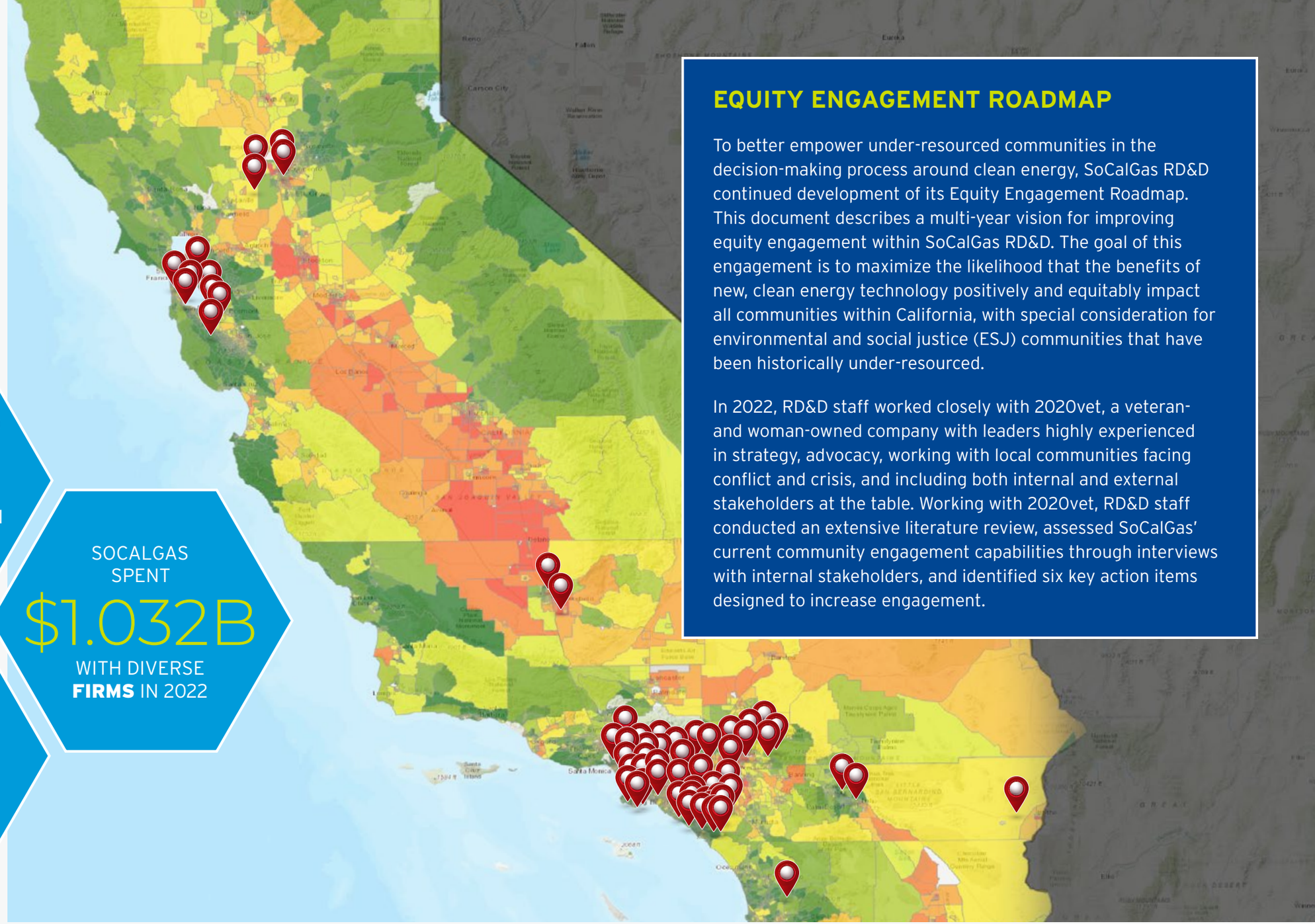
$1.032B

WITH DIVERSE **FIRMS** IN 2022

SOCALGAS WORKED WITH

578

DIVERSE **SUPPLIERS** IN 2022



EQUITY ENGAGEMENT ROADMAP

To better empower under-resourced communities in the decision-making process around clean energy, SoCalGas RD&D continued development of its Equity Engagement Roadmap. This document describes a multi-year vision for improving equity engagement within SoCalGas RD&D. The goal of this engagement is to maximize the likelihood that the benefits of new, clean energy technology positively and equitably impact all communities within California, with special consideration for environmental and social justice (ESJ) communities that have been historically under-resourced.

In 2022, RD&D staff worked closely with 2020vet, a veteran- and woman-owned company with leaders highly experienced in strategy, advocacy, working with local communities facing conflict and crisis, and including both internal and external stakeholders at the table. Working with 2020vet, RD&D staff conducted an extensive literature review, assessed SoCalGas' current community engagement capabilities through interviews with internal stakeholders, and identified six key action items designed to increase engagement.

SPOT LIGHT

2022 EQUITY ACTIVITIES

Engineering professor realizes childhood dream and inspires others

Dr. Bihter Padak conducts combustion engineering research while providing guidance, insight, and encouragement to aspiring female and minority students.

Dr. Bihter Padak: "I'm not only trying to show the students what it's like to be an engineer, but also to serve as a role model for female or minority students."

As a child, Dr. Bihter Padak dreamed of becoming a professor. "Growing up in Istanbul, Turkey, my first encounters with professors were in the medical field," said Padak, who realized her childhood dream and now serves as both an Assistant Professor in the Mechanical and Aerospace Engineering Department at The University of California, Irvine (UCI) and the Associate Director of the UCI Combustion Laboratory (UCICL).

Dr. Padak's educational journey was one of exploration and knowledge-seeking. In high school, she first became interested in chemistry. A few years later, while studying chemical engineering at the Istanbul Technical University (İTÜ), she took a course on reaction engineering. "I knew then that I wanted to pursue graduate studies in reaction engineering and kinetics," said Padak.

At this point, she encountered what appeared to be an insurmountable hurdle. At İTÜ, it is usually expected that faculty candidates spend time outside the country to broaden their perspectives. "I don't come from a wealthy family, so I didn't think I could afford to travel to the United States or enter a PhD program—a pivotal step to becoming a professor," said Padak.

Fortunately, Dr. Padak studied under Professor Birgul Ersolmaz, who would become her mentor. "In my junior year, Professor Ersolmaz, who received her PhD in the United States, told me that if I could receive a graduate assistant position, then I would not have to pay for tuition and would receive a stipend to cover my living expenses," said Padak.

Armed with this revelation, Dr. Padak dedicated herself to her studies and soon entered graduate programs at Worcester Polytechnic Institute in Worcester, Massachusetts and then at Stanford University. After earning her doctorate from Stanford, she accepted a faculty appointment in the Chemical Engineering Department at the University of South Carolina, where she conducted research until her move to UCI in 2018.

At UCICL, Dr. Padak and her team are researching ways to reduce greenhouse gas emissions and combat climate change. To secure funding for these activities, she spends considerable time preparing grant applications. On several occasions, she has also worked closely with SoCalGas, including on a project recently funded by the California Energy Commission (CEC). "One of the best parts about collaborating with SoCalGas on fundamental research is their willingness to publish the results," said Padak. "With their help, we are actually contributing to science."

In addition to this technical and scientific work, Dr. Padak believes in the importance of serving as a role model to female or minority students who may not receive much encouragement in Science, Technology, Engineering, and Math (STEM).

"People are often surprised to find that I am an engineering professor conducting combustion-related research," said Padak. "As both a graduate student and as a professor, I have noticed that it can be challenging for women to advance in academia, especially in the sciences. I am doing my part to change this situation."

Looking back on her career to date, Dr. Padak believes that the relationships she has formed and maintained have been instrumental in helping her achieve and far exceed her childhood goals. "My work with Professor Ersolmaz showed me the value of having a mentor," said Padak. That experience inspired Dr. Padak to help her own students with career development decisions and preparation of application materials.

Dr. Padak also participates in outreach activities to underrepresented minorities, especially school-age children. She has helped elementary students perform hands-on science experiments and regularly gives a lecture called "Why Chemical Engineering" to middle and high school students. "I'm not only trying to show the students what it's like to be an engineer, but also to serve as a role model for female or minority students," said Padak.

"I want to help the students expand their ideas about what is possible for them to achieve and to find a career they feel passionate about," said Padak. "I know it worked for me. I love research and teaching and if I had to do it all over, I would be a professor again."

Dr. Padak works with graduate students in the lab.

SoCalGas RD&D Program Areas

Program Goals and Structure

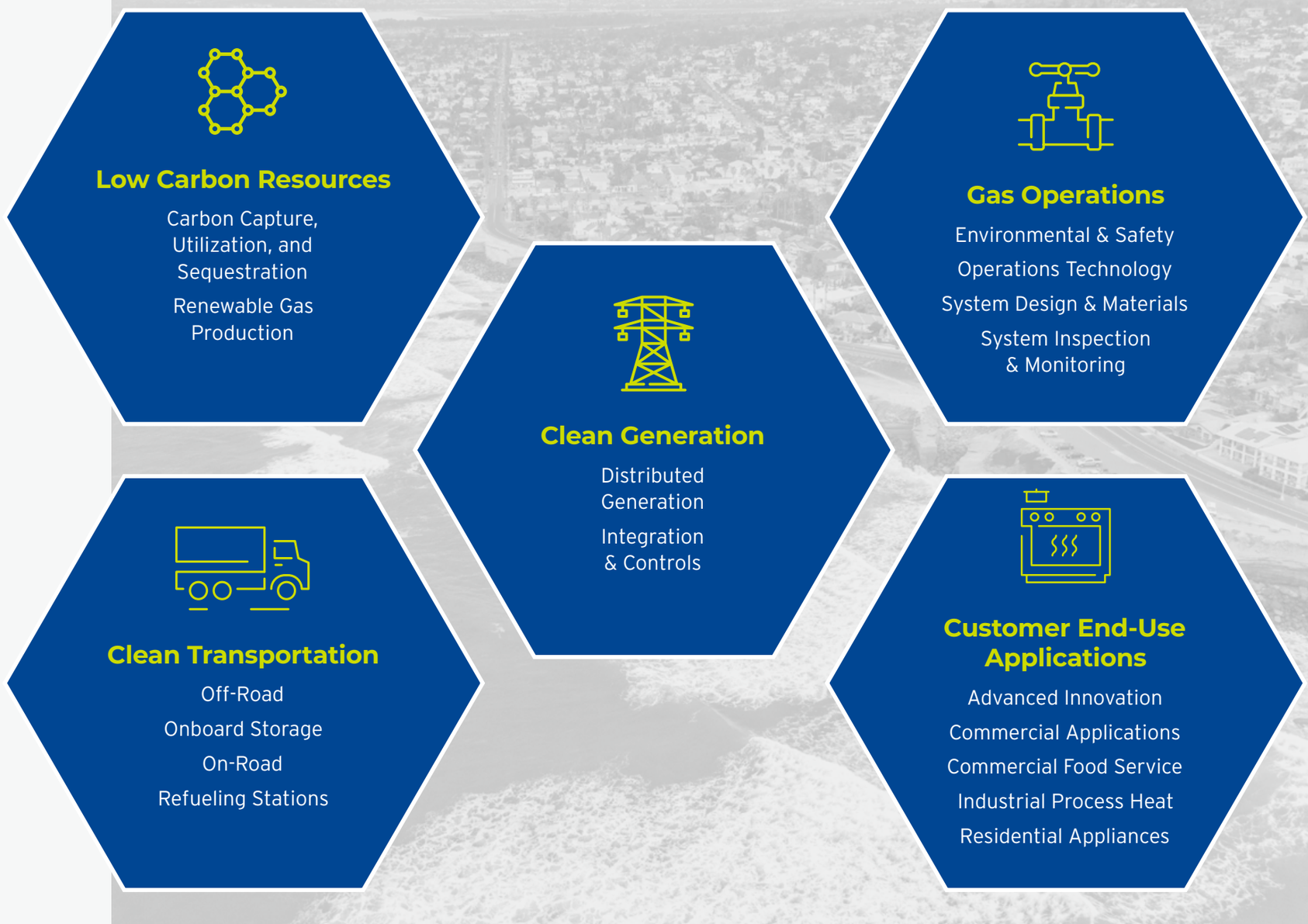
The goals of SoCalGas RD&D are to identify, test, and commercialize transformational new energy technologies that will reduce GHG and criteria air pollutant emissions, maintain the energy affordability that natural gas has historically provided, and advance the safety, operational efficiency, and reliability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

Concurrent with the pursuit of these goals, SoCalGas seeks to decarbonize its pipeline by replacing conventionally sourced, fossil-based natural gas with increasingly higher amounts of RNG and, potentially, blends of 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 considers 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 2022, SoCalGas RD&D 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



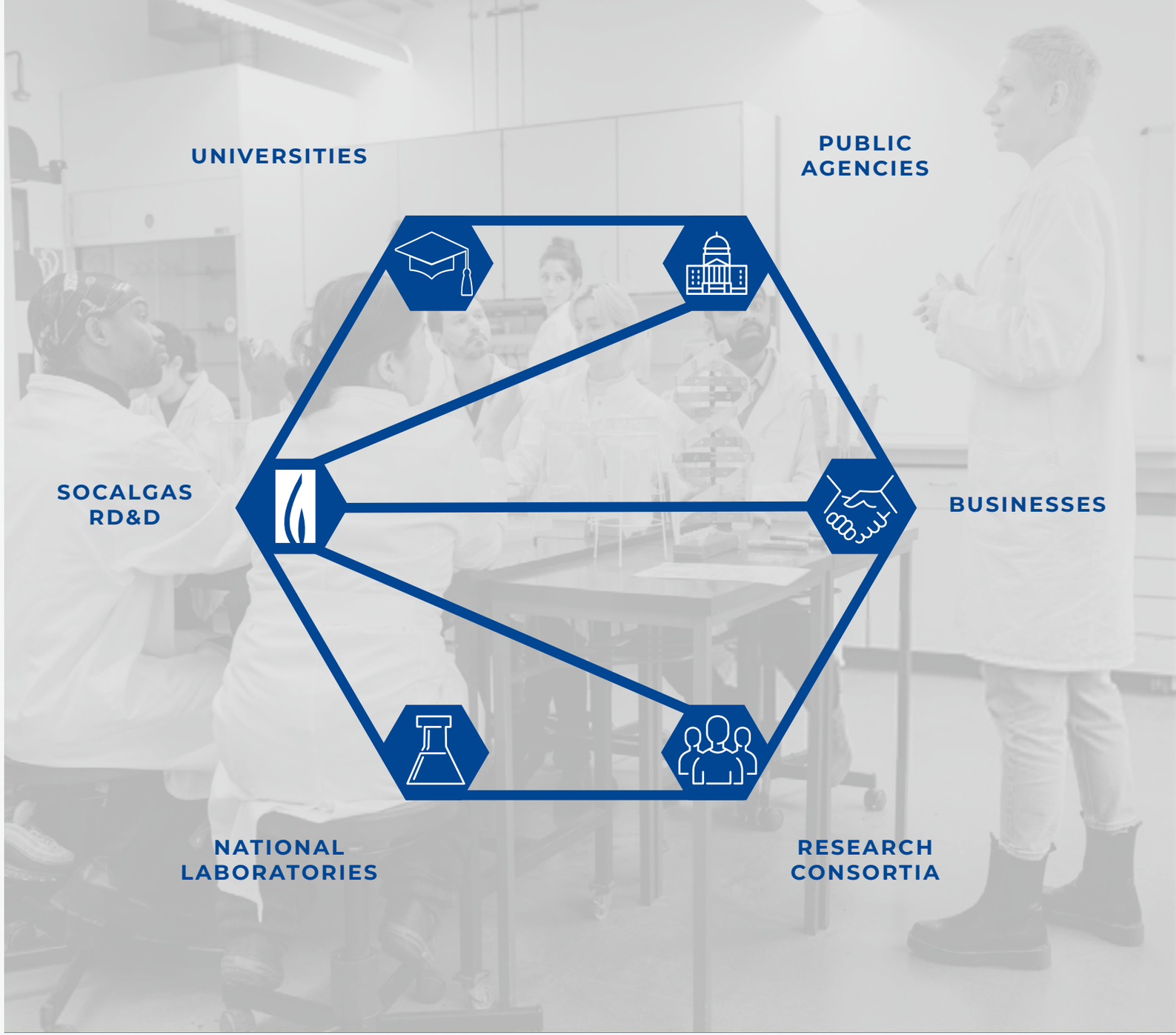
Research Collaborators

SoCalGas RD&D 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 science and technology experts, other utilities, and industry stakeholders in open dialogues. These dialogues help SoCalGas 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 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 collaborative partnerships, and seek public and private funding opportunities, with the goals of securing additional co-funding and assembling the most capable and impactful team of subject matter experts to work on a project.

See Appendix for more information.



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 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 addition, the Low Carbon Resources program area aims to promote and advance new technologies for carbon capture and the reuse of captured carbon in the manufacturing of useful products or its permanent sequestration in depleted oil wells and saline aquifers.

This program area includes two subprograms.

Carbon Capture, Utilization, and Sequestration

This subprogram focuses on carbon capture, utilization, and sequestration (CCUS)—all vital in the fight against climate change. Roughly half of the excess CO_2 released into the atmosphere by human activity is absorbed by plants and the world's oceans. CCUS technologies seek to capture and utilize or sequester the balance of these CO_2 emissions through a variety of approaches, including direct air capture coupled with either conversion into plastics, cement, and biofuels (carbon capture utilization, or CCU) or sequestration into depleted oil fields and saline aquifers (carbon capture sequestration, or CCS). This subprogram's portfolio also includes methane pyrolysis projects in which solid carbon is produced from a methane feedstock and captured simultaneously with hydrogen generation.

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.

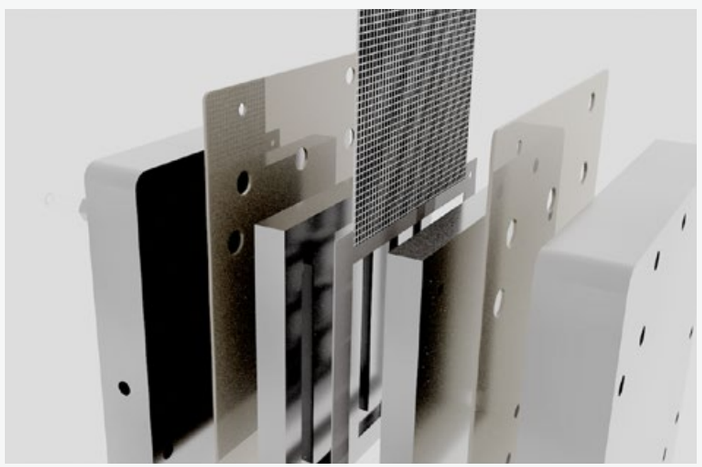
SPOT LIGHT

LOW CARBON RESOURCES

A carbon dioxide-converting device enables useful carbon-neutral consumer products

Electrochemical decomposition of carbon dioxide paves the way for shifting petroleum-derived materials to becoming carbon-neutral.

TOTAL PROJECT COST:	**$3,125,000**
SOCALGAS:	$500,000
COFUNDING:	$125,000
DOE:	$2,500,000



Twelve's electrochemcial system is built in repeating stacked units, each consisting of alternating charged plates, gaskets, electrodes, and membranes.

The United States emitted approximately six billion metric tons of carbon dioxide equivalent emissions in 2020.[7]

Combatting these emissions will require significant investment in zero-carbon energy sources as well as in the capture, utilization, and/or underground sequestration of greenhouse gases. Carbon capture and utilization (CCU) is a growing field that leverages chemical processes to produce carbon-neutral consumer products that are traditionally made from petroleum.

In 2015, Dr. Etosha Cave and Dr. Kendra Kuhl teamed up with Nicholas Flanders to commercialize an electrochemical conversion system they developed at Stanford University. The system transforms carbon dioxide from common emission sources into carbon monoxide and other compounds. Their company, Twelve, couples this process with a variety of chemical reactions to produce useful materials such as polymers for sunglasses or low-carbon jet fuel, among other applications.

"Most of the carbon intensity from something like jet fuel comes from the fact that it is derived from petroleum," said Dr. Cave. "Our products are essentially carbon-neutral because they incorporate carbon dioxide from biogenic or other emission sources. The result is a 90% reduction in carbon emissions because you're not burning something that was formerly in the ground."

Electrochemical systems like the one Twelve is developing are built in repeating stacked units, much like sandwiches. "Each unit consists of alternating charged plates, gaskets, electrodes, and membranes," said Dr. Cave. "Water permeates one side of the stack and a gaseous stream of carbon dioxide the other. As the gas and water make their way through the unit, they eventually meet at the catalyst."

This intersection drives the desired chemical reaction when an operator applies electricity to the system. In this case, carbon dioxide is transformed into carbon monoxide and water, with a small amount of hydrogen as a byproduct. These outputs become inputs to a secondary process in which

operators can produce useful chemicals and compounds from recycled carbon that form the basis of polymers for car parts, sunglasses, other daily household objects, and fuels.

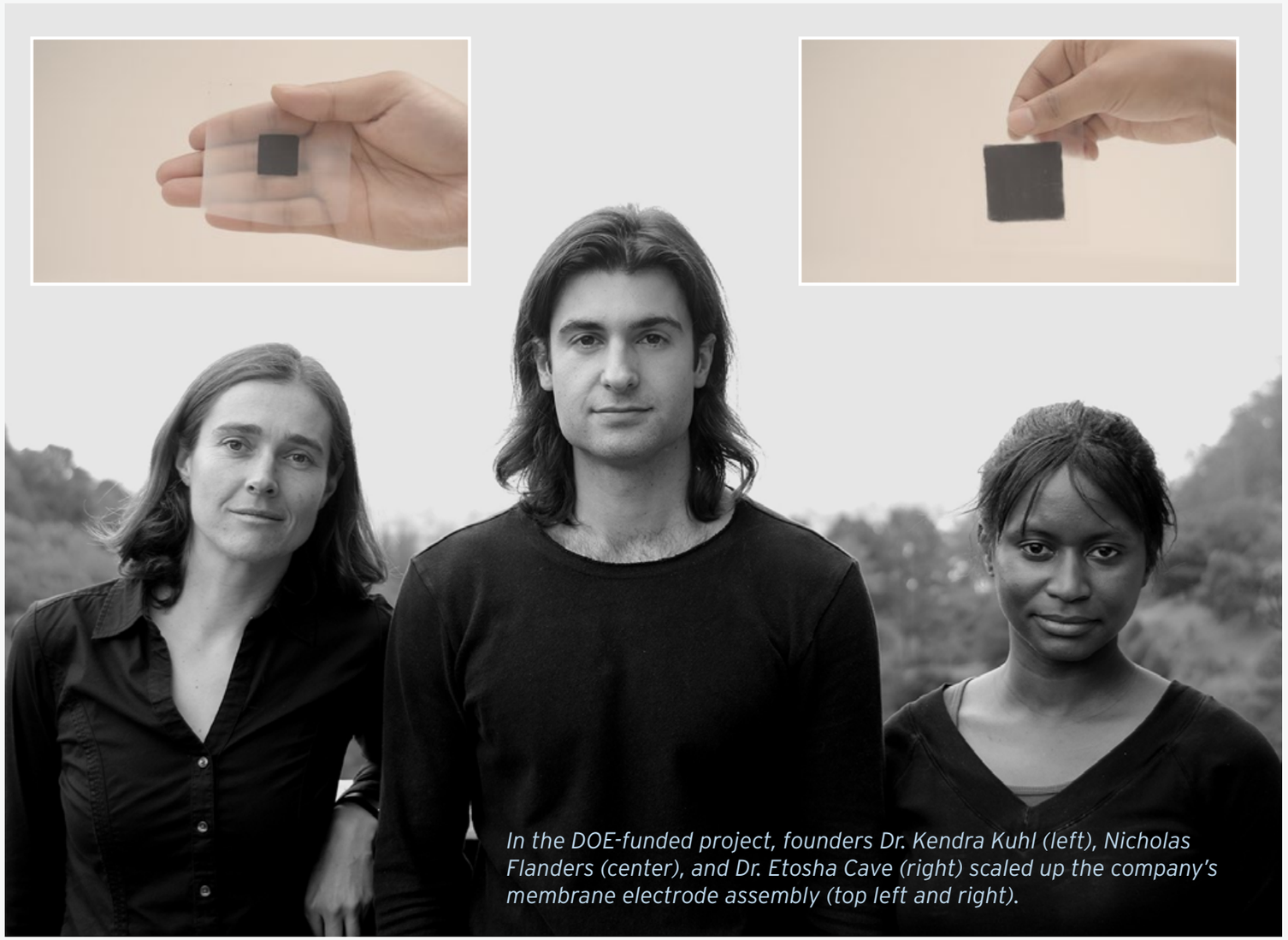
"At Twelve, we're a carbon transformation company," said Dr. Cave. "We see carbon dioxide as a molecule that, once transformed, can become an array of products that we currently make from petroleum."

"Carbon transformation technology exists and, with support from strategic partners and government sources, we are building up the industry," said Dr. Cave. Twelve is developing a way to consume carbon dioxide instead of putting it into the atmosphere. This approach enables society to make carbon-based products that they already enjoy out of carbon dioxide instead of petroleum.

For help developing its carbon transformation technology, Twelve applied for and won a $2.6-million grant from the U.S. Department of Energy (DOE) in 2019. "SoCalGas RD&D provided $500,000 in cost share to the project, which really strengthened our application," said Dr. Cave. "Equally important, SoCalGas brought credibility to the new technology. Having a well-known name like that in the reviewer pool at the DOE was consequential and really showed our commitment to commercialization."

The goal of the DOE-funded project, which kicked off at the end of 2020, was to advance the demonstration-scale system from several kilowatts (kW) to a megawatt-sized unit by scaling up the membrane electrode assembly (MEA). The first step involved sizing up the individual pieces and then optimizing their performance by tweaking the electrochemistry. "Once the MEAs had been scaled up and met quality control requirements, the team assembled them into modular 100- to 200-kW stacks for testing," said Dr. Cave.

"By increasing unit size to hundreds of kilowatts, overcoming the quality control issues, and demonstrating the larger system's performance, a megawatt-scale process is now within reach," said Dr. Cave. At that size, the system outputs can become inputs for large jet fuel production facilities. Success on this project has brought the U.S. one step closer to having a scalable source of sustainable aviation fuel.



In the DOE-funded project, founders Dr. Kendra Kuhl (left), Nicholas Flanders (center), and Dr. Etosha Cave (right) scaled up the company's membrane electrode assembly (top left and right).

PROGRAM:

GAS OPERATIONS

The Gas Operations RD&D program area supports pipeline gas delivery networks 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 public, company employees, and 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 Gas Emissions R&D Emission Strategy Program under the SB 1371 compliance plan, pursuant to the Gas Leak Abatement OIR (R.15-01-008).

Operations Technology

This 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 life cycle 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 nontraditional sources (biogas and hydrogen-blend) on overall natural gas quality and system integrity.

System Inspection & Monitoring

This subprogram's objectives 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 area leverage artificial intelligence, machine learning, and preventive and predictive maintenance technologies—including data analytic models and data lakes—and include 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.

SPOT LIGHT

GAS OPERATIONS

Research consortium creates a better way to implement low-carbon innovation

NYSEARCH supports development of database that enables utilities and RNG producers to streamline the interconnection process and reduce capital costs.

TOTAL PROJECT COST:	**$222,380**
SOCALGAS:	$24,710
COFUNDING:	$197,670

Traditionally, RNG producers have had to produce custom engineering designs for each interconnection skid, resulting in high capital costs and lengthy development cycles.

Renewable natural gas (RNG) is natural gas derived from a variety of organic waste materials, including food waste, garden clippings, and degradable carbon sources such as cardboard or wood. A study conducted by the University of California, Davis estimates that more than 20 percent of California's current residential natural gas demand could be met by RNG derived from the state's existing organic waste.[8]

To realize the benefits of producing RNG at scale, production facilities must interconnect with existing natural gas infrastructure. To date, RNG producers have had to produce custom engineering designs for each interconnection (IC) skid, resulting in high capital costs and lengthy development cycles.[9]

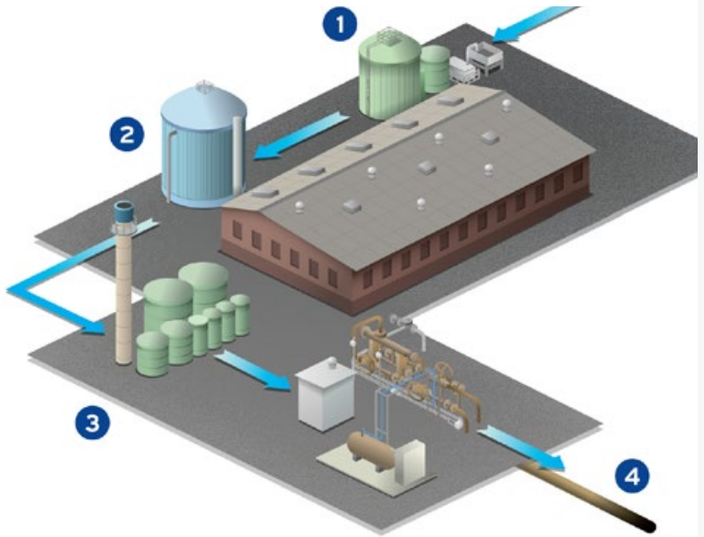
To address these challenges, the NYSEARCH research consortium—on behalf of 11 of its Local Distribution Company (LDC) members—collaborated with SoCalGas to develop a digital database that would provide a common framework for RNG interconnection. This framework would enable LDCs and RNG producers to select IC skid designs that best fit their needs, streamline the IC process, and reduce capital costs that may otherwise have been prohibitive.

NYSEARCH engaged Campos EPC—a diverse business enterprise specializing in engineering, procurement, and construction—to develop a standardized design and database.

Campos EPC conducted interviews with utility members of NYSEARCH in early 2022. The company also distributed a comprehensive questionnaire. The goal of this information gathering was to establish the basic engineering conditions and design parameters necessary for developing two foundational IC skid designs, one open-air and one enclosed.

During this process, Campos EPC interviewed the SoCalGas engineering team responsible for RNG interconnection. "SoCalGas contributed a wealth of information

How organic waste is converted into RNG



1. Waste products, such as sludge, food waste or manure are processed in a biodigester.
2. The biodigester breaks down the organic material to create biogas – a mixture of methane and other elements.
3. The biogas can then be processed and conditioned leaving behind RNG, which can be used interchangeably with traditional natural gas.
4. This RNG can be used where it is produced for things like generating electricity or fueling vehicles, or it can be injected into a utility pipeline for transportation to other customers.

that helped Campos EPC develop foundational designs that could easily be modified to meet the needs of the SoCalGas service territory, while remaining compliant with California and federal requirements," said Ahra Kwon, Senior Project Manager for NYSEARCH. Importantly, the same foundational designs could be modified to meet the needs of utilities anywhere in the country.

Based on these utility interviews and the responses to the questionnaire, Campos EPC developed piping and instrumentation, electrical, and structural drawings for the open-air and enclosed IC skids, as well as 3D models. The development of standardized designs was important to the funding utilities, which sought ways to minimize cost and time spent on design.

Once the designs were complete, Campos EPC set out to develop the Microsoft® Excel®-based equipment database, which incorporated American Society of Mechanical Engineers (ASME) requirements, standards, and calculations.

"Using the tool's drop-down menus and color-coded cells, RNG producers and gas utilities could input a variety of utility-specific parameters such as operating pressure and flow rate and then select the specific types of equipment that would complete a site-specific IC skid design," said Kwon. The database then provides a detailed cost estimate that includes both the skid itself and associated materials. It also provides the information that can serve as the basis for additional engineering and construction drawings.

One of the greatest challenges facing RNG producers is understanding how to share IC costs with an LDC. A project's database and foundational designs would aid producers in delineating which parts of a system are owned by the gas utility and which are producer-owned, thereby providing a basis for cost share.

The IC database also gives LDCs and RNG producers a head start, enabling them to avoid time-consuming and costly custom engineering by starting with one of the two foundational designs. "This solution provides a baseline that can then be modified and customized to fit the specific needs of any given utility," said Daphne D'Zurko, Executive Director at NYSEARCH.

Campos EPC has completed development of the software tool and, through NYSEARCH, distributed it to the 11 member utilities. "There is tremendous value in the collaborations between NYSEARCH and our consortium members," said D'Zurko. "Through their membership dues, they can leverage their research dollars and also their knowledge. In many cases, the amount of innovation they get as a result is ten- or twentyfold what they would have gotten on their own."

"SoCalGas is a champion of many of the innovations that NYSEARCH pursues," said D'Zurko. "I can't say enough about the value of gas companies that take the lead in finding innovations and then backing them up with both people and resources. They are leading the industry."

For this project, the true innovation was standardization. NYSEARCH member utilities—which collectively serve 32 million customers across the United States— were encouraged to focus on standardization to accomplish project objectives. By employing the same design standards and requirements when accepting gas from RNG producers, the process would reduce the cost of implementation and facilitate more use of RNG nationwide. "Innovation breeds innovation," said Kwon. "Once LDCs begin to use this solution, there is no telling what they will develop."

PROGRAM:

CLEAN TRANSPORTATION

The Clean Transportation program supports activities that reduce environmental impacts related to the transportation sector. Focusing on utilization of 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 area includes four subprograms.

Off-Road

This subprogram focuses on developing zero-emission off-road transportation solutions using 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. This subprogram has 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 hydrogen storage. Onboard storage, which requires compressed storage and/or the use of advanced adsorption technologies, is a critical element needed for increased utilization of hydrogen as a transportation fuel.

On-Road

This subprogram targets the development, demonstration, and deployment of zero-emission medium- and heavy-duty on-road vehicles. The focus is zero-emission, on-road transportation technologies using 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. This subprogram also seeks to identify and manage concerns and issues related to refueling, from storage and safety to standardization.

SPOT LIGHT

CLEAN TRANSPORTATION

California Port deploys hydrogen fuel cell trucks for zero-emission cargo handling

GTI Energy leads demonstration of hydrogen fuel cell yard tractors for emissions reductions at the Port of Los Angeles.

TOTAL PROJECT COST:	**$12,105,413**
SOCALGAS:	$372,500
COFUNDING:	$11,732,913

The project team developed and demonstrated two zero-emission hybrid hydrogen fuel cell yard trucks at port terminals operated by TraPac at the Port of Los Angeles.

For over two decades, the Port of Los Angeles has had more shipping container throughput than any other port in the Western Hemisphere. Every day, thousands of containers arrive at the port via ship, train, or truck and are then transported to the next steps on their journeys using heavy-duty cargo handling equipment powered by diesel, which provides the power, performance, and ease of refueling needed to operate in the demanding port environment.

Unfortunately, diesel-powered equipment is also a major source of carbon emissions and toxic air pollutants, including nitrogen oxides (NOx) and particulate matter (PM). The single largest source of port-related cargo handling emissions is the diesel yard truck, also known as the terminal tractor. These workhorses of the port put in as many as 20 hours per day, lifting and moving heavy cargo trailers, stopping only once daily for refueling.

In 2019, GTI Energy, SoCalGas, ZEN Clean Energy Solutions, Frontier Energy, Capacity Trucks, and HTEC—Canada's leading clean hydrogen production, distribution, and dispensing solutions company—began collaborating on the Zero-Emissions for California Ports (ZECAP) project.[10] Funded in part by the California Air Resources Board, the project's goal was to develop and demonstrate two zero-emission hybrid hydrogen fuel cell yard trucks at port terminals operated by TraPac at the Port of Los Angeles.

For each unit, the team configured a Capacity Trucks Trailer Jockey Series TJ9000 glider with a BAE Systems electric drive powertrain and an FCveloCity®-HD85 fuel cell from Ballard Power Systems, as well as onboard hydrogen storage tanks. "We chose yard trucks because they were well suited to replacement of their diesel engines with the hydrogen fuel cell drive," said Bart Sowa, a senior project manager with GTI Energy. "Their duty cycle is also quite demanding, making them an ideal test case."

SoCalGas provided $372,500 in cost share to the project as well as access to its network of customers, technology

partners, and research organizations. SoCalGas RD&D staff also offered valuable perspectives about infrastructure utilization and product commercialization.

In 2020, the project team completed engineering design on the hydrogen fuel cell yard trucks and the custom fueling infrastructure, beginning assembly of the yard trucks late in the year. Despite COVID-related delays, the team took the project through permitting, manufacturing, and implementation at the end of 2022 and is expected to complete all elements of the project in 2023. The project had multiple components.

The first was identifying a demonstration site. TraPac, a port terminal operator, offered the use of its facilities, allowing the project team to locate the on-site hydrogen refueler in an area of its terminal optimized for yard truck refueling but out of the way of normal operations. "TraPac was very enthusiastic about integrating the hybrid hydrogen fuel cell yard trucks into their operations," said Sowa.

The second critical component was developing the two hybrid hydrogen fuel cell yard trucks. "No commercial version of this type of vehicle existed anywhere in the world," said Sowa. "It took Capacity Trucks seven different iterations juggling multiple design constraints before they delivered the final vehicles."

The resulting trucks combine a hydrogen fuel cell drivetrain with 9 kilograms of onboard hydrogen storage and an 85-kilowatt-hour battery. This architecture enables the yard trucks to operate for approximately 11 hours on hydrogen and an additional 6 hours on batteries. Refueling takes roughly 10–20 minutes—slightly slower than diesel but an order of magnitude faster than recharging the trucks' electric batteries.

Designed to be skid-mounted and temporarily bolted down, the on-site fueler developed by HTEC could hold up to 190 kilograms of hydrogen. "With the demonstration duty cycle of eight hours per day, that was enough fuel for two to three weeks of operation," said Mary Fry, Director of Production Assets at HTEC. "During the project, we sought to mimic the diesel fueling process as much as possible." Zen Clean Energy Solutions helped permit the fueling station.

To quantify the project's results and better understand vehicle performance and energy consumption, Frontier Energy is collecting and analyzing vehicle data throughout the operations period. Frontier will disseminate its findings through conferences and other venues and will use the data to develop a commercialization study that includes a market study and a model of potential adoption rates. To share information with the public, the project team developed a website and conducted a webinar.[11,12]

"The project has been a great success," said Sowa. "We have demonstrated that hydrogen can be a safe and clean alternative to diesel fuel in the port environment." The yard truck operators particularly appreciated the new vehicles, which were designed to look and operate like their diesel counterparts. "The new yard trucks are also quiet, do not smell or vibrate, and provide significantly more torque than the vehicles they replaced. Some of the TraPac drivers specifically asked to be assigned to the new yard trucks."

Based on this project's success, TraPac has begun exploring how to transition all of its cargo handling equipment to zero emission. "They are not alone," said Sowa. "Other potential end users have been asking about testing the hybrid hydrogen fuel cell yard trucks at their own facilities. As a result, Capacity has already begun developing a second-generation model for demonstration and commercialization."

The project made significant progress in reducing some of the stigma associated with hydrogen. "The new hydrogen fuel cell yard trucks broke down barriers by educating the operators, many of whom had expressed hesitation about trying out the new technology," said Sowa. "Now, they understand that hydrogen, like other conventional fuels, can be safely used as a fuel."

The project also represented an important step forward in developing a thriving hydrogen market in Southern California. "The hydrogen industry has struggled for decades to balance supply and demand to justify large investments in either production or end-use applications," said Sowa. "This project demonstrated to the industry that hydrogen is feasible as a heavy-duty transportation fuel and could begin to realize economies of scale."

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.

SPOT LIGHT

CLEAN GENERATION

Highly scalable generators have potential to accelerate transition to carbon-free grid

Mainspring Energy has introduced a novel, proven power generation technology that is modular, dispatchable, and fuel flexible.

TOTAL PROJECT COST:	**$2,381,725**
SOCALGAS:	$100,000
COFUNDING:	$2,281,725

Mainspring Energy deployed its modular linear generator at Food 4 Less, a Kroger brand grocery store in Colton, California.

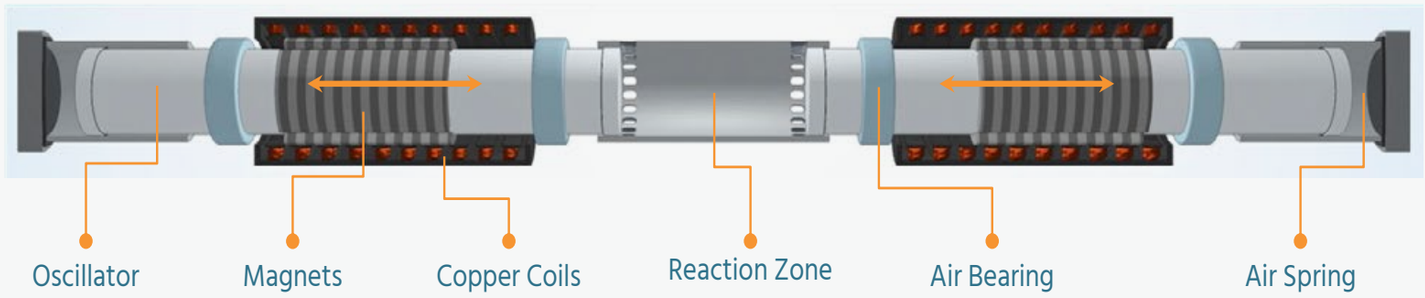
The move to decarbonize the grid is picking up speed, driven by cost reductions in clean electricity, legislation, and growing interest among investors and consumers. As increasing amounts of wind and solar electricity come online, however, their variability challenges grid stability and jeopardizes the smooth transition to a carbon-free grid.

To help overcome these obstacles, Mainspring Energy developed a modular linear generator capable of providing dispatchable power using a variety of gaseous fuels, including natural gas, renewable natural gas (RNG), green ammonia, and green hydrogen. The company sought and won a grant from the California Energy Commission's Public Interest Energy Research Program to demonstrate this innovative technology in 2017.

"Our goal was to deploy this novel approach at a customer's site to illustrate high system uptime, low emissions, and high electrical efficiency over nine months," said Adam Simpson, Chief Product Officer and Founder of Mainspring Energy. Mainspring deployed the unit at Food 4 Less, a Kroger brand grocery store, in Colton, California.

SoCalGas provided valuable support to the project, bringing $100,000 in match funding and facilitating a quick interconnection to its natural gas network. "It was great working with them," said Simpson. "This project enabled SoCalGas to evaluate an early installation of our linear generator with an eye toward potentially purchasing it for applications at some of its own sites. More broadly, it helped us understand the technology so that we could better promote its adoption by a wide range of customers looking for low-emission energy reliability and resilience."

The linear generator consists of a center reaction cylinder, two opposed oscillators, and two outer air springs. Each oscillator incorporates magnets for electricity production using copper coils that encircle portions of the generator. For this project, Mainspring installed a grid-connected, modular 230-kilowatt (kW) linear generator operating on natural gas.



The Linear Generator Core: A linear generator is an electromechanical device that directly converts linear motion into electricity using chemical or thermal energy.

The power generation cycle: 1. A mixture of air and fuel are compressed in the center reaction zone until a low temperature reaction occurs. **2.** The reaction drives the two oscillators, carrying magnets, through copper coils, directly producing electricity through linear motion. **3.** The outer air springs are compressed to return the oscillators for the next cycle.

The operating cycle of the generator begins with the compression of a fuel-air mixture in the reaction cylinder. This reaction is driven by energy stored in the air springs from the previous cycle. Compression continues until a low-temperature, non-combustion reaction occurs uniformly, without burning or a flame. The reaction causes the oscillators to move outward.[13] "A portion of the kinetic energy is directly converted into electricity through the copper coils and the rest is stored in the air springs for the next compression cycle," said Simpson.

The system's low-temperature reaction achieves high thermodynamic efficiency and near-zero emissions. "By eliminating the need for flame, it also keeps the peak temperature well below the threshold for NOx formation," said Simpson. "That, in turn, removes the need for any NOx after-treatment equipment."

The demonstration proved highly successful. The linear generator provided dispatchable power 24 hours per day for the entire nine-month demonstration. The system produced 230 kW of net AC power when building load was sufficient and followed building load when it dropped below 230 kW.[14]

"Mainspring's linear generator technology has allowed our business to manage electricity expenses better and lower its carbon footprint," said Jeff Guth, Regional Director, Construction, at The Kroger Co. "We have already begun adopting this technology at other locations in our enterprise to expand this program."

Moving forward, the linear generator has great potential. "Because it is fuel-flexible, end users can switch to cleaner fuels such as RNG or green hydrogen as they become available," said Simpson. "This flexibility enables them to select the fuel with the greatest abundance, lowest cost, and lowest carbon intensity at any given time." The generators are also portable, allowing end users to place them exactly where power is needed and to combine multiple 230-kW units into larger, megawatt-scale systems.

The technology can provide valuable benefits to the electricity grid. "With our dispatchable generators, end users can ramp power down as on-site solar generation ramps up, turn off power while the PV system exports power, and then ramp power back up as on-site solar stops producing," said Simpson. "Customers like this flexibility because it not only provides cost savings while maximizing the value of their solar, but it also helps displace or offset grid power from the dirtiest power plants."

Mainspring Energy learned valuable lessons from this project and was able to develop design improvements that it expects will increase power, efficiency, and reliability while lowering cost. "Since completing the project, we have seen significant market interest from national and multi-national corporations and have been able to raise capital for a sustained market launch," said Simpson. "From both our perspective and the customer's perspective, the project was a big success."

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, nontraditional 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 heating, ventilation, and air conditioning (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 rely primarily on fuel supplied by SoCalGas for cooking and water heating.

Industrial Process Equipment

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

Residential Appliances

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

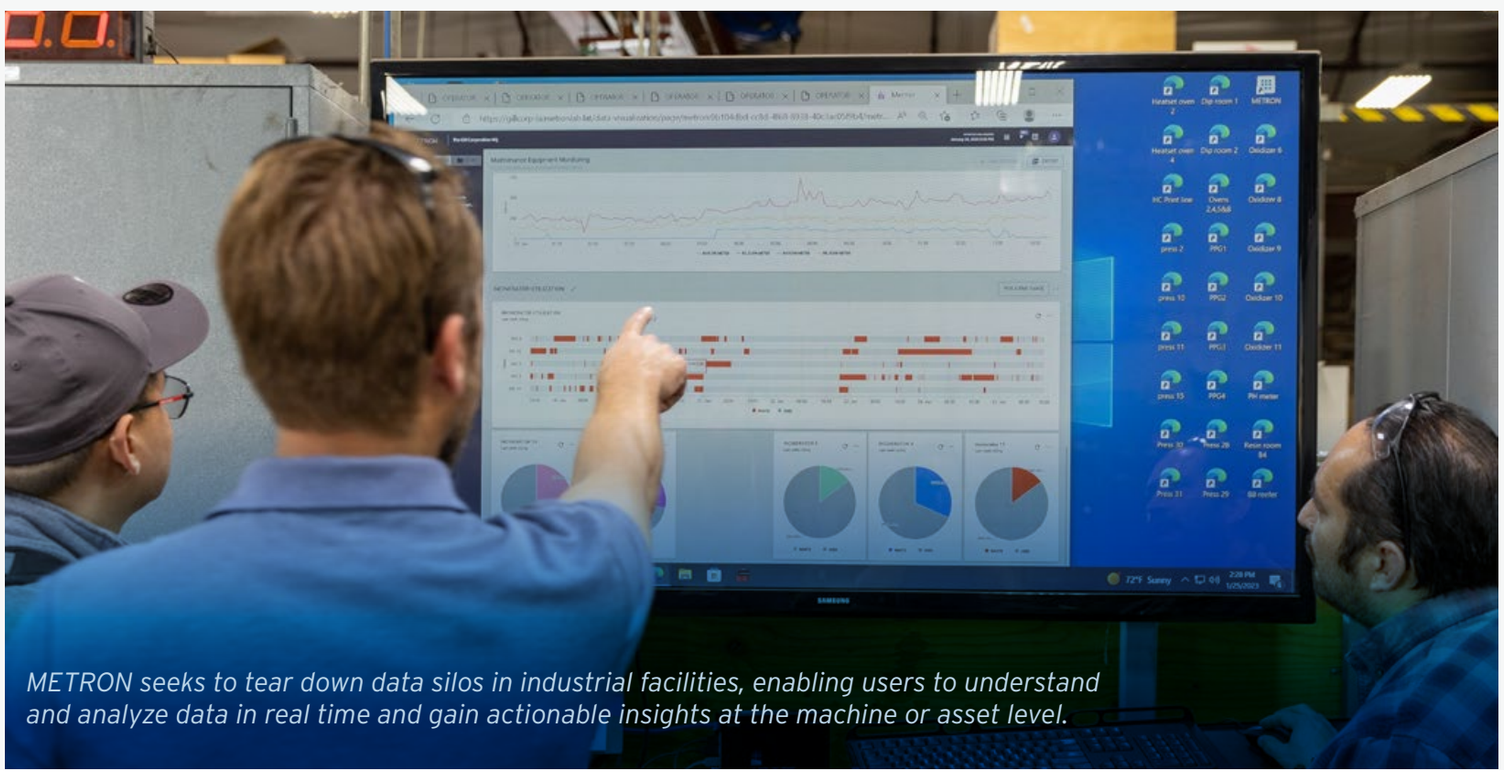
SPOT LIGHT

CUSTOMER END-USE APPLICATIONS

New insights are created by breaking down industrial data silos with digitization

METRON, a key player in the "industry of the future," is reducing energy consumption, helping to lower utility bills, and shrinking carbon footprints.

TOTAL PROJECT COST:	**$481,460**
SOCALGAS:	$481,460
COFUNDING:	$0



METRON seeks to tear down data silos in industrial facilities, enabling users to understand and analyze data in real time and gain actionable insights at the machine or asset level.

The world is in the midst of a technology disruption, a fourth industrial revolution driven by increasing interconnectivity and smart automation. This transition has the potential to unlock tremendous increases in the energy efficiency of many industrial processes, reducing energy bills and shrinking carbon footprints.

The primary challenge associated with this transition is data collection. The sheer number of legacy factories, facilities, and power plants that lack connected devices or sensors, however, makes adequate data collection quite difficult.

To address this challenge, energy technology company METRON has created an innovative software-as-a-service (SaaS) product and set of strategies. "We established METRON to tear down the data silos that existed within industrial facilities and bring data to multiple users," said Pierre Groleau, General Manager North America at METRON. "Our goal was to provide a toolset that helps

users understand and analyze data in real time and gain actionable insights at the machine or asset level."

METRON's technology provides great value when it is installed at an industrial facility. In 2020, the company collaborated with SoCalGas to identify a suitable demonstration site among the gas utility's large customers. After review, METRON selected The Gill Corporation, a leading manufacturer of high-performance composite materials and products for the aerospace, transportation, and other industries.

At project inception, The Gill Corporation did not possess a centralized energy management system for monitoring or visualizing the company's energy consumption. "With this project, our goal was to better understand and optimize system performance and energy flows, with a particular focus on gas and electricity," said Groleau. "Our endgame was to reduce energy costs."

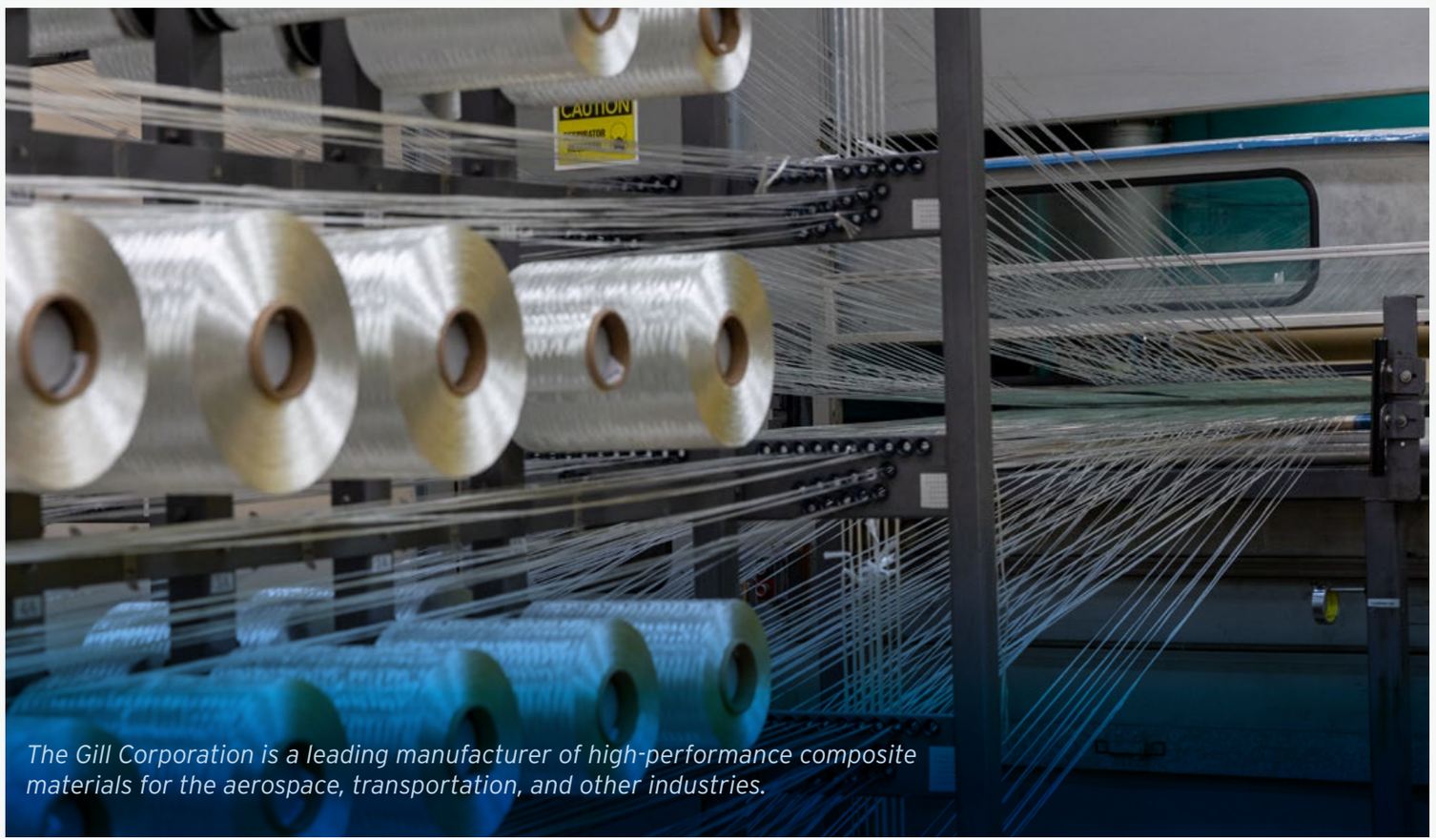
Work on the project began with a detailed analysis of the site's existing data sources and hardware followed by data aggregation for immediate observation. "We then looked carefully for the gaps in the data stream that prevented full digitalization of the facility's performance," said Groleau. Upon completion of this analysis, METRON developed a digitization roadmap that identified the sensors and associated hardware necessary to close the data gaps.

Upon installation of the sensors, METRON deployed its software ecosystem and professional services to drive significant energy use cost savings and emission reductions.

The success of the project was a direct result of the positive collaboration among METRON, The Gill Corporation, and SoCalGas. Through its participation on this project, The Gill Corporation was able to identify an estimated annual savings of $150,000—achievable through a capital investment of $100,000—cutting the facility's yearly utility bill of $2,685,000 by 6% and reducing CO_2 emissions by nearly 1,000 metric tons per year. To validate those numbers, SoCalGas had them checked by a third-party measurement and verification organization.

By demonstrating its technology under real-world conditions, METRON gained valuable insight into which parameters consume the most energy and learned where to start deploying resources to create energy models and optimizations for longer term benefits. Siting the project in the SoCalGas service territory opened up a new market for METRON—one with a large number of potential industrial end users.

"We had already begun commercialization efforts in the U.S. market," said Groleau. "Through the relationship we built with SoCalGas and our success on this project, we have gained additional traction." METRON can now approach other clients within the SoCalGas portfolio with proposals to digitize their facilities and implement energy management solutions that can scale at low capital cost. "That benefits us, SoCalGas, and their industrial customers."



The Gill Corporation is a leading manufacturer of high-performance composite materials for the aerospace, transportation, and other industries.

Appendix

2022 Funding Recipients

2020vet, Inc.

A-1 Alternative Fuels

Acoustics LP

Airgas USA, LLC

Alliance for Sustainable Energy, LLC

Argus International, Inc.

Arthur D Little, LLC

Barr Engineering Co.

Battelle Memorial Institute

Bloom Energy Corporation

Blue Frontier, LLC

Brillio, LLC

Brownfield Solutions, Inc.

Burns & McDonnell Engineering Co.

C4-MCP, LLC

California Institute of Technology

CALSTART

Captura Corp.

Cellular Accessories for Less

Center for Transportation and the Environment

Club Colors Buyer, LLC

Colorado State University

Connection

Creaform USA, Inc.

Cummins Electrified Power NA, Inc.

Darcy Partners LLC

DI Drill Survey Services, Inc.

DNV GL USA, Inc.

Douglas G Honegger

EDM Services, Inc.

Electricore, Inc.

Electric Power Research Institute

EN Engineering, Inc.

EvoIOH, Inc.

FedEx Corporation

Gas Machinery Research Council

Getty Images, Inc.

Golden Gate Zero Emission Marine, Inc.

Greater Ontario Business Council

GTI Energy

H2U Technologies, Inc.

Hal Hays Construction, Inc.

Haringa Compressor Co.

Hi-Line Engineering & Fabrication, Inc.

Horizon Fuel Cell Americas, Inc.

Hyet Hydrogen USA, LLC

Immaterial Ltd.

Innovative Environmental

Int Translations

IWVC, LLC

Lawrence Livermore National Laboratory

Linde Engineering North America LLC

Mainspring Energy, Inc.

Mar Vista Family Center

McMaster-Carr Supply Co.

Metron

Momentum

Netcentric Technologies, Inc.

Noble Thermodynamic Systems, Inc.

Northeast Gas Association

Oak Ridge National Laboratory

Operations Technology Development

Opus 12, Inc.

Oxford Global Resources, LLC

Parsons Environment & Infrastructure

Pipeline Research Council International, Inc.

Process Ecology, Inc.

Ramboll US Consulting, Inc.

Regents of the University of California

R. R. Donnelley

Scaled Power Incorporated

South Coast Air Quality Management District

Sowing Seeds for Life

Stafford Multimedia, LLC

Stantec Consulting Services, Inc.

Stream Global Innovations

Structural Integrity Association, Inc.

SuperbTech, Inc.

Sustain SoCal

Susteon, Inc.

The INGAA Foundation, Inc.

The REM Engineering Co., Inc.

The Sourcium Group

Staples Contract & Commercial, LLC

ULINE

University of Southern California

Utilization Technology Development

William Salit Design

Yankee Scientific, Inc.

Youth Science Center

RD&D Alumni Companies

ANESI GAS HEAT PUMPS

AVNOS

BLUE FRONTIER

BRIDGER PHOTONICS

BRIMSTONE

C1ZERO Decarbonizing Natural Gas

CAPTURA

CLEAN ENERGY SYSTEMS

Electrochaea

H2U TECHNOLOGIES

Immaterial

kevala

LANTEC PRODUCTS INCORPORATED

METRON

noble thermodynamics

SCALED POWER

SIERRA ENERGY

STARS Technology Corporation

Susteon

twelve

Upstart Power A Smarter Generator for a Cleaner Tomorrow™

ZERO EMISSION INDUSTRIES

2022 Publications

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2022 Government Agency Funding Awards

Lead Investigator	Research Program	RD&D Funding Committed	Funding Awarded	Agency
GTI Energy	CEUA	$700,000	$1,770,000	CEC
BioVind	GO	$50,000	$999,970	CEC
UCLA	GO	$15,000	$5,658,000	CEC
UCLA	GO	$5,000	$1,200,000	CEC
California Institute of Technology	LCR	$300,000	$2,200,000	DOE
UCLA	LCR	$350,000	$749,999	CEC
Susteon, Inc.	LCR	$350,000	$750,000	CEC
Summit Utilities	LCR	$2,342,505	$4,977,437	DOE
TOTAL		**$4,112,505**	**$18,305,406**	

2022 Policy Drivers

Category	Regulations & Policy Drivers
GHG Emissions	**Assembly Bill (AB) 32:** Reduce CO_2 emissions 40% below 1990 levels by 2030 **Senate Bill (SB) 100:** Zero-carbon electricity by 2045 **AB 1279:** By 2045, achieve a carbon-neutral California economy and reduce statewide anthropogenic GHG emissions to at least 85% below 1990 levels **AB 3232:** Building decarbonization **SB 1101:** Carbon Sequestration: Pore Space Ownership and Carbon Capture, Utilization, and Storage Program
Pipeline Safety	**CPUC General Order 112F:** Rules governing design, testing, operation, and maintenance of gas transmission and distribution systems **U.S. Department of Transportation (DOT) 49 Code of Federal Regulations (CFR) Part 192:** Federal pipeline safety regulations **AB 1900:** Biomethane quality standards **Order Institute Rulemaking (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 RNG
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 vehicles be zero emission by 2045 for all operations where feasible **Low Carbon Fuel Standard (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, especially to improve local air quality and public health

Research Collaborators

Universities

SoCalGas regularly collaborates with scientists, engineers, and other academics at some of our nation's most prominent universities, including Stanford University, the California Institute of Technology (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 use. University collaborators also possess expertise in modeling, technoeconomic analysis, and life-cycle 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 DOE to advance science and technology. Researchers and scientists at the 17 national labs tackle the critical scientific challenges of our time—from combatting 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 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 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 staff regularly work with numerous agencies, including DOE, CEC, the California Air Resources Board, and the Pipeline and Hazardous Materials Safety Administration (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, SoCalGas RD&D is about developing and promoting practical applications to overcome challenges facing the energy sector, in alignment with California's decarbonization goals. To help ensure that the new technologies and products supported by SoCalGas advance to real-world applications and markets, RD&D staff leverage their connections, knowledge, and expertise by working closely with leading equipment manufacturers 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

SoCalGas RD&D staff have developed strong ties with several research consortia focused on the gas energy industry. The membership of many of these organizations consists of utility companies across North America. Typically, these consortia serve member utilities by facilitating technical collaboration and pooling financial and technical resources to collectively address ongoing or anticipated challenges in the gas industry. By working closely with these and other similar organizations, RD&D 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, SoCalGas RD&D is a member of four subscription-based organizations: Northeast Gas Association (NGA)/NYSEARCH, Operations Technology Development (OTD), Pipeline Research Council International (PRCI), and Utilization Technology Development (UTD).

NORTHEAST GAS ASSOCIATION (NGA)/NYSEARCH[15]

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 local distribution companies (LDCs) that have common interests and needs, such as continually improving the operation, safety, efficiency, maintenance, and upgrade of gas delivery systems.

Today, as part of NGA, NYSEARCH manages numerous projects in various stages of development. NYSEARCH has grown steadily in recent years because of its success in delivering high-value RD&D projects. The organization is unique in its

ability to help member companies and partners leverage RD&D investments while targeting their participation to projects that best meet their individual needs. The core of the NYSEARCH model is joint collaboration and guidance from participating members. These members participate in a variety of RD&D projects, organized under the following categories:

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

Total 2022 Projects
27

Initiated
4

Completed
9

2022 Dues
$72,250

Total RD&D Funding
$130,214

Operations Technology Development[16]

OTD is a member-controlled partnership of 26 natural gas distribution companies formed to develop, test, and implement new technologies. The objective of OTD is to address a wide range of technology issues relating to gas operations and its infrastructure. Its projects are designed to:

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

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

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

Total 2022 Projects
55

Initiated
8

Completed
17

2022 Dues
$511,812

Total RD&D Funding
$319,742

Pipeline Research Council International[17]

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 2022 Projects
50

Initiated
8

Completed
20

2022 Dues
$148,147

Total RD&D Funding
$153,310

Utilization Technology Development[18]

UTD is at the forefront of research, development, and deployment for end-use equipment and appliances. As a not-for-profit corporation led by its 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, combined heat and power (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
- Reduce energy consumption

Total 2022 Projects
112

Initiated
27

Completed
14

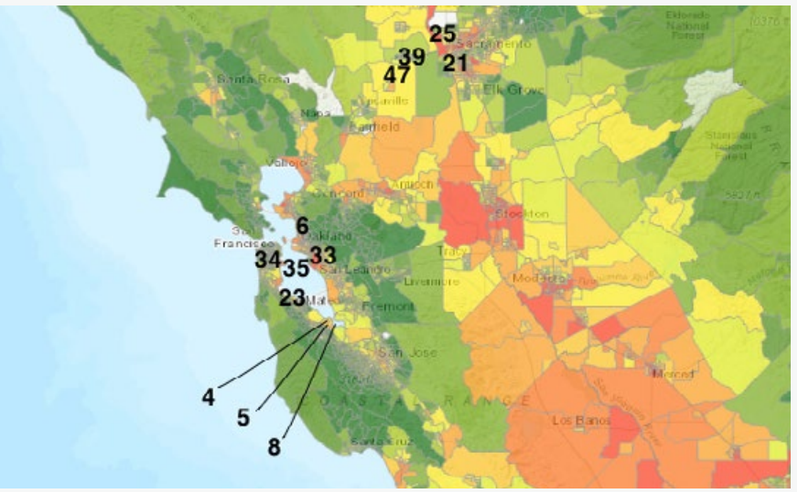
2022 Dues
$350,000

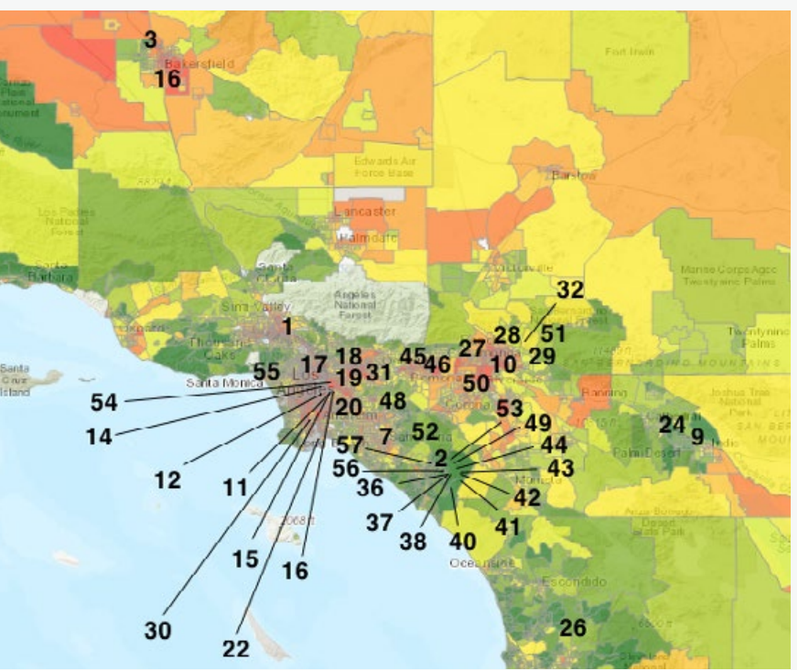
Total RD&D Funding
$370,073

- Enable safe, reliable, and resilient operation of end users' equipment and energy delivery systems
- Achieve superior environmental performance
- Integrate with renewable energy sources

UTD collaborates 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.

Projects in Environmental and Social Justice Communities





The RD&D program supported 61 projects located in ESJ communites in 2022. 57 of the projects listed below, are located in Southern California. The remaining four are located in Florida and Colorado.

Low Carbon Resources

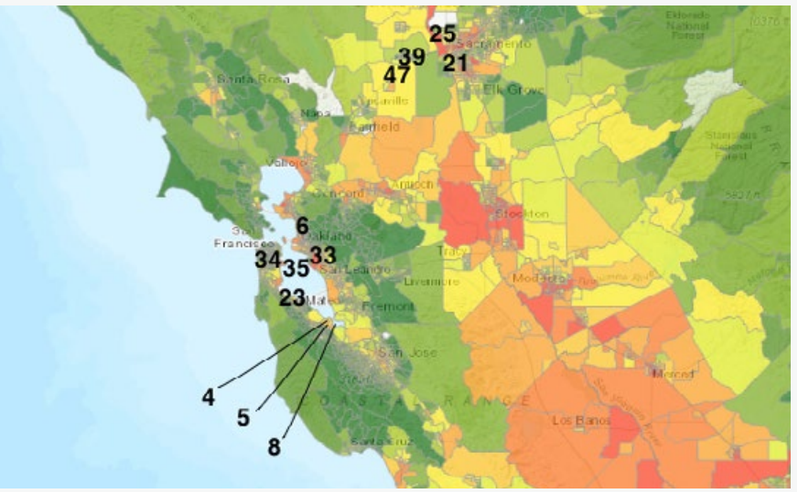
1. Captura CO_2 Capture from Oceanwater Using Highly Efficient Electrodialyzer Demonstration; Pasadena
2. Electricore Direct Air Capture Using Novel Structured Adsorbents Demonstration; Fountain Valley
3. IWVC Combined Water and CO_2 Direct Air Capture System Demonstration; Bakersfield
4. Stanford Energy Efficient Strategies for Capture of Atmospheric CO_2; Stanford
5. Susteon Stanford Iron-Oxide Based Catalytic Methane Pyrolysis Development; Stanford
6. Twelve PEM CO_2 Electrolyzer Scale-up to Enable MW-Scale Electrochemical Modules; Berkeley
7. Kore Biosolids Pyrolyzer Field Test; Los Angeles
8. Scaling of Microbial Power to Gas Conversion for Long Term Operation (M2018-011 Ph I, II); Stanford
9. STARS Corporation Electric Induction Steam Methane Reforming (SMR) Demonstration; Thousand Palms
10. UCR Speeding Anaerobic Digestion Through CO_2 Microbubbles; Riverside

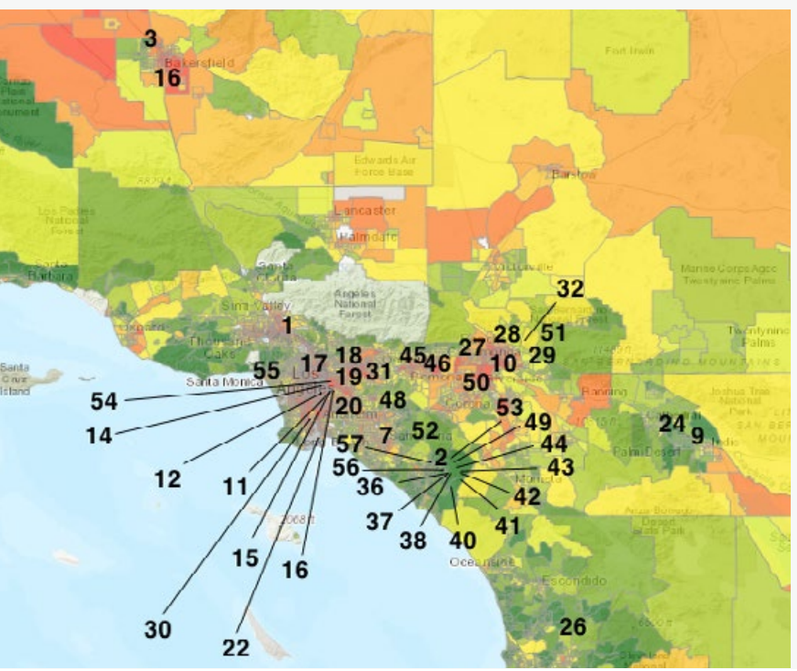
Gas Operations

11. Low NOx Portable Analyzer; Pico Rivera
12. Smart Shutoff Technology for Commercial and Residential Buildings (5.20.k) (CEC GFO-19-502, Group 2); Pico Rivera
13. Validation of Next Generation Predictive Emissions Monitoring System for Gas Turbines (CPS-2-03); Blythe
14. 3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management (8.20.m) (CEC GFO-19-502, Group 4); Los Angeles, Bellflower, Pico Rivera
15. Data Logger Evaluation Project - Phase II; Pico Rivera
16. Enhanced Locating Technologies for Underground Pipelines with Better Accuracy (8.20.l) (CEC GFO-19-502, group 3); Pico Rivera, Bakersfield
17. Technology Testing Assessment Facilities (AMI Smart Metering); Pico Rivera
18. Blending Modeling (Hydrogen); Pico Rivera
19. Living Lab for Hydrogen (M2021-008); Pico Rivera
20. Modeling and Assessing PE Assets with 3D Scanning Technology; Pico Rivera

Clean Transportation

21. GTI Energy Hydrogen Fuel Cell Switcher Locomotive Demonstration; West Sacramento
22. GTI Energy Hydrogen Fuel Cell Yard Truck Port of Los Angeles Demonstration; Wilmington
23. ZEI Harbor Craft Demonstration; San Mateo
24. A1 Alt Fuels Fuel Cell Electric Paratransit Shuttle Demonstration; Thousand Palms
25. Cummins Integrated Fuel Cell Electric Powertrain Demonstration; West Sacramento





26. GTI Energy Symbio Class 8 Long-Haul Hydrogen Fuel Cell Truck Demonstration; Poway
27. SCAQMD Heavy Duty Truck Engine In-Use Emission Study; Riverside
28. SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study; Riverside
29. UC Riverside Hydrogen Blended Natural Gas Engine Durability Test; Riverside

Clean Generation

30. EPRI ORC Waste Heat Recovery Demonstration; Compton
31. GTI Energy Marathon/EC Power mCHP Testing and Demonstration; City of Industry
32. Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration; Colton
33. Noble Thermodynamic Systems Ultra-Efficient CHP using a Novel Argon Power Cycle Development; Alameda
34. QSI Nano-Power Generation System Proof-of Concept; San Francisco
35. Scaled Power 40kw Turbogenerator Low Emissions Burner Development and Testing; San Francisco
36. UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing; Irvine
37. UCI Fuel Flexible Rotary Engine MicroCHP Development; Irvine
38. UCI Low-Cost Sensors for Smart Burners Research; Irvine
39. Blue Frontier Fuel Cell Integrated Air Conditioning System Dynamic Lab Testing; Davis
40. UCI Fuel Cell Supported Nanogrid Controls Evaluation; Irvine
41. UCI Fuel Cells in Data Research; Irvine
42. UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research; Irvine
43. UCI Hydrogen Energy Storage and Integration with Dispatchable Power Generator System Design; Irvine
44. UCI Integrated SOFC, Solar, and Storage System in ZNE Residential Nanogrid Design; Irvine

Customer End-Use Applications

45. METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration; El Monte
46. GTI ENERGY Model-Based Control Hospital Decarbonization Demonstration, Baldwin Park
47. UC Davis Aerosol Sealant Demonstration; Davis
48. GTI ENERGY SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration; La Habra
49. UCI Hydrogen Blend Commercial Stove Low NOx Catalytic Burner Development; Irvine
50. GTI ENERGY Burner Exchange to Support Radiative Recuperator Demonstration; Ontario
51. GTI ENERGY Ceramic Radiant Tube Inserts for Waste Heat Recovery Demonstration; San Bernardino
52. GTI ENERGY Waste Heat Effective Transfer in Brewery & Distillery Demonstration; Santa Ana
53. UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration; Irvine
54. EAC H2 Home Appliance Set Validation Test Research; Pico Rivera
55. GTI Energy Strategic Pathways and Analytics for Tactical Decommissioning of Natural Gas Infrastructure Research; Santa Monica
56. UCI Catalytic Burner Retrofitted Water Heater Lab Demonstration; Irvine
57. UCI Low NOx Water Heater Retrofit for Hydrogen Blends Development; Irvine

Acronyms

Acronym	Definition
AB	Assembly Bill
ASME	American Society of Mechanical Engineers
Caltech	California Institute of Technology
CARB	California Air Resources Board
CCS	carbon capture sequestration
CCU	carbon capture utilization
CEC	California Energy Commission
CHP	combined heat and power
CO_2	carbon dioxide
COVID-19	Coronavirus Disease 2019
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
GHG	greenhouse gas
GML	Gas Mapping LiDAR
HVAC	heating, ventilation, and air conditioning
IC	interconnection
İTÜ	Istanbul Technical University
kW	kilowatt
LBNL	Lawrence Berkeley National Laboratory
LDC	local distribution company
M	million
MEA	membrane electrode assembly
MS-SOFC	metal-supported solid oxide fuel cell
NA	North America
NGA	Northeast Gas Association
NIST	National Institute of Standards and Technology
NOx	nitrogen oxides
NYSEARCH	A part of The Northeast Gas Association.
OTD	Operations Technology Development
PHMSA	Pipeline and Hazardous Materials Safety Administration
PM	particulate matter
PRCI	Pipeline Research Council International
R&D	research and development
RD&D	research, development, and demonstration
RNG	renewable natural gas
SaaS	software-as-a-service
SB	Senate Bill
SCG	SoCalGas
SoCalGas	The Southern California Gas Company
STEM	Science, Technology, Engineering, and Math
TPF	thermal particle fluid
UC	University of California
UCI	University of California at Irvine
UCICL	UCI Combustion Laboratory
U.S.	United States of America
UTD	Utilization Technology Development
ZECAP	Zero-Emissions for California Ports

Endnotes

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

2022 SUMMARY OF ONGOING AND COMPLETED PROJECTS

LOW CARBON RESOURCES

SUBPROGRAM: CARBON CAPTURE, UTILIZATION, & SEQUESTRATION

Battelle - PNNL Production of CO_2-Negative Building Composites Development - CRADA 553

This project seeks to develop a decarbonization approach that sequesters 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, lignite, and carbon dioxide. Pacific Northwest National Laboratory will build off of its "Integrated Capture and Conversion of Carbon dioxide (CO_2) to Methanol" (IC3M) process to develop a platform to produce carbon-dioxide-negative composite building materials. This approach will result in 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 into the composite industry. 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. In 2022, the team demonstrated the chemical fixation of CO_2 on multiple sources of lignin and lignite particles and was in the process of scaling up 100-gram batches to manufacture composites. The team has dialed in manufacturing procedures for extruding baseline composites of un-functionalized lignin at an unprecedented 70% by weight filler content without the need for costly lubricants or chemical additives. In the coming year, the team will be extruding composites at various loadings of functionalized CO_2LIG particles and identifying composites with optimal mechanical properties and durability. The team will also perform a techno-economic and life cycle analysis of the process. This study will determine the economics of the process and the magnitude of CO_2 reduction potential for these promising CO_2-negative composite materials.

Co-Funders: DOE

Start Date: 10/21/2021
End Date: 10/31/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$3,240,000**
Total SCG Cost: **$540,000**
Total Co-Funding: **$2,700,000**
Benefits:

C4-MCP Microwave Catalysis for Process Intensified Modular Production of Carbon Nanomaterials from Natural Gas Development

The goal of this project is to design and develop a pilot demonstration microwave reactor system. 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. The intensified modular approach is key and will enable the unit's deployment at flared gas sites. The method used in this project relies on using a microwave reactor to convert methane into hydrogen and carbon nanotubes (CNTs) and 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 analyses to identify commercial opportunities for the carbon nanomaterials produced in this process. To support these efforts, carbon nanomaterial products will be analyzed for their quality and potential commercial application. In 2022, the project team completed work in process optimization, catalyst development, and CNT product characterization.

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
2022 Funds Expended: **$0**
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

Captura CO_2 Capture from Oceanwater Using Highly Efficient Electrodialyzer Demonstration

The project goal is to design, develop, and demonstrate the operation of an oceanic carbon dioxide capture system capable of extracting carbon dioxide from ocean water at a capacity of 100 tons/year. Captura proposed the scale-up and testing of their technology in this project by building and demonstrating a 100-ton/year pilot unit. This pilot will fill the critical need to demonstrate an integrated prototype device of the overall system at a large enough scale to assess the cost levers and system scalability. The system has an ocean water intake rate of 700 gallons per minute and a carbon dioxide extraction rate of 100 liters per min. A preliminary techno-economic analysis indicated that the Captura system could capture oceanic carbon dioxide for $500/ton of carbon dioxide at 1,000 tons/year and $100/ton at 1,000,000 tons/year. The project will ultimately 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. In Q3 2022, the project team deployed a small-scale system at the Kerckhoff Marine Laboratory in Newport Beach, CA, to test the technology in real seawater conditions. The group plans to complete fabrication and demonstrate the 100-ton/year system in early 2023.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$350,000**
Total Project Cost: **$750,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$0**
Benefits:

Electricore Direct Air Capture Using Novel Structured Adsorbents Demonstration

This project aims to design, build, and operate a field test unit capable of capturing carbon dioxide from the air and producing a concentrated 30 kg/day stream with at least 95% purity. Electricore aims to advance direct air capture (DAC) technology by combining a vacuum-temperature swing carbon dioxide adsorption process with structured adsorbent beds. This project will validate current state-of-the-art DAC technology and provide valuable 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, they began work on sorbent selection, testing, and optimization. The team completed prototype development, site preparation, and system commissioning activities in 2022. Specifically, Svante and Climeworks developed and optimized several iterations of bench-scale sorbent beds, which the team tested in cyclic DAC process operation. Field testing is ongoing and will continue through Q2 2023, helping to inform techno-economics and life-cycle analysis of the technology.

Co-Funders: Svante, Climeworks, DOE

Start Date: 10/01/2020
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$200,000**
Total Project Cost: **$4,980,280**
Total SCG Cost: **$450,000**
Total Co-Funding: **$4,530,280**
Benefits:

FLECCS -- Rapid Temperature Swing Adsorption (TSA) for CO_2 Capture

The goal was to advance the commercialization of technology that effectively captures carbon dioxide emissions from natural gas power plants and other industrial processes. This project furthered 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 team modeled the TSA carbon dioxide capture technology and a natural gas combined cycle power plant in Southern California. Turndown ratios at the plant range from 25% to 100% due to high market renewable energy penetrations. Technologies that mitigate greenhouse gas (GHG) emissions from fossil-fueled power plant flue gas will benefit ratepayers by improving air quality and reducing the carbon footprint of these facilities. The project's objectives were to 1) demonstrate a solid-sorbent-based, rapid-cycle TSA system for carbon dioxide capture applications from fossil power plant 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. In 2022, the group performed the final techno-economic analysis. In the final report, the team considered cost modeling and various tax incentives to identify scenarios most relevant to deploying this technology. In general, modest operational and capital expense reductions provided enough cost savings to enable economical deployment.

Co-Funders: DOE ARPA-E

Start Date: 09/01/2020
End Date: 04/01/2022
Status: Completed
2022 Funds Expended: **$0**
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

IWVC Combined Water and CO_2 Direct Air Capture System Demonstration

This project aims to design, build, and operate a hybrid direct air capture (HDAC) system that captures 30 tons per year of carbon dioxide and 300 tons per year of water. IWVC is developing HDAC technology capable of capturing water and carbon dioxide from ambient air in one system. The team will test a new carbon capture technology called "Isothermal Water Vapor and CO_2 Capture," originally developed at the Pacific Northwest National Laboratory. The team expects the HDAC to produce 10 tons of potable water for every ton of CO_2 captured. The 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. This project kicked off in 2020. The project team completed the design of an HDAC system in 2021. In 2022, the group formally selected the Bakersfield, CA, demonstration site. Additionally, the research team synthesized the DAC adsorbent material at the University of North Texas and ordered all major components. In 2023, Barr Engineering in Salt Lake City, UT, will fully assemble the unit and ship it to Bakersfield to commence operation, testing, and data collection activities.

Co-Funders: DOE

Start Date: 10/10/2020
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$200,000**
Total Project Cost: **$3,170,000**
Total SCG Cost: **$672,000**
Total Co-Funding: **$2,500,000**
Benefits:

IWVC Hybrid Direct Air Capture to Fuels Demonstration

This project aims to build a commercially relevant demonstration unit to capture carbon dioxide (CO_2) and water from ambient air and design a process for converting CO_2 and water to zero-carbon fuels. The end-to-end method comprises IWVC's unique hybrid direct air capture (HDAC) technology and an electrically driven CO_2 system to generate value-added e-fuels. The HDAC system enables self-contained (no external supplies needed, including water) production of CO_2 and water. IWVC has received support from the Office of Naval Research (ONR) for this project, given the strategic importance of water and carbon-neutral fuel production for defense purposes. Project work will include 1) detailed design for a 300 tons-CO_2 (~3000 tons-H2O) per year HDAC unit to validate the specific electrical, heat, mass, and fluid flow requirements conducted for this project; 2) procurement, component manufacturing, assembly, and shakedown testing of the complete 300 ton-CO_2 HDAC unit in preparation for field testing; 3) field testing of the HDAC unit and preparation of a final report on the testing, results, conclusions, and recommendations; and 4) an initial conceptual design of a fuels synthesis system that could be constructed and added to the back-end of the HDAC unit in a future phase of this project. The team initiated the project in Q4 2022 and expects engineering design to commence in Q1 2023.

Co-Funders: Office of Naval Research (ONR), TotalEnergies

Start Date: 11/01/2022
End Date: 10/31/2024
Status: Active
2022 Funds Expended: **$250,000**
Total Project Cost: **$4,685,545**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,185,545**
Benefits:

PNNL Integrated CCU System (IC3M) for C1 and C2 Production Development

PNNL has developed an integrated platform to capture and convert carbon dioxide (CO_2) to Materials called IC3M. It created this platform supported by a Technology Commercialization Fund partnership with DOE-FECM and SoCalGas. In the early tests conducted at PNNL, this technology demonstrated methanol production at low temperatures (below 180°C) from hydrogen and CO_2 captured in a liquid solvent. This project will build upon these early results by further assessing the flexibility of the IC3M system in producing other useful chemicals. The team will develop the platform to produce various chemicals (formic acid, methyl formate, ethylene glycol, methane, and ethanol) and improve current methanol conversion rates. Conventional CO_2 capture and utilization technologies require CO_2 desorption, compression, and transportation before use. In the IC3M system, captured CO_2 becomes directly integrated into a final product so that the energy needed for CO_2 desorption and compression is avoided. The project approach involves adapting other catalysts and reagent co-feeds for the same capture solvent system developed in the previous research effort. The strategy will enable the research team to tune the catalyst and process conditions required to target several large-market hydrocarbon products. By reducing the need for additional energy inputs, IC3M may become a viable technology for modular distributed-scale processing platforms, which could enable applications such as separating and converting CO_2 from landfill gases, wastewater treatment gases, and manure off-gas.

Co-Funders: DOE

Start Date: 09/01/2022
End Date: 08/30/2024
Status: Active
2022 Funds Expended: **$660,000**
Total Project Cost: **$3,300,000**
Total SCG Cost: **$660,000**
Total Co-Funding: **$2,640,000**
Benefits:

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

PNNL Methane Pyrolysis for CO_2-Free H2 and Carbon Nanomaterials Co-Production Development - CRADA 576

The objective of this project is to develop further and scale up the methane pyrolysis technology developed in earlier efforts. To date, the project team has focused on i) understanding the catalyst science for thermocatalytic decomposition of methane (TCD), which resulted in the development of a patent-pending bimetallic catalyst offering favorable activity, stability, and selectivity under industrially relevant process conditions, ii) developing a novel, patent-pending process to enable the separation of produced carbon and catalyst, and re-synthesis of the catalyst using recycled materials, iii) performing limited characterization of the produced carbon materials, and iv) performing detailed process modeling to perform a techno-economic assessment. The additional scope proposed here will accelerate the commercial deployment of TCD for CO_2-free hydrogen and valuable solid carbon nanotubes (CNT) co-product by i) scaling up the production of CNT co-product using a scalable, fluidized bed reactor (25 g catalyst scale versus the 1 g catalyst scale demonstrated to-date), ii) producing at least 40 g of CNT product via multiple cycles of TCD, carbon-catalyst separation, and catalyst re-synthesis, to enable the production of sufficient quantities of solid carbon to explore its market potential, iii) understanding the quality of the co-product CNTs at a larger scale, through advanced characterization, and iv) beginning to explore multiple promising high volume carbon product applications (thermoplastics, automotive composites, battery, and cement reinforcement applications). This project was initiated in Q4 2022, and work is expected to commence in Q1 2023.

Co-Funders: N/A

Start Date: 10/13/2022
End Date: 10/12/2023
Status: Active
2022 Funds Expended: **$425,000**
Total Project Cost: **$425,000**
Total SCG Cost: **$425,000**
Total Co-Funding: **$0**
Benefits:

Stanford Energy Efficient Strategies for Capture of Atmospheric CO_2

This project aims to continue developing sorbent technology pioneered by Stanford University, which can react with carbon dioxide in the presence of water while also requiring low regeneration energy. Traditional direct air capture (DAC) systems use basic metal oxides known to bind to carbon dioxide strongly and form carbonates but need extremely high temperatures to convert back into oxides. Stanford's goal is to regenerate the metal oxide sorbent's post-carbon dioxide capture to avoid using high 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, thereby regenerating the sorbent. This project's novelty is exploring non-equilibrium plasmas that are low-temperature, renewable energy-powered, and could provide a sustainable way to capture and concentrate carbon dioxide. This project kicked off in Q4 of 2021. In 2022, the project team developed an experimental system to evaluate the use of plasma in DAC systems. The team studied the effects of inert and reactive plasmas on efficiency and performance during operation. The team also studied side reactions and other conversion mechanisms that occurred while using reactive plasmas.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$130,000**
Total SCG Cost: **$130,000**
Total Co-Funding: **$0**
Benefits:

Susteon High-Capacity Regenerative Structured Sorbent Development for DAC Applications

The objective of this project is to develop a structured material system (SMS) for capturing carbon dioxide from the air. The purpose of this project is to optimize the composition of the SMS to maximize the 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 4 to justify its scale-up and pilot test in a subsequent project. The goals of the bench-scale technology projects 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 make certain 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. In 2022, Susteon designed and built a bench-scale DAC test unit to evaluate the structured sorbent system's performance. Testing on lab-scale samples thus far has demonstrated carbon dioxide adsorption at ambient conditions and subsequent desorption using an integrated electrical heating mechanism. Additionally, the team has completed short-term cyclic testing to confirm system performance and mass balance during operation.

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

Start Date: 09/01/2021
End Date: 08/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,903,877**
Total SCG Cost: **$25,000**
Total Co-Funding: **$1,878,877**
Benefits:

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

Susteon Low-Temperature Regeneration Sorbents for Direct Air Capture of CO_2 Development

This project aimed to develop catalyzed direct air capture (DAC) sorbents with enhanced adsorption and desorption kinetics and higher sorbent working capacity to lower the overall cost of DAC. These sorbents are amine-doped solid sorbents catalyzed by Susteon's proprietary ionic liquid shown in laboratory tests to increase the CO_2 desorption rate by 40 to 80% and increase CO_2 working capacity by about 100%. In laboratory tests, these catalysts showed that the proprietary ionic liquid used in 100 to 200 ppm levels is sufficient to enhance sorbent performance for CO_2 capture from air. Techno-economic analysis using laboratory data for the sorbents indicates the cost of DAC is at about $200/tonne CO_2 today with the potential to decrease to less than $100/tonne CO_2 when fully matured at a commercial scale of 1 million tonne/year capacity.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 09/30/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$999,687**
Total SCG Cost: **$100,000**
Total Co-Funding: **$899,687**
Benefits:

Susteon Plasma Assisted Catalytic Conversion of CO_2 and Propane to Propylene and CO Development

This project aims to develop a novel Catalytic Non-Thermal Plasma (CNTP) process to synergistically combine low-temperature plasma with metallic/bi-metallic catalysts in a scalable reactor for utilizing CO_2 as a soft oxidant to produce ethylene and propylene from ethane and propane, respectively. 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. This technology offers many advantages: low-temperature operation (100° to 300°C vs. 700° to 900°C for steam cracking), quick start-up time (minutes vs. several hours for steam cracking), wide turndown ratio, smaller footprint, multiple stops and starts capability, on-demand operation, and modularity. The project team has developed two optimized catalysts. They are Cr and Ga supported on Al_2O_3. The team tested these catalysts in a plasma reactor. Test results have shown that they can obtain propane conversion as high as 60% and propylene yield as high as 80%. However, the project team could not conclusively confirm the synergistic effect of the plasma and catalyst. They are carrying out more tests under various conditions of plasma power, catalyst composition, and temperature. The project team will also perform process modeling and techno-economic analyses once all experimental work is finished. They aim to assess if this route can provide cost parity with existing production technologies for ethylene and propylene without any green premiums while utilizing CO_2.

Co-Funders: DOE

Start Date: 12/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,255,364**
Total SCG Cost: **$120,000**
Total Co-Funding: **$1,135,364**
Benefits:

Susteon Stanford Iron-Oxide Based Catalytic Methane Pyrolysis Development

The main objective of this project is to develop and demonstrate a methane pyrolysis unit capable of producing 10kg H2/day at less than $2 H2/kg with co-production of carbon nanotubes at under $10/kg. Stanford University and Susteon have begun developing a methane pyrolysis process to produce high-purity hydrogen and carbon nanotubes from the catalytic pyrolysis of methane. This project explores developing a unique iron-based catalyst to produce carbon nanotubes and hydrogen in a fluidized bed reactor. The team will develop a process to regenerate and reuse the catalyst and create synthesis methods that can easily be scaled to produce commercial quantities of catalyst using existing manufacturing infrastructure. The project kicked off in Q4 of 2021, and work has begun to optimize the catalyst and revise the process design. In 2022, the team made several improvements to the reactor design, including integrating structured catalyst supports resulting in much higher solid carbon recovery yields.

Co-Funders: DOE ARPA-E

Start Date: 11/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$100,000**
Total Project Cost: **$2,415,139**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,915,139**
Benefits:

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

TCF-19-17862 Integrated Capture and Conversion of CO_2 to Methanol (ICCCM) Process Technology (CRADA 449)

This project aimed to develop a solvent-based prototype system that integrates carbon dioxide capture and catalytic hydrogenation into methanol. Pacific Northwest National Laboratory (PNNL) carried out the work. It created the patent-pending integrated carbon dioxide capture and conversion process, which has the potential for significant cost savings compared to conventional carbon management approaches. Using batch reactor processing with a precombustion solvent system, PNNL first demonstrated an integrated catalyst-solvent approach suitable for combined capture and conversion. In 2020, the team successfully established the processing 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. This demonstration is likely the first formation of methanol using a post-combustion solvent in the presence of a heterogeneous catalyst. In 2021, the team advanced the integrated catalyst-solvent system by improving the catalytic activity required for commercial adoption, demonstrating an improved methanol selectivity of >90%. A bench-scale reactor was designed and fabricated for utilization in the final demonstration in 2022 and successfully illustrated single-pass operation and methanol synthesis for 10 hours using a simulated flue gas mixture. Techno-economic analysis performed for the methanation reaction suggests that this technology could be cheaper and more efficient than conventional Sabatier processes when deployed at scale. The team will further develop this technology in a new project with funding from the office of Fossil Energy and Carbon Management at the DOE.

Co-Funders: DOE

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

Twelve PEM CO_2 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 a megawatt (MW)-size enables industrial applications where Twelve can convert large quantities of carbon dioxide into fuels and plastics. Twelve needed to scale the membrane electrode assembly (MEA) active area to 1,600 cm2 to build MW-scale stacks capable of over 800 kg of carbon dioxide conversion per day. Twelve has identified five high-level project objectives required 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 life-cycle 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. They also completed flow-field optimization and PEM design activities. In 2022, the team fabricated and tested the first large-scale, 700 cm^2 electrolyzer for hundreds of hours. The project team also completed a final techno-economic analysis and life cycle assessment. This process identified several key drivers to lower the anticipated cost of carbon monoxide, especially stack and MEA optimization, and reduced catalyst loading to minimize CapEx.

Co-Funders: DOE, Twelve

Start Date: 11/30/2020
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$160,000**
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

SUBPROGRAM: RENEWABLE GAS PRODUCTION

Caltech Hybrid Electrochemical and Catalytic Hydrogen Compression System Development

Researchers at Caltech propose to develop a hybrid electrochemical, catalytic approach for the generation of compressed hydrogen. This technology differs from water electrolysis in that it involves a two-step process in which the active media is first electrochemically charged and then sent to a catalytic reactor to generate hydrogen directly. A benefit of this catalytic compression technology is that hydrogen can be produced on-demand with no intermediary steps at high pressure (up to 700 bar), allowing it to be stored with no additional compression or used for vehicle refueling. Low-cost hydrogen in a power-to-gas-to-power (PGP) system can help enable gigawatt (GW) scale and affordable long-duration energy storage. The project will focus on the off-peak operation to decouple and leverage renewable electricity intermittency and pricing. With data obtained during testing, the team plans to develop a comprehensive techno-economic analysis (TEA) to model the costs and performance of the system under these conditions. The project team also plans to integrate the hybrid technology to compress low-pressure hydrogen generated via water electrolysis.

Co-Funders: DOE/ARPA-E

Start Date: 11/01/2022
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$300,000**
Total Project Cost: **$2,500,000**
Total SCG Cost: **$300,000**
Total Co-Funding: **$2,200,000**
Benefits:

EvolOH High-speed AEM Electrolyzer Manufacturing Development

The goal of this project is to develop high-speed coating methods for anion exchange membrane (AEM) electrolyzer production to increase overall manufacturing speed and capacity. EvolOH's electrolyzer technology combines the performance advantages of proton exchange membrane (PEM) electrolysis (pure water feed, fast response, load-following, pressurized hydrogen production) with the cheap, non-platinum group metal (PGM) materials used in traditional alkaline electrolysis. EvolOH has designed its technology to accommodate roll-to-roll manufacturing, which can achieve nearly an order of magnitude improvement in production rate over state-of-the-art electrolyzer manufacturing methods. Increasing electrolyzer production speed and reducing material costs represents a meaningful strategy to lower the levelized costs of hydrogen and increase the domestic supply of hydrogen production equipment. The project team aims to achieve high-speed membrane coating in this process, which they have identified as the current manufacturing bottleneck. The team will also validate the performance and stability of electrolyzer cells and stacks developed using this production technique.

Co-Funders: N/A

Start Date: 12/01/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$150,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$150,000**
Benefits:

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

This project aimed to develop and identify electrocatalysts synthesized from earth-abundant elements for utilization in modular, scalable, and cost-competitive polymer electrolyte membrane (PEM) based electrolyzers. H2U Technologies Inc. is a startup company exploring high-throughput catalyst discovery technology developed under a joint program between the U.S. Department of Energy and Caltech. The objective of this project involved the testing and scale-up of earth-abundant electrocatalysts previously developed and tested at bench scale. In 2021, the project team completed the analysis of current PEM electrolyzer manufacturing process costs and identified several opportunities to reduce them for the total system. In 2022, H2U scaled up the production of non-Iridium catalysts and developed a test bench for evaluating electrolyzer hardware. Additionally, the team screened new catalysts for use in PEM electrolysis.

Co-Funders: N/A

Start Date: 03/04/2021
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$160,000**
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

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

This project aimed to overcome catalyst sulfur poisoning to enable commercially viable Catalytic Hydrothermal Gasification (CHG) processing during the hydrothermal liquefaction (HTL) of aqueous waste streams by improving the operational lifetimes of catalysts. Pacific Northwest Laboratory (PNNL) has developed 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 contained sulfur compounds. Like other noble metals and many other catalysts, ruthenium is deactivated or poisoned by exposure to sulfur. The project identified potential sulfur-tolerant catalysts active in sulfide 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 sulfide ruthenium-carbon catalyst possesses a stable CHG performance of 480+ hours' time-on-stream. PNNL plans to continue improving the activity of unsupported sulfide CHG catalysts. In 2021, the team explored different catalyst systems for their reactivity and sulfur sensitivity. They performed a techno-economic analysis to determine overall system cost, including catalyst lifetime, catalyst cost, and available carbon credits. In 2022, the team submitted a final report detailing the discovery of a new catalyst formulation that has the potential to be many times cheaper than the state-of-the-art catalyst. This novel catalyst has high activity and stability for the CHG process.

Co-Funders: N/A

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

Kore Biosolids Pyrolyzer Field Test

This project aims to reduce risk and improve the potential for financing future commercial deployments by conducting field tests to verify component integrity at high temperatures, feedstock throughput, and gas product quality and composition. 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 thinning, municipal solid waste, and food waste. The project team will demonstrate the operation of feedstock conveyance and drying, pyrolytic conversion, and gas cleanup and cooling. Construction at SoCalGas' Olympic Base concluded in late 2021. Commissioning activities for the pyrolyzer began immediately afterward. System operations and testing began in 2022. Using data gathered during the testing period, Kore will report on system performance and techno-economic analysis and decommission their facility in Q1 2023.

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

Start Date: 02/13/2017
End Date: 01/15/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$6,100,000**
Total SCG Cost: **$1,500,000**
Total Co-Funding: **$4,600,000**
Benefits:

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. In Q4 2021, the team reached an agreement with FirstElement Fuel (FEF). 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 instance of a Linde HydroPrime unit in the Americas. Construction of the Linde HydroPrime unit was completed and shipped to the FEF site in 2022. The team is planning construction and installation activities for 2023.

Co-Funders: N/A

Start Date: 11/15/2019
End Date: 09/30/2024
Status: Completed
2022 Funds Expended: **$148,091**
Total Project Cost: **$2,540,000**
Total SCG Cost: **$2,540,000**
Total Co-Funding: **$0**
Benefits:

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

LLNL Modular Hybrid Electrobioreactor Demonstration

This project aims to advance the integrated electrobioreactor technology developed at Lawrence Livermore National Laboratory (LLNL). State-of-the-art bioreactor technology works in two stages, producing hydrogen in an electrolyzer and bubbling that through a reactor where carbon dioxide and hydrogen are converted into methane and water using methanogenic archaea. In earlier work, the team tested integrating an electrolyzer into a bioreactor to supply hydrogen on demand for upgrading carbon dioxide to methane. This one-stage approach helps to address the low solubility of hydrogen in water and represents a potentially simplified engineering approach over existing bioreactor technology. In this project, the team will leverage LLNL's advanced manufactured 3D electrodes and test various flow-field configurations to optimize performance in the electrobioreactor. The team also plans to test performance at different operating conditions (e.g., feedstocks of varying purity and at various levels of turn-down). The project kicked off in late Q4 2022.

Start Date: 11/23/2022
End Date: 02/29/2024
Status: Active
2022 Funds Expended: **$150,000**
Total Project Cost: **$2,030,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$1,280,000**
Benefits:

NREL Biologically Derived Hydrogen From Organic Solid Wastes Research

The goal of this project is to test and identify suitable feedstocks for biotechnology developed at the National Renewable Energy Laboratory (NREL) that can produce hydrogen from organic solid waste streams rich in cellulose content. The core of this technology employs microbial, dark fermentation to harness the chemical energy and electrons in these wastes for hydrogen production. The NREL team has leveraged their expertise in microbial strain engineering and bioprocess design to create strains and fermentation strategies that achieve high conversions of the organic solid waste streams to hydrogen. The project team plans to test their engineered microbes to enhance anaerobic digestion (AD) technologies by further processing cellulose-enriched "hard-to-digest" materials into hydrogen. These wastes may be from less complex sources (e.g., dairy residues) or highly complex sources (e.g., biosolids or sludges produced during municipal wastewater treatment). This carbon-neutral approach can potentially be carbon-negative when paired with carbon capture technologies. In addition to the ongoing work to evaluate these feedstocks, the project team will also work with researchers at Argonne National Laboratory to perform a detailed techno-economic analysis for this hydrogen production pathway.

Co-Funders: DOE/HFTO, NREL

Start Date: 12/01/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$189,320**
Total Project Cost: **$394,320**
Total SCG Cost: **$189,320**
Total Co-Funding: **$205,000**
Benefits:

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

The goal of this project is to integrate biomethanation and electrolysis to realize the synergies that the two processes have. Hydrogen's inherently low solubility in water can challenge power-to-gas biomethanation and other gas fermentation processes. This low solubility limits the availability of hydrogen to the biocatalyst. The methods are also burdened by the high capital costs of the water electrolyzer used to make green hydrogen. The National Renewable Energy Laboratory (NREL) is working to eliminate expensive hardware unnecessary in producing hydrogen for this purpose. By co-locating the electrolyzer with a chemical reactor, some of the sub-systems normally needed to produce pure "dry" hydrogen, which is necessary for fueling but not for processes like biomethanation can be removed. This approach could avoid thousands of dollars in equipment costs while improving system efficiency by preventing hydrogen losses or additional energy to dry the gas. These improvements resulted in a non-provisional patent application in 2021. 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. In 2022, the team completed the advanced electrolyzer system design, removing unnecessary sub-systems and implementing a novel strategy to measure hydrogen flow rate using stack current from the electrolyzer. The team also worked with the University of Chicago and Perma Pure to develop technology to recycle water in the biomethanation reactor.

Co-Funders: DOE

Start Date: 05/01/2019
End Date: 10/05/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$4,400,000**
Total SCG Cost: **$700,000**
Total Co-Funding: **$3,700,000**
Benefits:

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

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

Start Date: 07/31/2019
End Date: 07/06/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$2,305,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$2.300,000**
Benefits:

This project aims 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. They based the design 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. They outfitted it with multiple ports for sensors. The bioreactor also includes multiple sight glasses for viewing and a high-speed camera to monitor gas mixing. The team will install the bioreactor in a custom 16' trailer that will travel to biogas sites to demonstrate the production of RNG. Data from this mobile system will be available to regulators to accelerate the certification of the RNG production pathway from biomethanation. In 2022, the NREL team worked with Argonne National Laboratory researchers to develop a life cycle analysis for the RNG produced from biomethanation. One major takeaway of this study was that the carbon intensity (CI) score of RNG produced via this pathway heavily depends on the CI and source of electricity used to power the electrolyzer. When using a fully renewable electricity supply, RNG made from biomethanation of swine manure-derived carbon dioxide is ~-100 g CO_{2eq} per MJ, demonstrating carbon-negative fuel production. The new mobile bioreactor system is expected to be operational and deployed to biogas sites by the end of the 2023 calendar year.

Co-Funders: DOE, Electrochaea

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: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$805,625**
Total SCG Cost: **$87,720**
Total Co-Funding: **$717,905**
Benefits:

One desirable and promising path to storing intermittent, renewable electrical energy is Power-to-Gas technology. The goal of this project 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 the growth and metabolism of microbial cells during long-term operation of a bio-electro-chemical reactor; 2) data analysis and interpretation concerning 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. Phase II began in 2020 and aimed to identify the methanogenic archaea most suitable for intermittent electromethanogenesis to study further the dynamics and robustness of predictable and unpredictable electrical power supplies. In 2021, the project team identified Methanococcus Maripaludis as the most stable strain for further study of the intermittent process of electromethanogenesis. The team also studied how the strain responded to physical and chemical changes associated with the intermittent operation of an integrated electrosynthesis reactor. In 2022, the team concluded the project using real-world curtailed energy profiles in the electromethanogenesis system. When using curtailed wind power profiles, the electrical efficiency of the electrosynthetic reaction was >75%; when using curtailed solar power profiles, the efficiency was >95%. The final report demonstrated that electromethanogenesis is a potentially effective way to convert excess or curtailed electricity and carbon dioxide into renewable methane.

Co-Funders: NYSEARCH Members

STARS Corporation Electric Induction Steam Methane Reforming (SMR) Demonstration

Start Date: 04/01/2020
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$888,914**
Total Project Cost: **$4,200,000**
Total SCG Cost: **$3,600,000**
Total Co-Funding: **$600,000**
Benefits:

The goal of this project is to demonstrate and deploy a novel steam methane reforming (SMR) process to produce renewable hydrogen. STARS Corporation is developing an advanced, highly efficient SMR reactor that utilizes induction-based heating. STARS' reactor design uses micro- and mesoscale catalytic channels and efficient heat recycling to demonstrate record efficiencies in converting electrical energy and natural gas to produce hydrogen. STARS' reactor technology features modularized construction capability and a small footprint. This technology will support on-site storage and fueling operations for SunLine Transit's fleet of hydrogen-powered buses in Thousand Palms, California. The team completed site construction and equipment installation in 2022 and is underway with commissioning activities for all major equipment. The group estimates that renewable hydrogen production will commence in Q1 2023.

Co-Funders: N/A

- 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)

Project goals included lowering equipment costs by improving manufacturing processes, developing innovative designs, and stimulating equipment supply chains. In collaboration with the Pacific Northwest National Laboratory (PNNL) and Oregon State University, SoCalGas and STARS Technology Corporation worked 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 assisted with the near-term commercialization of STARS systems for distributed hydrogen production. 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. In 2022, PNNL demonstrated a world-record electrical-to-chemical efficiency of >80% in an inductively heated SMR reactor. In addition, the team will deploy the microchannel reactors and heat exchangers developed in this project at a pilot-scale hydrogen generation demonstration in early 2023.

Co-Funders: N/A

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

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. Susteon also aims to use the CNTP reactor to demonstrate its ability to deliver sustainable aviation fuel from carbon dioxide and methane. This approach will create an opportunity for the utilization of captured carbon dioxide to provide a new pathway to reduce greenhouse gas emissions in an otherwise difficult-to-decarbonize sector. This project follows up on CNTP technology developed in a previous project with the Jet Propulsion Laboratory, in which lab-scale technology was successfully demonstrated. The CNTP reactor uses plasma to improve the conversion of methane and water into hydrogen-rich syngas at much lower temperatures relative to other steam methane reforming technologies. The team completed design and equipment procurement activities for a bench-scale unit. After commissioning the equipment in 2022, test results showed that, when using commercially available catalysts, the CNTP reactor can lower the steam methane reforming temperature from 900°C to 400-450°C to produce syngas that has a composition with high hydrogen content (~70 to 75%) and low CO content (1 to 5%). This syngas composition significantly reduces the cost of downstream hydrogen purification.

Co-Funders: N/A

Start Date: 08/01/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$50,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$0**
Benefits:

TCF-19-17586 LLNL Composite Sorbents - Enabling Economical Biomethane Production

The goals of this project are to determine the economic and technical feasibility of a full-scale demonstration after the two-year project. Lawrence Livermore National Laboratory (LLNL) and SoCalGas are working to refine and demonstrate a new class of sorbents for upgrading raw biogas to biomethane. This approach offers the potential to reduce cost barriers to biomethane production significantly. This strategy would, in turn, allow small producers to leverage this renewable energy resource to generate revenue. The focus of the technology maturation activities are 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 sorbent production; 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 with Xebec to operate a small-scale pilot (SSP) of the LSU at Xebec's testing facility. In 2022, LLNL successfully scaled up sorbent production for use in the SSP. The target completion date for the SSP will be 2023. LLNL will produce a techno-economic analysis of SSP for future maturation activities.

Co-Funders: DOE

Start Date: 10/15/2019
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,020,300**
Total SCG Cost: **$770,300**
Total Co-Funding: **$250,000**
Benefits:

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

UCR Speeding Anaerobic Digestion Through CO_2 Microbubbles

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 the team will operate it as normal. The second will be the experimental digester and have the Perlemax technology implemented into its heat exchanger recirculation loop. The team will compare results from the experimental digester to those of the control to determine if the carbon dioxide microbubbles statistically affect 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 team will optimize sludge and carbon dioxide flow rates to maximize volatile solid conversion and methane production rates. In 2021, the team completed the design and fabrication of the microbubble equipment. Installation, commissioning, and testing of the equipment are delayed until 2023 due to equipment and materials shortages.

Co-Funders: CalSEED

Start Date: 06/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$300,840**
Total SCG Cost: **$150,840**
Total Co-Funding: **$150,000**
Benefits:

West Biofuels Renewable Gas Separation System and Techno-Economic Assessment

The objectives of this project are 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, 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 required. Modeling efforts have focused on modifying existing National Renewable Energy Laboratory (NREL) mixed alcohol production models to reflect recent process modifications. In 2021, applying the gas hydrate separation concept in the continuous flow arrangement showed promise, meriting further investigation. Furthermore, other separation technologies—membrane and pressure swing adsorption—are being investigated to make sure successful project completion. In 2022, despite significant downtime due to equipment damage, repair, and supply issues, the team recommissioned the system to begin long-term testing runs, data collection, and analysis activities. Using data from these runs and natural gas separations modeling support from NREL, techno-economic analysis will be refined and reported in 2023.

Co-Funders: CEC

Start Date: 10/01/2019
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$0**
Total Co-Funding: **$200,000**
Benefits:

GAS OPERATIONS

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

SUBPROGRAM: ENVIRONMENTAL & SAFETY

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

The project objective was 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) Recommended Practice (RP) 1173. In Phase I, the project team broke down API RP 1173 into its core components and methodologies for consideration as a business process at the enterprise level. The team used the BPMN to identify business units critical to an organization's PSMS and how those units interact in the PSMS across the organization. In Phase II, the team completed a literature review of the safety and construction industries and an examination of RP 1173 for contractor-related references. Gas utility case studies were performed using the BPMN process mapping their PSMS to identify key themes, implications, and expectations for a contractor's role in PSMS. The results were published in a final report, "Pipeline SMS Study: The Contractor's Role." This report contained recommended practices for incorporating contractors into the PSMS. Also, the results were presented at API's May 2022 Pipeline, Control Room & Cybernetics Conference to foster industry PSMS alignment. SoCalGas plans to use the research to benchmark its own PSMS and as a reference for the continuous improvement process required in API RP 1173.

Co-Funders: OTD Members

Start Date:	12/04/2020
End Date:	09/15/2022
Status:	Completed
2022 Funds Expended:	**$0**
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)

The objective of this project is to test and demonstrate a three-dimensional electromagnetic technology to locate subsurface metallic infrastructure such as metal cutters in polyethylene (PE) service tees. Most locating technologies do not have high-accuracy antennae to find underground facilities with high confidence, much less with plastic. Knowing the precise locations of buried infrastructure has the potential to save money by mitigating dry-hole excavations. In 2021, the team used the project data to determine the accuracy and effectiveness of the pipe-locating technology in identifying metallic cutters in buried PE service tees, which generates an intrinsic and unique fingerprint. In 2022, sponsors provided a variety of service tees that were classified and tested, with the system yielding positive results of geospatial accuracy and pipe depth. The data was collected and analyzed to determine the accuracy of the 3D position (latitude, longitude, depth) of the service tee cutter and to distinguish the service tee cutters from other metallic anomalies, such as emplaced clutter, against data in the library. The project team found that the emplaced clutter creates a fingerprint that is not unique to any tee cutter and instead creates a false positive. Upon project completion, the team will present the results in a webinar and deliver the testing and field demonstration reports to sponsors. SoCalGas could benefit from the ability to locate subsurface metallics because it has the potential to reduce damage to its lines, which reduces damage to life, property, and community.

Co-Funders: OTD Members

Start Date:	02/01/2021
End Date:	02/16/2023
Status:	Active
2022 Funds Expended:	**$0**
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

AERMOD NO2 Modeling Improvement Project – Dissemination of Results (CPS-11-5B)

The project objective is to assess the performance of the American Meteorological/Environmental Protection Agency Regulatory Model (AERMOD), the U.S. Environmental Protection Agency's (EPA) compliance tool for estimating impacts from air pollutant emission sources. This model overestimates ground-level NO2, which could lead to unnecessary NOx reduction system retrofits and compressor unit replacements. Previously, SoCalGas worked with Pipeline Research Council International (PRCI), the Interstate Natural Gas Association of America Foundation, the American Petroleum Institute, and other trade associations to build a robust emission dataset to assess the AERMOD model and to develop recommendations for improving AERMOD. The project team also identified pathways and methodologies to enhance model impact estimates from reciprocating engines, completed additional analyses, and recommended model changes. In this phase of the project, PRCI and sponsors will support EPA as they implement model changes and present the results in a workshop disseminating the AERMOD modifications to the public. The knowledge transfer involves in-person and web meetings with EPA staff and supports an EPA specialty conference involving AERMOD experts in a panel discussion. A tool that accurately assesses emissions could assist in planning for air emission reductions.

Co-Funders: PRCI Members

Start Date: 12/14/2022
End Date: 12/15/2023
Status: Active
2022 Funds Expended: **$34,050**
Total Project Cost: **$61,732**
Total SCG Cost: **$34,050**
Total Co-Funding: **$27,682**
Benefits:

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

The project objective was to assess the performance of the American Meteorological/Environmental Protection Agency Regulatory Model (AERMOD), the U.S. Environmental Protection Agency's (EPA) compliance tool for estimating impacts from air pollutant emission sources. Previously, 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 to assess the AERMOD model and to develop recommendations for improving AERMOD. The project team also identified pathways and methodologies to enhance model impact estimates from reciprocating engines. The team completed additional analyses, recommended model changes, and gathered EPA comments in this phase. The project team compiled the results into a final report available on the PRCI website. The next step is for PRCI and sponsors to support EPA as they implement model changes and present the results in a workshop disseminating the AERMOD modifications to the public. A tool that accurately assesses emissions will assist in planning for air emission reductions.

Co-Funders: PRCI Members

Start Date: 01/01/2019
End Date: 07/11/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$613,600**
Total SCG Cost: **$53,429**
Total Co-Funding: **$560,171**
Benefits:

B31Q Training Documentation Portal (8.20.a)

The objective of this project was 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 list from other sources, including the Pipeline and Hazardous Material Safety Administration and the Midwest Energy Association. SoCalGas plans to use the research as reference material for its Pico Rivera Training Facility.

Co-Funders: OTD Members

Start Date: 01/01/2020
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$129,000**
Total SCG Cost: **$40,000**
Total Co-Funding: **$89,000**
Benefits:

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

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

The project objectives addressed a serious safety concern regarding odorant fade by developing best practices for odorizing high-rise and low-occupancy, low-use buildings and providing a risk mitigation guide. Odorants are added to natural gas, which is odorless, to act as a warning agent and aid in detecting leaks via the sense of smell. Odorant fade is a common phenomenon that affects new, unconditioned pipes in high-rise, low-occupancy, and low-use buildings and has been observed in low-gas-flow situations. This project performed lab tests to investigate odor fade in coated and uncoated pipes and determined odorant saturation times. The results confirmed that lines with rust experienced odor fade under low-flow conditions. The project team published an interim report in 2021, recommending that additional testing be added to the project scope to validate the findings and provide sponsors with a risk assessment procedure and mitigation options. In 2022, the project completed the additional testing. The team used the testing results and developed two mathematical models to predict odorant fade in uncoated pipes with rust. The team also evaluated coated and plastic pipes to see if those pipe materials were affected by odor fade, but they did not observe the same phenomenon. The team published models to predict odor fade in the final report. The project results will lead to a safer energy supply for ratepayers. SoCalGas will analyze and review the results to determine if any modifications to its standards are needed.

Co-Funders: OTD Members

Start Date: 04/17/2017
End Date: 10/07/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$364,700**
Total SCG Cost: **$40,776**
Total Co-Funding: **$323,924**
Benefits:

Center for Hydrogen Safety

The Center for Hydrogen Safety (CHS) aims to foster a global community around hydrogen safety. CHS was launched in April 2020 with the United States Department of Energy (DOE) as a strategic partner along with the Hydrogen Council and California Fuel Cell Partnership. CHS supports and promotes the safe handling and use of hydrogen across industrial and consumer applications in the energy transition. 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. Previously, a Codes & Standards working group was formed focusing on H2-NG blending in natural gas pipeline systems. Since creating 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. Building upon the knowledge-gathering efforts in 2021 from multiple sub-working groups, the CHS H2-NG blending working group began developing a Best Safety Practice (BSP) for leak detection technologies and methodologies. Key input from natural gas pipeline operators, detection technology experts, and other industry partners will result in a first draft BSP that the team can share on the US DOE-funded h2tools.org website. BSP development is in progress, with a first draft scheduled in early 2023. In 2023, SoCalGas participation in CHS transfers out of the GasOps RD&D program.

Co-Funders: JIP Members

Start Date: 11/01/2019
End Date: 11/01/2022
Status: Completed
2022 Funds Expended: **$4,735**
Total Project Cost: **$4,265,771**
Total SCG Cost: **$65,771**
Total Co-Funding: **$4,200,000**
Benefits:

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

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 make important methane studies available to sponsors. 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 2022, the CMR collected and summarized information from 39 papers and reports, 20 projects, and nine conferences. In addition to these base efforts, the CMR has begun focusing on generating new informational content for members and has created a video series on the differences between inventory and calculated methane emissions and real-world emissions. The CMR also hosted two workshops, one on real vs. calculated emissions and one on industrial and commercial end-use emissions. The information and data from CMR helps 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. In 2023, support for the CMR will transition to the SoCalGas Emission Strategy Program.

Co-Funders: OTD Members

Start Date: 10/01/2016
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$25,000**
Total Project Cost: **$1,055,000**
Total SCG Cost: **$75,000**
Total Co-Funding: **$980,000**
Benefits:

Centrifugal Compressor Dry Gas Seal Reliability Enhancement IV (CPS-5-10A)

Dry seals are critical components in preventing greenhouse gas (GHG) release in centrifugal compressors. These seals, however, are known to fail, resulting in releases of GHGs into the environment and causing centrifugal compressor shutdowns that result in service interruptions. This project investigated the causes of seal failures. In previous phases under Gas Machinery Research Council, which Pipeline Research Council International did not participate in, the project team used test rigs in the laboratory to collect data on seal performance and factors that caused seal failures. The team used those data in a simulation to predict failures and causes. In phase IV, the team performed root cause analysis on seal failure modes based on operational parameters and seal materials. This additional phase improved the predictability model for seal performance to minimize failures and prevent the accidental release of GHGs into the environment. A final report was delivered along with the seal predictive model to sponsors. The project group will disseminate the research results to seal manufacturers to improve seal design and performance. SoCalGas could benefit in the future from better and more reliable seals, as could other utilities that operate centrifugal compressors. Ratepayers would also benefit from increased safety and reduced risk of disruptions in their energy supply.

Co-Funders: PRCI Members

Start Date: 04/13/2022
End Date: 07/12/2022
Status: Completed
2022 Funds Expended: **$3,734**
Total Project Cost: **$29,500**
Total SCG Cost: **$3,734**
Total Co-Funding: **$25,766**
Benefits:

CEPM for Turbochargers (CPS-14B-08)

The objective of this project is to develop turbocharger performance models from the data collected from a variety of past PRCI projects, as well as 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 approach will enable them to schedule maintenance and repairs before the engine cannot meet emissions limits. The team completed model development in 2020. Closures related to the ongoing COVID-19 pandemic delayed the collection of additional data needed to refine the model and perform validation testing. In August 2021, the project team completed data collection and used the information to validate the performance monitoring model. The team finished the validation of the turbocharger model in 2022. However, the team encountered a problem with one of the two models, the turbine model, used in the overall turbocharger performance model. The turbine model requires further refinement to improve performance predictability. This problem has resulted in the team moving the completion date to the end of the first quarter of 2023. The final deliverable for the project will be a final report and the models to predict turbocharger performance. SoCalGas could utilize the models to support compressor management to improve turbocharger performance.

Co-Funders: PRCI Members

Start Date: 01/31/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$102,101**
Total SCG Cost: **$8,653**
Total Co-Funding: **$93,448**
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)

This project will assemble California climate data from 1980-2019 to improve two models for forecasting weather conditions. Weather forecasting models are used to find utility infrastructure vulnerabilities in extreme weather events. Such events include extremely dry conditions posing wildfire 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. University of California San Diego and the Scripps Institution of Oceanography were awarded this California Energy Commission project. It will assemble climate data from California between 1980 and 2019 to improve both models for forecasting weather conditions. The improved models would enable utilities to assess infrastructure risks associated with exposures to short-term and long-term extreme weather events. The datasets and model results will be available online to utilities, climate researchers, and the public. SoCalGas is participating in the Technical Advisory Panel for the project. In 2022, the project team has been working on the production models and is midstream in producing the "dry" and "wet" re-analyses. The project team is considering expanding the project to include data from 2020-2021, which would incorporate several extreme weather events into the Reanalysis production. SoCalGas will use the results of this project as part of its geohazard risk management plan that protects the infrastructure from future extreme weather events and energy supply disruptions to ratepayers.

Co-Funders: CEC

Start Date: 06/30/2020
End Date: 03/31/2024
Status: Active
2022 Funds Expended: **$2,533**
Total Project Cost: **$1,368,550**
Total SCG Cost: **$5,000**
Total Co-Funding: **$1,363,550**
Benefits:

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

This Pipeline Research Council International (PRCI) greenhouse gas (GHG) strategic research priority project studied hydrogen as a fuel to run compressor engines. It focused on the large bore, slow speed, lean burn engines. Compared to fossil-fueled methane, hydrogen fuel does not produce GHG emissions. This study investigated methane reforming technologies to produce hydrogen and explored how hydrogen-blended fuel affected engine operations, performance, and emissions. This project looked at new and existing steam reforming technologies and compared the advantages and disadvantages of each. Technology was to be selected to produce hydrogen for compressor engines for laboratory evaluation, prototype development, field evaluation, and durability assessment. The PRCI technical committee determined that this phase was not warranted. This project also looked at how hydrogen blended fuel will affect engine efficiency, GHG emissions, and NOx emissions. Prior research showed using hydrogen, or hydrogen-blended fuels, reduced GHG and NOx emissions, but the research was for engines not used by most utilities. The project team recommended additional research on engine efficiency and emissions when using hydrogen and hydrogen-blended fuel in compressor engines used by utilities, including a laboratory-scale pilot test. The results of this study were published in a PRCI report in 2022. This work could lead to using hydrogen or hydrogen-blended fuels to run compressor engines, including SoCalGas compressor engines. SoCalGas plans to use the report's results to evaluate future hydrogen and hydrogen-blended fuel projects to support the goal of reducing GHG and NOx emissions from compressor engines.

Co-Funders: PRCI Members

Start Date: 03/16/2021
End Date: 08/19/2022
Status: Completed
2022 Funds Expended: **$4,507**
Total Project Cost: **$289,100**
Total SCG Cost: **$12,905**
Total Co-Funding: **$276,195**
Benefits:

- 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)

This Operations Technology Development project aims to identify gaps in regulations and other safety and industry standards where pipeline transport of H2-NG blends may not be addressed and potential solutions to address the gaps. Parts 190, 191, and 192 of Title 49 of the Code of Federal Regulations address safety and other requirements for transporting natural gas by pipeline. Natural gas pipelines are also covered by additional safety and industry standards (e.g., American Society of Mechanical Engineers, International Organization for Standardization). SoCalGas has prioritized reducing its carbon footprint and greenhouse gas emissions and is investigating using 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 project team completed all tasks except the interviews with national and international hydrogen system operators and natural gas utilities investigating, experimenting, or looking to implement H2-NG blending, which will be scheduled and completed in Q1 of 2023. Upon completion of interviews, the team will compile all applicable codes and standards into a spreadsheet with an associated abstract summary for a gap analysis. The team will publish the results in a whitepaper that includes all hydrogen and H2-NG codes, standards, and practices; a gap analysis of H2-NG blending; and recommendations for H2-NG blending guidelines and best practices. SoCalGas will use the results of this research to develop and update its standards and best practices for hydrogen and H2-NG blends, supporting the safety, reliability, and efficiency of H2-NG operations. The results could also lead to the development of statewide hydrogen and H2-NG blending standards.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$502**
Total Project Cost: **$170,000**
Total SCG Cost: **$5,502**
Total Co-Funding: **$164,498**
Benefits:

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

The objective of this project was to identify compressor station or facility inefficiencies and the technologies that could improve efficiency and reduce GHG emissions. Compressor stations are the leading source of Greenhouse Gas (GHG) emissions for gas utilities, and inefficient operations lead to increases in emissions. This project investigated technologies that could improve operating efficiencies, thereby decreasing GHG emissions at compressor stations. The project team completed a literature search of available technologies with the potential to increase operational efficiencies and lower GHG emissions. Forty technologies were identified, with compressor restaging, dual-system drives, and capacity control, which were spotlighted as having significant potential for reducing GHGs at compressor stations. The team published project findings in a final report to guide gas utilities in decreasing GHG emissions at compressor stations by implementing technologies that increase operating efficiencies. SoCalGas plans to review the findings to determine which technologies warrant further evaluation to determine the feasibility of implementation to reduce GHG emissions at its compressor stations to benefit ratepayers with cleaner energy.

Co-Funders: PRCI Members

Start Date: 03/16/2021
End Date: 10/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$88,500**
Total SCG Cost: **$1,444**
Total Co-Funding: **$87,056**
Benefits:

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

Greenhouse Gases Emissions Reduction (SRP-GHG-01)

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$6,605**
Total Project Cost: **$3,838,835**
Total SCG Cost: **$32,339**
Total Co-Funding: **$3,806,496**
Benefits:

Pipeline Research Council International (PRCI) established a Strategic Research Priority (SRP) to coordinate efforts to reduce Greenhouse gas (GHG) emissions across all technical committees. In 2022, the SRP funded five new projects: Evaluate In-Situ Valve Repair Techniques (CPS-17-09), High Flow Sampler Replacement (MEAS-9-03), Low-Cost Instruments to Detect/Quantify Leaking Seals, Packings, and Dump Valves (MEAS-9-02), Improve GHG Leak Detection (CPS-17-04), and Assessment of Temporary Repair Methods (CPS-3-15A). Work continued on: Regulatory Support for GHG Emission Reductions (CPS-11-09), Continuous Monitoring and Diagnostics for Facility Efficiency (CPS-14-06), and Reciprocating Engine Exhaust Methane Slip Reduction (CPS-17-08). Six projects were completed with final reports on the PRCI website: Methods to Reduce Pipeline Blowdowns to Effectuate Repairs/Inspections (MATR-3-15) researched current best practices for mitigating releases of GHG from pipeline blowdowns; CFD Study of Pre-chamber Ignition Mechanism for GHG Reduction (CPS-14-05) concentrated on combustion efficiency by modeling precombustion chambers (PCC) in compressor engines to reduce uncombusted methane; Flow Sensors for Continuous Monitoring and Diagnostics for Equipment Efficiency Monitoring (MEAS-5-28) researched flow sensors used to determine equipment efficiency at compressor stations showing results on available retrofittable and non-retrofittable sensors; Methane Leak Detection and Quantification (PL-1-08) compared several types of sensors developing a guide for the selection of methane detection equipment. See the individual project summary for details on Fuel Reforming and Segregation as an Alternative for Compressor Fuel (CPS-14-07) and Improvement in Facility Efficiency (CPS-17-07).

Co-Funders: PRCI Members

Identify and Validate Best Practices for Applying Heat to Steel Near PE (5.19.s)

Start Date: 10/03/2019
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$117**
Total Project Cost: **$188,617**
Total SCG Cost: **$100,617**
Total Co-Funding: **$88,000**
Benefits:

The objective of this project is to identify and validate best practices for applying heat to steel near polyethylene (PE) material. Field welding of 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. The team worked on developing a preliminary simulation model with improvements aimed at reducing computational time. The team verified the physics behind the simulation. The project team is also developing and validating a standalone heat transfer calculator. It will include user inputs of critical parameters of welding, heat, pipe size, and local field conditions. The model will then calculate and display the maximum temperature at the PE-steel pipe interface. The calculator will also display a graphical representation of the 3D model. In 2022, the project team continued to fine-tune the conjugate heat transfer Multiphysics model and started the validation testing. This project benefits SoCalGas in reviewing and confirming best practices outlined in Company standards for welding near PE pipe, along with ensuring the integrity and safety of PE pipelines.

Co-Funders: OTD Members

Improving HCA Classification Methods (8.21.f)

Start Date: 03/01/2021
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$17,360**
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 (HCA) and moderate-consequence areas (MCA) through modern data analysis and data sources. An HCA is an area where a release of natural gas would adversely impact the health and safety of the affected population. The current methodology used to define consequence areas is set by Pipeline and Hazardous Materials Safety Administration. This methodology allows for using outdated data that do not factor in population dynamics or development patterns in and around urban areas. Disregarding these fluctuating patterns in the model creates the potential for some areas to be misidentified. This misclassification 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. In 2022, data acquisition and processing for the project study area continued. Additionally, the project began the data analysis by comparing the satellite vendor's building structure data to the project sponsor's data. SoCalGas intends to use this research to 1) enhance monitoring efforts in locating facilities that affect HCAs and MCAs and 2) explore alternative methods of monitoring the pipeline right-of-way for improving 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 (JIP) was to determine if welding onto an in-service pipeline containing a mixture of methane, and hydrogen increases the risk of hydrogen cracking in the weld seam or the weld hydrogen level, i.e., the level of hydrogen embedded in the weld. 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, hot tap branch connections) without service interruptions. This project included welding experiments with different mixtures and pressures of hydrogen and methane. The results indicate that weld hydrogen levels vary depending on the pipe wall thickness, the weld heat input, and the partial pressure of hydrogen during in-service welding onto a pipe pressurized with blended hydrogen and methane. The most significant increase in weld hydrogen levels occurred when welding thinner materials at higher heat inputs. The team also observed various reactions between the pipe contents, steel pipe base material, and surface oxides. The results indicate welding onto steel exposed to high-pressure blended hydrogen and methane for an extended period caused no significant increase in the weld hydrogen level. The project team developed mitigation measures to prevent hydrogen uptake during in-service welding and, for cases where they cannot avoid an uptake, account for the additional hydrogen in the weld by further limiting the maximum allowable heat-affected zone hardness. SoCalGas will use the research to support developing an industry standard for hydrogen in-service welding processes.

Co-Funders: JIP Members

Start Date: 05/14/2020
End Date: 06/30/2022
Status: Completed
2022 Funds Expended: **$2,000**
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 was to develop a technology roadmap with a timeline and recommended solutions for Local Distribution Company (LDC) decarbonization challenges. The research included 1) a literature review of key decarbonization technologies, 2) the execution of a state-of-the-art (SOTA) study and 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 addressed policies, regulations, assets, and technical challenges specific to LDCs. The roadmap identified specific R&D activities to pursue. The project provided a deeper understanding of existing gaps and challenges along with the data to make informed decisions regarding decarbonization and combatting climate change. The key deliverables included a decarbonization roadmap report and a GIS-based interactive story map to visualize and track projects globally. These deliverables are available only to project sponsors via the NYSEARCH website. The outcome of this research will be used in discussions related to the SoCalGas decarbonization strategy, direct planning efforts, and prioritization of technology development projects.

Co-Funders: NYSEARCH Members

Start Date: 11/18/2021
End Date: 09/16/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$166,675**
Total SCG Cost: **$15,150**
Total Co-Funding: **$151,525**
Benefits:

Low NOx Portable Analyzer

The objective of this project is to investigate and experimentally determine the feasibility of an electrochemical portable analyzer test to measure low NOx and low CO emissions. The experimental outcome will include an assessment of (1) limits of detection, (2) stability, and (3) repeatability for NOx measurements less than five ppm and CO measurements less than 20 ppm. Portable emission analyzers using electrochemical cell technology have matured to provide reliable and accurate results. Recently, a PRCI project led EPA to accept new portable analyzer test methods. Portable analyzers are accurate enough to verify compliance with the low limits. Still, the need exists to push the technology and measurement even lower, which drives the limit of the technology. There is a need to understand the detection limit of portable analyzers and develop recommendations or additional provisions for ultra-low measurements, specifically in the 1.5 to 5 ppm range. The project tasks include developing a test plan and systematic testing in the laboratory and the field. The team will provide a final report detailing the limits of detection, stability, and repeatability for low NOx and CO measurements. Successful results may lead to regulators accepting the portable emissions analyzer as a valid measurement tool for verifying regulatory compliance for these ultra-low sources.

Co-Funders: N/A

Start Date: 9/1/2022
End Date: 3/31/2023
Status: Active
2022 Funds Expended: **$57,780**
Total Project Cost: **$60,000**
Total SCG Cost: **$60,000**
Total Co-Funding: **$0**
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 to develop a safe, cost-effective "look-ahead" obstacle detection system for HDD equipment. This project seeks to develop further 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 HDD. This process will 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 2022, the redesign of the HDD bore head radar, communication link, and system software were completed, along with data analysis and reporting for the project. The project was delayed slightly due to personnel and equipment shortages resulting from the ongoing COVID-19 pandemic. Field testing started in late 2022 and will continue into 2023. If the project proves successful, SoCalGas will demonstrate the technology for use in preventing HDD damage.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2017
End Date: 03/31/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$3,786,446**
Total SCG Cost: **$62,346**
Total Co-Funding: **$3,724,100**
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 with a study on regulators' reliability and failure modes and life-cycle testing on "used" regulators. Causes of service regulator failures were identified by utility sponsors with the main causes: debris/contaminant buildup, diaphragm rupture triggered by flow surge/over-pressurization, material deterioration due to exposure to severe environmental conditions, and pressure fluctuations during service lifetime. Therefore, the service lifetime of regulators depends not only on the build quality of the regulator but also on external factors such as the quality of gas and the presence of debris/contaminants. Flow and endurance testing was performed on regulators of various ages supplied by the sponsors with only one failure. The regulator which failed the flow test; upon analysis was found that the regulator orifice was blocked by debris, which had coalesced over time, eventually blocking the flow of gas. The project team determined, based on the empirical evidence of the low failure rate of service regulators and performance of service regulators subjected to an endurance test and other laboratory tests, it can be implied qualitatively that the reliability and durability of service regulators are high. A final report has been issued by the sponsors, which includes the recommendation that rather than perform further testing to establish the failure envelope for service regulators, research should be focused 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 material selection processes.

Co-Funders: OTD Members

Start Date: 10/31/2018
End Date: 01/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$120,000**
Total SCG Cost: **$1,572**
Total Co-Funding: **$118,428**
Benefits:

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

Plastic Gas Pipe Damage Assessment due to high-pressure water jets and cross bores (5.23.g)

The objective of this project is to evaluate the effect of high-pressure (HP) water nozzles used in the sewer cleaning industry on polyethylene (PE) pipe materials to determine the impact on PE cross-bores. The team will work with industry leaders to identify multiple water nozzles used in the sewer industry, construct a testing rig, and develop guidelines to close the knowledge gap between safe and unsafe water jetting on cross-bores. Cross-bores are when PE pipe is inadvertently installed into sewers or sewer laterals. HP sewer pipe cleaning jets can create holes or damage PE cross-bores during sewer cleaning, resulting in gas leaks or more serious incidents. Currently, no standard or guideline limits the pressure and performance of sewer cleaning nozzles so they do not damage PE cross-bores. The deliverables for this project will be a final report detailing the results of the HP nozzle testing and a set of guidelines written by the project team for sewer cleaning and the use of HP water nozzles around plastic cross-bores. The team will standardize these guidelines and the test procedure so that new sewer cleaning nozzles can be tested and evaluated. The standards could benefit SoCalGas by reducing risk, improving safety and pipeline integrity, reducing costs associated with damage and resulting incidents, and informing SoCalGas' Integrity Management Plan.

Co-Funders: OTD Members

Start Date: 12/14/2022
End Date: 12/29/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$21,551**
Total Co-Funding: **$128,449**
Benefits:

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

This multi-year Pipeline Research Council International Strategic Research Priority project aims to reduce criteria pollutants and greenhouse gas (GHG) emissions from legacy compressor engines. The project will investigate 1) the effects of quenching in the main chamber, 2) the nitrogen formation mechanism and pre-combustion chamber size and nozzle geometry, and 3) early ignition and seeding radicals in the main chamber. The team completed the literature review in 2021. In 2022, the project team ran dynamic computational models simulating combustion mechanisms for natural gas and different concentrations of hydrogen blends and completed the comparison of the natural gas model results to engine test data from laboratory evaluation of an engine running on natural gas. The team plans to compare the hydrogen blend model results to the engine test data from laboratory evaluation of an engine once they complete testing using hydrogen blended fuels. The team will use comparison work between the models and test data to fine-tune the model for the future design, prototyping, and field evaluation of the pre-combustion chamber in 2023. The results from this project could be used to retrofit legacy engines and changes in controls, which could lead to reductions in GHG emissions without compromising criteria pollutants. 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 to combating climate change and improving air quality. SoCalGas will also benefit from the research if it can use a new pre-combustion chamber to reduce GHG emissions and retrofit engines without replacing them.

Co-Funders: PRCI Members

Start Date: 08/31/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$7,082**
Total Project Cost: **$454,300**
Total SCG Cost: **$22,046**
Total Co-Funding: **$432,254**
Benefits:

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

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

During natural gas leak investigations, first responders need the means to assess gas concentration outdoors, in manholes, and within buildings. Knowing the gas concentration remotely at multiple locations 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" devices. In earlier 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 for Phase 4. The first is to develop pre-commercial units that can be tested by utility members. The second is to develop a wireless communication system to allow a leak investigator to monitor methane levels at multiple points remotely. In 2022, work started on design reviews for the mechanical assemblies. Initial integration of the project's mechanical, electrical, firmware and software components was completed as well as the first functioning prototype using silicone molded parts. The First Responder Mesh Network application has been developed as the GIZMO (Gas Investigation Zone Monitor). The prototype will be available for beta testing soon. Once the development of GIZMO is complete, further development of the Un-attended Methane Sensor will begin. Once this project is finished, SoCalGas will consider evaluating the technology for use in the field.

Co-Funders: OTD Members

Start Date: 09/01/2019
End Date: 3/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$358,000**
Total SCG Cost: **$27,000**
Total Co-Funding: **$331,000**
Benefits:

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 team found the main root causes to be site and operational practices. The research team concluded that effective measures to minimize confounding factors could include improving communications between excavators and locators in the one-call system and enforcing states' damage prevention programs. The project team developed a web-based program and database for correlating excavation damage incidents to site and operational practices based on incident data from National Transportation Safety Board (NTSB) 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. A project debrief webinar took place in January 2022. SoCalGas can use the information from this research as a reference to characterize the root cause of excavation damage.

Co-Funders: OTD Members, PHMSA

Start Date: 09/30/2019
End Date: 01/19/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$759,000**
Total SCG Cost: **$13,872**
Total Co-Funding: **$745,128**
Benefits:

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

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

The objective of this project is to provide the natural gas industry with the necessary hardware and software components to create a complete smart shutoff system solution. This integrated approach will be capable of detecting and terminating gas flow in response to a hazardous incident such as a fire, flood, or gas leak inside a residential or commercial structure. This project is co-funded by the California Energy Commission (CEC) to improve the safety and integrity of natural gas infrastructure. Deployment of smart shutoff systems can provide localized detection and mitigation needed to prevent hazardous events from becoming dangerous and costly. The project team will demonstrate and validate the technologies required for a smart shutoff system and identify any gaps or barriers that need to be addressed before commercialization. In 2021, the team modified the project scope to better understand the deployment of a Low Power Wide Area Network (LPWAN) at scale after identifying knowledge gaps in the communication methodology. The LPWAN is a network and a key component to the smart shutoff system that bridges communication between equipment at long distances, saves battery life, and can work with Aclara. In 2022, the project team temporarily installed an LPWAN system and smart shutoff technology at Pico Rivera. The team will continue the assessment of the Smart Safety Shutoff Systemin 2023. SoCalGas believes this project will add to the portfolio of R&D results produced by the CEC, benefiting the State of California and its ratepayers.

Co-Funders: OTD Members, CEC

Start Date: 08/04/2020
End Date: 08/04/2023
Status: Active
2022 Funds Expended: **$3,908**
Total Project Cost: **$1,438,792**
Total SCG Cost: **$25,019**
Total Co-Funding: **$1,413,773**
Benefits:

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 work 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 potential. 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 natural gas and energy areas. In 2022, Stanford published five research papers: 1) Detecting and quantifying methane emissions from oil and gas production: algorithm development with ground-truth calibration based on Sentinel-2 satellite imagery; 2) Advances in Applied Energy; 3) Identifying coal plants for early retirement in India: A multidimensional analysis of technical, economic, and environmental factors; 4) Functionality-based life cycle assessment framework: An information and communication technologies (ICT) product case study; and 5) Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey. In addition, Stanford NGI also conducted several meetings and workshops. At the end of 2022, SoCalGas performed a benefit-cost analysis of its membership and decided to discontinue it.

Co-Funders: NGI Members

Start Date: 01/01/2019
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$1,795,000**
Total SCG Cost: **$225,000**
Total Co-Funding: **$1,570,000**
Benefits:

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

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

The goal of this project was to map the dispersion of hydrogen, methane, and hydrogen-methane blends (6% and 20% hydrogen) in an experimental setting. Physical tests and computer simulations were used in the study. All physical tests were limited to 25% lower-explosive-limit (LEL) concentration 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 gas behavior is altered and how gas detection is 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 comparison between the blended fuels and pure fuels was inconsistent, and a finite conclusion could not be reached. The team finished the final report and presented the results to project sponsors. The results from this study suggest that hydrogen blends have a higher dispersion rate than typical natural gas and can lead to longer detection times. SoCalGas plans to validate these results with field testing to support any changes to current operating procedures

Co-Funders: NYSEARCH Members

Start Date: 01/31/2021
End Date: 06/16/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$170,065**
Total SCG Cost: **$15,460**
Total Co-Funding: **$154,605**
Benefits:

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 (RFID) 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. The 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 pipes and points of interest, and assign a quality score to the location data that is then transferred to an operator's GIS. In 2022, the team continued working on optimizing the electronic pipe markers and enhancing the attachment methods for the markers to the PE pipe. The project team disagreed on whether electrofused or taped markers would be utilized. The methodology may differ by pipe size. Adding to the project delay was a change in the members of the project team which resulted in a reassessment of the path forward. PHMSA has granted an extension to the project end date.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2019
End Date: 3/31/2023
Status: Active
2022 Funds Expended: **$0**
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 outlines the program development and performance assessments. The tracking software will develop a Key Performance Indicator (KPI) 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. The team held a kickoff meeting in the third quarter of 2022. The team has started the first task of gathering requirements for analysis. Once the team develops the software, SoCalGas could use it to support the PSMS.

Co-Funders: OTD Members

Start Date: 11/24/2021
End Date: 05/24/2023
Status: Active
2022 Funds Expended: **$9,464**
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

Validation of Next Generation Predictive Emissions Monitoring System for Gas Turbines (CPS-2-03)

The project objective is to validate the next generation of predictive emission monitoring systems (PEMS) for gas turbines developed by Siemens Energy. The Siemens PEMS is a turbine operating parameter-based system for predicting turbine emissions. This approach is less costly than continuous emission monitoring systems, which have high capital investment and operating costs. A PEMS could also be used as a diagnostic tool for evaluating turbine performance and optimizing downstream control equipment to reduce operating costs and emissions. SoCalGas will partner with PRCI and Siemens Energy by using the turbine located at the SoCalGas Blythe facility for the PEMS validation. SoCalGas and Siemens Energy will gather operating data from actual operating conditions. Siemens will then use the data to evaluate its PEMS model. The final deliverable will be a report on the results of the PEMS validation. The project results could lead to lower environmental compliance costs, a new diagnostic tool for evaluating turbine performance, and optimization of control equipment operations for the utility industry and SoCalGas. SoCalGas will assess the outcome of this project to see if the PEMS will benefit its operations.

Co-Funders: PRCI Members

Start Date: 11/01/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$4,851**
Total Project Cost: **$81,000**
Total SCG Cost: **$36,000**
Total Co-Funding: **$45,000**
Benefits:

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

This GTI Energy project intends to develop a Virtual Reality (VR) content library and delivery system that utilities can use to assist in training 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 guidance on deploying them. The project team will evaluate current VR technology to determine if new developments can enhance the VR training experience. SoCalGas using VR modules will improve learner retention, enhance the consistency of training delivered, allow operations to conduct training on demand, increase the number of real-life training scenarios available for trainees to experience, and reduce the risk of injury to trainees. The project team developed nine training modules, and SoCalGas evaluated this technology in 2022. GTI Energy is developing and re-developing the training modules on a new provider platform with an estimated completion date of March 31, 2023. GTI Energy created a draft implementation plan for SoCalGas in 2022 and will present the new modules, platform, and finalized implementation plan to the SoCalGas Training Department in early 2023. SoCalGas intends to implement this VR technology into its Training program.

Co-Funders: OTD Members

Start Date: 11/01/2019
End Date: 04/30/2023
Status: Active
2022 Funds Expended: **$0**
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)

Implementing Work Zone Intrusion Alarm (WZIA) technology can aid in the prevention of work zone injuries or fatalities. Unauthorized vehicles or pedestrians entering the work zone either accidentally or intentionally jeopardizes worker safety. The objective of this project is to perform market analysis and testing of WZIA technology. This project kicked off in mid-2022. The team completed research on WZIA equipment and the current technology market. The project team identified several technologies, including automatic flaggers, sonic intrusion alert devices, and geofencing systems with wearable alert devices for field employees. Several of these devices are focused on mitigative measures, while systems like automatic flaggers are focused on preventing work zone intrusion. Sponsors have provided their feedback on which types of technology should be evaluated, with a field demonstration planned for 2023. SoCalGas will analyze and review the results to determine if any equipment can be integrated into SoCalGas traffic control procedures and whether modifications are needed to its standards.

Co-Funders: OTD Members

Start Date: 11/19/2021
End Date: 04/30/2023
Status: Active
2022 Funds Expended: **$8,000**
Total Project Cost: **$140,000**
Total SCG Cost: **$9,333**
Total Co-Funding: **$130,667**
Benefits:

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

SUBPROGRAM: OPERATIONS TECHNOLOGY

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 buried infrastructure can significantly aid in mitigating these risks and preventing damage. In this CEC co-funded project, GTI developed a 3D visualization software for mapping underground pipelines and improving asset management. To achieve this, several existing and proven technologies were analyzed and field tested to create the Locate Technology Platform (LTP). This platform assists field users in visualizing infrastructure location data from various viewpoints. In 2022, field demonstrations of the LTP were performed by two sponsors, including SoCalGas. During Q4 2022, SoCalGas completed the field test of the locating devices and data collection efforts at various sites within the SoCalGas territory. In 2023, the project team will begin the analysis of data from the field demonstrations. The development of this technology will save field time, lowering the cost of data collection. SoCalGas can potentially utilize this research to improve the three-dimensional geospatial accuracy of existing GIS data.

Co-Funders: OTD Members, CEC

Start Date: 06/30/2020
End Date: 11/30/2023
Status: Active
2022 Funds Expended: **$28,814**
Total Project Cost: **$2,088,785**
Total SCG Cost: **$89,349**
Total Co-Funding: **$1,999,436**
Benefits:

Advanced Locating Technology with Exodigo (8.22.p)

The objective of this project is to evaluate the capabilities and performance of a non-intrusive subsurface mapping platform that uses multiple sensors and artificial intelligence to provide a digital geolocated representation of underground assets. The ability to map and locate existing underground infrastructure with increased accuracy and completeness of pipeline data supports damage prevention for gas utilities. The project scope includes performing a baseline evaluation of the technology at GTI Energy's pipe farm and a field demonstration at a sponsor location. The team will perform a comparative analysis between this technology and other locating technologies previously evaluated on the known underground pipe system at GTI Energy. The team will deliver a final report which will provide the analysis and comparative results and identify potential use cases within the natural gas industry. If this technology demonstration is successful, it could give the utilities another option for locating or mapping underground assets. SoCalGas may pursue its own field demonstration and evaluation after reviewing the project deliverables.

Co-Funders: OTD Members

Start Date: 10/18/2022
End Date: 10/18/2023
Status: Active
2022 Funds Expended: **$42,000**
Total Project Cost: **$220,000**
Total SCG Cost: **$77,648**
Total Co-Funding: **$142,352**
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 team designed the project to map the requirements under the 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. The project began with a Pipeline Hazardous Materials Safety Administration (PHMSA) kick-off meeting in late 2021. In 2022, the project team made substantial progress. The project team submitted testing procedures for proposed mechanical load tests and sample sizes to PHMSA. The project team also started the identification of gaps in regulations related to qualifications for composite pipes' maximum operating pressures and testing. After completing these tasks, the project team will begin testing composite pipes to evaluate material properties that could be incorporated into the 49 Code of Federal Regulations Part 192 to qualify composite pipes. If successful, this project could result in the acceptance of composite materials as an alternative to traditional pipeline repair systems, offering cost advantages and corrosion protection. SoCalGas could use the results to evaluate composite repair systems for use in its pipeline repair program to provide cost savings to ratepayers and improve its pipeline integrity program.

Co-Funders: OTD Members, PHMSA

Start Date: 12/14/2021
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$8,000**
Total Project Cost: **$1,008,320**
Total SCG Cost: **$11,019**
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 objectives of this project were to reduce the operational complexity of Explorer Robotic Platforms deployment for In-Line Inspection applications and to increase their overall capabilities by automating operation and control functions. In Phase I, the project team evaluated the automation potential of the existing hardware and identified required modifications. In Phase II, the team implemented software and hardware modifications to enable upstream feature recognition, pipeline mapping capabilities, and autonomous control scripts for simple maneuvers. Phase III focused on refinements needed to adapt the system for commercialization. In Phase III, the team completed the following tasks: 1) the redesign of control modules and components and the pipeline mapping inertial measurement unit (IMU); 2) the refinement of system bend detection, bend orientation, bend start, and alignment; 3) the development of pipeline ready IMU data collection hardware, data processing software, and commercial hardware that can detect all pipeline features including tees and autonomously traverse straight sections, bends, and back-to-back bends in the pipeline; and 4) full system laboratory testing and field testing on a commercial inspection. The project objective was achieved with the automation module successfully integrated into the Explorer Robot. The robot will move to the commercialization phase, where the project team will further refine the system to finalize the automation module for commercial inspections. The improved automation may reduce vendor operational costs, and the development of IMU capability will enable SoCalGas to have GPS data for all identified features.

Co-Funders: NYSEARCH Members, Invodane

Start Date: 02/28/2017
End Date: 10/14/2022
Status: Completed
2022 Funds Expended: **$0**
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 was to evaluate a structural reinforcing system for in-situ repair of damaged in-service polyethylene (PE) pipe. Mechanically damaged PE piping is typically repaired by removing and replacing the damaged section. This process can be costly and may require the installation of a gas bypass to avoid interruption to customer service. Current options for the in-service repair of damaged pipes are few, costly, and not universally accepted. This study's repair method consisted of applying a composite reinforcement wrap over the affected area and applying heat for curing. A practical PE permanent repair system would save time and money while minimizing service disruptions. The team prepared three sets of samples for testing in this project, including MDPE (Medium Density Polyethylene) and vintage Aldyl-A. Set 1: five 2" MDPE pipe specimens Squeezed-off (Control samples); Set 2: six 2" MDPE pipe squeezed-off and repaired; and set 3: six Aldyl-A specimens squeezed-off and repaired. The initial plan was for the samples to be tested in a cyclic pressure test. However, the project group switched to Long-term hydrostatic strength (LTHS) testing due to equipment issues. The samples underwent LTHS and quick burst testing. The experimental results indicated that the 'repairs' were working as intended; that is, the repair patch suppressed creep at the squeeze location, which led to failure outside of the repair patch. SoCalGas could utilize the knowledge gained about this composite product and repair method to either perform an in-house evaluation or continue the research to observe the feasibility of this repair method in the field.

Co-Funders: OTD Members

Start Date: 05/07/2018
End Date: 07/29/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$75,900**
Total SCG Cost: **$8,576**
Total Co-Funding: **$67,324**
Benefits:

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

The objective of this project is to build upon research identified by Operations Technology Development (OTD) 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 battery capacity levels, and completed accuracy tests on all three meters for an outdoor accelerated life test. In 2022, all testing for the smart DRGM was completed, while testing for the USMs is ongoing. 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 for ultrasonic meters.

Co-Funders: OTD Members

Start Date: 12/02/2020
End Date: 03/10/2023
Status: Active
2022 Funds Expended: **$375**
Total Project Cost: **$129,000**
Total SCG Cost: **$5,375**
Total Co-Funding: **$123,625**
Benefits:

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

Data Logger Evaluation Project - Phase II

The objective of this project is to evaluate a commercially available data logging technology for collecting data associated with the fusion joint process. Thermoplastic pipeline joints are produced in the field using a 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. This process has significant potential for errors and is not an efficient means of integrating the fusion data into company systems, thus encumbering review and analysis. Furthermore, in cases of failure, the fusion data is not readily available for review to aid the investigative process. During the project's first phase, the team performed a proof-of-concept evaluation for a commercially available data logger. In phase II, the team is researching the process of data collection, storage, and integration into company systems. 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 before being placed into service. In 2022, the project team worked with a data logger manufacturer and a SoCalGas IT team to identify software developments needed for data integration into Company data management systems. Additionally, the team has worked on resolving technical issues with the data logger, continued to collect fusion data in the field, and conducted training for welding instructors. Moreover, the project team worked on preparing a plan for the next steps of this project. A final report describing the work performed, and the necessary software developments will be provided.

Co-Funders: N/A

Start Date: 06/15/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$19,630**
Total Project Cost: **$71,000**
Total SCG Cost: **$71,000**
Total Co-Funding: **$0**
Benefits:

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

This California Energy Commission (CEC) –co-funded project's objective is to improve the safety and integrity of underground natural gas pipelines by increasing the accuracy of horizontal and vertical pipeline location data. The approach is based on enhancing and adapting 3D electromagnetic detection technology to locate buried pipelines. It supplements the technology with an in-pipe mechanism to focus on congested areas and plastic materials. SoCalGas and Pacific Gas and Electric (PG&E) are partners in the project along with CEC. SoCalGas will focus on transmission infrastructure, and PG&E will focus on distribution infrastructure located in congested urban areas. This improved technology provides real-time three-dimensional data encountered in the field, including different pipeline materials, buried depth, and surface cover. In 2022, the vendor, GTI Energy, and SoCalGas personnel completed measurements of several transmission lines. The project team is in the process of analyzing the data for accuracy. Once completed, the results will be made available to sponsors.

Co-Funders: OTD Members, CEC, Others

Start Date: 11/04/2020
End Date: 11/30/2023
Status: Active
2022 Funds Expended: **$5,563**
Total Project Cost: **$2,222,903**
Total SCG Cost: **$26,768**
Total Co-Funding: **$2,196,135**
Benefits:

Enhancements to ASTM F2897 Encoding Standard for Gas Distribution Components (5.22.v)

The objective of this project is to review and affirm the underlying mathematical model and requirements within the American Society for Testing and Materials (ASTM) F2897 and to make targeted enhancements to its completeness and efficacy. In addition, a goal is to develop an implementation guide within the ASTM standard to aid the proper application and use of the system. After nearly a decade of existence and use, there is a need to review and enhance ASTM F2897 "Standard Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)." Polyethylene (PE) pipe and tubing manufacturers utilize this standard to incorporate a 16-digit barcode on the materials they produce for tracking and traceability purposes. The project team will review the standard and verify that all the gaps are addressed and that the standard provides the necessary information for all types of materials for successfully applying barcodes. This project is important as SoCalGas will eventually implement barcode scanning of materials in the field for improved tracking and tractability. The final deliverable will be the revised ASTM F2897 standard.

Co-Funders: OTD Members

Start Date: 06/17/2022
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$25,000**
Total Project Cost: **$151,000**
Total SCG Cost: **$32,827**
Total Co-Funding: **$118,173**
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)

Start Date: 11/19/2021
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$10,000**
Total Project Cost: **$132,000**
Total SCG Cost: **$12,055**
Total Co-Funding: **$119,945**
Benefits:

The objective of this project is to evaluate the accuracy and overall performance of micro-thermal gas metering modules that measure hydrogen-blended natural gas and biomethane gas volumes. The introduction of low-carbon fuels, such as hydrogen-blended natural gas and biomethane, into a gas system means more diversified sources of gas with varying compositions. 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. Microthermal technology, per the manufacturer's claim, accurately measures and self-diagnoses varying gas compositions, which are the beneficial features needed by gas system operators to transport cleaner, low-carbon fuels reliably. The micro-thermal gas meter module consists of a Micro-electromechanical Systems (MEMS) based calorimetric microsensor. The sensor element uses temperature distribution characteristics to determine gas velocity and volume. In 2022, the project kicked off, and the project scope, test plan, test matrix, and procurement of testing components were completed. The start of testing was delayed due to supply chain issues, but it is now underway, with expected completion in mid-2023. The results of the performance tests will be provided in a final report. If the performance testing is successful, SoCalGas plans to conduct a field test of the micro-thermal gas metering modules to determine if they can accurately measure biomethane and hydrogen blended natural gas for possible future direct delivery to their customers.

Co-Funders: OTD Members

GIS Portal Data Quality Improvement

Start Date: 06/01/2020
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$60,495**
Total SCG Cost: **$60,495**
Total Co-Funding: **$0**
Benefits:

The objective of this project was to test and evaluate a range of GIS tools and to develop recommended methods based on the analysis. This project can improve the reliability, quality, and effectiveness of the data collection process for distribution field employees. The current methods of collecting and transferring data from the field to the office could be more efficient and present opportunities for human error, which can lead to inaccurate Geographic Information System (GIS) data. Adopting the latest GIS mapping technologies will allow SoCalGas to create a process that leads to higher-accuracy positional data. The field personnel captured real-time kinematic (RTK) corrected and highly accurate Global Positioning System (GPS) data while performing routine activities for the project. In 2022, SoCalGas evaluated two base stations, three GPS rovers, and three data collectors. This evaluation resulted in the team recommending the most appropriate set of tools to capture the location of pipeline facilities using a combination of GIS data and hardware (GPS, tablet, underground pipe locator) and the best method to utilize the tools. The expected project benefits to SoCalGas are improved approaches to capture and transfer field data to the GIS mapping system and decreased time to perform the capture task.

Co-Funders: N/A

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

GNSS Consortium (5.7.p)

The Global Navigation Satellite System (GNSS) Consortium intends to facilitate knowledge and information sharing on rapidly developing GNSS technology and to determine how to apply this information to daily utility operations. The project team will accomplish this through technology evaluations and integrations, workshops, pilot projects, demonstrations, best practices and standards, and general information sharing. The focus on technology evaluation helps reduce the cost and complexity of deploying GNSS for routine utility construction operations and maintenance activities. High-accuracy GNSS data collection is essential to a utility's geospatial data management and Geographic Information Systems (GIS) integrity. The GNSS Consortium was initiated in 2017. In 2023, GTI Energy will continue to perform demonstrations and inform the project sponsors about the latest innovations and research in the geospatial technology industry. The project team will upload all deliverables to the enhanced web-based library, including technology evaluation reports, multimedia materials, training documentation, a close-out webinar, annual workshop materials, and a yearly GTI Energy GIS Week presentation. By staying abreast of current and cutting-edge advanced GNSS technology, SoCalGas will be equipped to make informed investment decisions related to geospatial technology and benefit from enhanced operational efficiencies, regulatory compliance, improved quality of field-collected data, and improved system integrity. SoCalGas intends to disseminate the research to its internal stakeholders for implementation in daily operations. SoCalGas hopes to identify low-cost alternatives for geospatial tracking of high-volume distribution pipeline components.

Co-Funders: OTD Members

Start Date: 12/14/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$270,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$255,000**
Benefits:

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) was to bring industry stakeholders together to address knowledge gaps in the plastic piping industry. The team addressed these gaps through research and the development of standards and guidelines designed to enhance the integrity of plastic gas distribution systems. The objective of the Plastics JIP program was 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 was to identify and discuss industry needs, achieve consensus on the prioritization of issues for project research, and participate in the direction and review of the various project efforts. JIP worked on several areas, including 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. In 2022, JIP's efforts included evaluating mechanical couplings used on PE pipe exposed to heavy hydrocarbons or mechanical couplings installed on PE pipes and then exposed to heavy hydrocarbons.

Co-Funders: OTD Members, JIP Members

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

Market Study and Technology Assessment of a High Concentration Hydrogen Leak Detector (T-792)

The objective of this project is to perform a state-of-the-art study to identify technologies for walking and mobile leak survey instruments to detect up to 100% hydrogen. Molecules of hydrogen are smaller than those of methane, and at higher blended percentages of hydrogen (20% - 100%), hydrogen could leak and not be detected using existing methane and hydrogen sensors. These higher hydrogen percentages may require specific leak detection technologies or existing equipment retrofitting. The natural gas industry needs research to identify the parameters for choosing the correct leak detection device for gas blends containing over 20% hydrogen. The project team will deliver a shortlist of potential technologies for walking and mobile leak detection applications and a roadmap for technology evaluation and development. This project could benefit SoCalGas by providing a shorter-term solution for hydrogen leak detection for gas blends containing over 20% hydrogen, which could enhance safety, reduce emissions, and save time and capital in the transition to utilizing these blends. SoCalGas could take the results to determine if developing a leak detector for gas blends containing over 20% hydrogen is warranted and if this detector could be made commercially available.

Co-Funders: NYSEARCH Members

Start Date: 11/23/2022
End Date: 08/31/2023
Status: Active
2022 Funds Expended: **$6,940**
Total Project Cost: **$71,127**
Total SCG Cost: **$6,940**
Total Co-Funding: **$64,187**
Benefits:

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

Screening Remote Flow Monitoring and Control (5.22.u)

Start Date: 10/31/2022
End Date: 10/31/2023
Status: Active
2022 Funds Expended: **$28,000**
Total Project Cost: **$130,000**
Total SCG Cost: **$42,824**
Total Co-Funding: **$87,176**
Benefits:

With the increasing amount of renewable natural gas (RNG) in the distribution network, Distribution System Operators now have an additional role in managing the volume of gas from multiple injection sources. As the industry transitions, smart technologies could aid in the remote operation and flow management of the natural gas infrastructure. The objective of this project is to perform a review and screening of the latest advancements in smart and remote equipment applications for distribution systems. The project scope includes 1) identifying operator requirements and needs, 2) performing a market study to review the latest remote equipment and related communication systems, and 3) determining which products are in development and which are commercialized. The remote equipment includes on/off valves, regulation valves, pressure reduction gas stations, and backflow compressors. The project team will deliver a final report at the end of the research to include the industry needs and market product gaps for remote flow monitoring technologies. Future District Regulator Station designs will consist of proven remote monitoring and control equipment that will further enhance the operational safety and flexibility of the system and allow for RNG capacity.

Co-Funders: OTD Members

Technology Testing Assessment Facilities (AMI Smart Metering)

Start Date: 01/01/2019
End Date: 04/01/2023
Status: Active
2022 Funds Expended: **$7,673**
Total Project Cost: **$124,300**
Total SCG Cost: **$124,300**
Total Co-Funding: **$0**
Benefits:

This project aims to evaluate new technologies, tools, and equipment at the SoCalGas Gas Meter Test Rack or Situation City. A frequent challenge faced by utilities is the need to find tools or technologies that increase safety, lower operation and maintenance costs, improve accuracy, and replace existing obsolete equipment and tools. SoCalGas has constructed its test facilities to simulate portions of the company's operating system. This approach enables the evaluation of new tools or technologies without impacting system operations or customers. 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, multi-variable sensors, cathodic protection test stations and supports an integrated distribution automation system. To date, meters were tested and then returned to the manufacturer so that they could address concerns of inaccuracy. In 2022, the manufacturer delivered updated meters that addressed the previous measurement and communication issues for the accelerated life accuracy testing. The meters passed ANSI B109 testing and are currently installed on the test rack, with testing scheduled to be completed in early 2023.

Co-Funders: N/A

Uniform Frequency Code (5.18.m)

Start Date: 07/01/2018
End Date: 02/07/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$135,000**
Total SCG Cost: **$5,322**
Total Co-Funding: **$129,678**
Benefits:

The objective of this project was to create a best practice uniform frequency code for radio frequency identification (RFID) devices used to locate buried utilities. This code established a consistent frequency setting for RFID devices based on their respective utility designation, such as gas, electric, or water. The Uniform Frequency Code project successfully drafted, reviewed, and finalized the consensus language required to produce two best practices and supporting documentation for publication in the Common Ground Alliance's (CGA) Best Practices Guide, Version 18. Through the efforts of this project, two new practices were created. In Chapter 2 – Planning and Design, Best Practice "2.19 Underground Electronic Utility Markers" was added beginning in version 18. In Chapter 6 – Mapping, Best Practice "6.19 As-Built Mapping of Underground Electronic Utility Markers" was added. Equally important, the "Guidelines for Underground Electronic Utility Marker Technology" text, which contains a table of commonly used frequencies for various underground electronic utility markers, was added to Appendix B of the CGA Best Practices Guide. SoCalGas will use the Best Practices of this technology for implementation into operational procedures. One use case is to mark new business stubs and other hard-to-locate scenarios.

Co-Funders: OTD Members

- 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 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 revised 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: Completed
2022 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)

The goal of this project was to update a Pipeline Repair Manual. Technology advancements offer pipeline companies the opportunity to extend the life of assets in place. Such advances include materials, techniques, products, and procedures. Pipeline Research Council International's (PRCI) Pipeline Repair Manual is widely used by the natural gas industry. The manual had not been updated or revised since the 2006 publishing of its sixth edition. In the 14 years since the last revision, many codes that governed pipeline repairs have changed, new codes have been implemented, and new repair technologies and techniques have been developed. With this project, PRCI completed a comprehensive update of the Pipeline Repair Manual, documenting these advances and providing engineering guidance on the appropriate repair techniques for various pipeline defects. SoCalGas uses the manual and is reviewing the changes and updating company standards, as necessary, to support, improve or enhance its pipeline integrity program.

Co-Funders: PRCI Members

Start Date: 06/30/2020
End Date: 05/31/2022
Status: Completed
2022 Funds Expended: **$0**
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

SUBPROGRAM: SYSTEM DESIGN & MATERIALS

Action Limits for RNG Specifications (7.23.k)

The objective of this project is to monitor available literature and gather operational data to support renewable natural gas (RNG) action limits for trace constituents. In 2020, the California Public Utilities Commission (CPUC) approved the Standard Renewable Gas Interconnection Agreement, which included a requirement to provide action-level specifications for ammonia, mercury, and siloxanes. Previous research determined that additional studies are needed to assess the effects of trace constituents on the natural gas pipeline infrastructure and end-user equipment, particularly mercury, on non-cryogenic end-user equipment. The project team will refresh the literature review for mercury studies and develop an experimental plan for laboratory testing at Southwest Research Institute for a future research project. The California utilities can benefit from this research since it fulfills a CPUC regulatory directive and supports pipeline integrity with a future recommendation on action limits.

Co-Funders: OTD Members

Start Date: 12/1/2022
End Date: 9/29/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$172,000**
Total SCG Cost: **$47,948**
Total Co-Funding: **$124,052**
Benefits:

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 risk of leakage. Developing a fusion cap and tapping tee assembly has limitations, and the fitting developer requires alignment tools for performing socket fusion on the tee tower. Due to the cost of alignment tools needed for the operation, and the limitations in the original design, the project team developed a new design. Samples of the re-designed alternative caps are being manufactured and will be sent to sponsors for evaluation in 2023. SoCalGas can use this research as a reference to improve the integrity of 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: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$112,400**
Total SCG Cost: **$32,115**
Total Co-Funding: **$80,285**
Benefits:

ARPA-E REPAIR Program (TTSP)

According to ARPA-E, 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 the existing pipe. REPAIR will advance the state of gas distribution pipelines by incorporating smart functionality into structural coating materials and developing new integrity/inspection tools. It will also create three-dimensional maps integrating 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 (TTSP) Committee. The program is funding seven teams developing robots that can provide polymer or metal coatings on the inside of the pipes and then run inspection tools to verify the coating integrity. As part of this effort, the teams are developing test procedures and hardware to confirm pipe life. In Q4 2022, the project teams presented project status reports and videos of their robots at a TTSP meeting.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 10/01/2023
Status: Active
2022 Funds Expended: **$1,190**
Total Project Cost: **$32,554,637**
Total SCG Cost: **$10,000**
Total Co-Funding: **$32,564,637**
Benefits:

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

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

The project objectives were to develop 1) a method to evaluate if changes in ultrasonic flow meter (USM) flowrate diagnostics (e.g., flow velocity profile, symmetry, swirl) cause a significant difference in the estimated measurement uncertainty of the USM station and 2) a software tool to perform this method automatically. The American Gas Association (AGA) currently requires additional uncertainty due to installation effects be less than +/- 0.3%. SoCalGas uses USMs to transport most of the gas delivered to its customers. The new software diagnostic tool incorporating artificial intelligence and knowledge-base information will enable gas operators to quantify system imbalances in near-real time, thereby reducing lost and unaccounted for gas volumes in conjunction with pipeline gas inventory calculations. The research resulted in the development of a new software diagnostic tool for users, which was demonstrated to sponsors in February 2021 and led to the drafting of a user guide and installation manual. A final report, user guide, installation manual, and software source code are available for Pipeline Research Council International (PRCI) members. Although the software tool and source code were successfully delivered and demonstrated, firewall security issues prevented sponsors from installing and testing the software. PRCI plans to develop the technology further and address these security issues for future developmental testing and software evaluation in the sponsor's environments.

Co-Funders: PRCI Members

Start Date: 03/01/2019
End Date: 06/03/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$118,000**
Total SCG Cost: **$3,819**
Total Co-Funding: **$114,181**
Benefits:

Blending Modeling (Hydrogen)

Hydrogen is an important sustainable, reliable, and cost-effective energy carrier. Hydrogen will help secure the 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 fuel-based energy sources with hydrogen produced from renewable sources. This project modeled the impact of blending hydrogen or off-spec renewable natural gas (RNG) into SoCalGas pipelines and facilities. Two important variables regarding hydrogen blending were assessed: (1) the time after injection for full mixing to occur and (2) the distance into the pipe at which full mixing will occur. To determine the achievement of full mixing after injection, the project team investigated the following concerns: the distance and time for injecting blended hydrogen or off-spec RNG and the concentration of hydrogen on the internal pipe surface. The team developed computational fluid dynamics models to simulate various scenarios and determine their impacts on SoCalGas pipelines and facilities. The results show that a mixer or blender will be needed since Hydrogen injection does not instantaneously blend uniformly at the injection point. The team decided to defer the study of blending station designs and placement of monitoring equipment to future research.

Co-Funders: N/A

Start Date: 12/20/2019
End Date: 06/15/2022
Status: Completed
2022 Funds Expended: **$2,087**
Total Project Cost: **$82,587**
Total SCG Cost: **$82,587**
Total Co-Funding: **$0**
Benefits:

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

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

This completed project pioneered the development of a common framework database for renewable natural gas interconnection skids (RNG-IC), allowing utilities to select the optimal design for their systems as they inject and transport increasing proportions of RNG. The project goal was to create a database that would serve as a valuable resource for local distribution companies to streamline the RNG-IC process and reduce costs with standardization. This project developed two standard RNG-IC skid designs: open-air and enclosed. These designs include various parameters such as instrumentation, measurement, regulation, gas quality analysis, and safety measures. This approach provides utilities with a system they can use to develop an RNG-IC skid that best fits their needs while delivering consistent manufacturing and implementation processes. The RNG-IC process involves considering gas quality management and designing customized piping and instrumentation to meet engineering standards. The project deliverable was an engineering package complete with a technical report, proposed RNG-IC skid design drawing set (i.e., electrical, mechanical, structural, and instrumentation and control piping and instrumentation diagram), and an excel-based tool that facilitates developing a bill of materials needed and their associated costs. The team delivered the package to project sponsors in October 2022, and they scheduled several tutorial sessions on how to use the excel tool. SoCalGas will use these designs, the tool, and the information from the project, as a knowledge resource for potentially developing their RNG skid designs.

Co-Funders: NYSEARCH Members

Start Date: 12/14/2021
End Date: 10/28/2022
Status: Completed
2022 Funds Expended: **$1,050**
Total Project Cost: **$222,380**
Total SCG Cost: **$24,710**
Total Co-Funding: **$197,670**
Benefits:

Corrosion Control Knowledge and Technology Integration for Safer California Natural Gas Pipeline System (GFO-21-506, group 1)

The project objective is to develop an integrative approach for corrosion control of natural gas pipelines based on mitigation, monitoring, inspection, evaluation, and prediction. The research will address integration barriers with instrumentation, software, and training related to natural gas system integrity management, pertaining to microbially and soil property-influenced corrosion. The goal is to formulate a performance-based, cost-effective risk assessment and management approach and test the methodology in collaboration with pipeline operators in California. The project deliverables include: 1) evaluate corrosion detection technologies and improve existing and emerging pipeline inspection technologies; 2) integrate several corrosion risk models; and 3) develop a toolkit that could improve the accuracy, validity, and accessibility of data collection. The project plan is to develop training to increase data collection efficiency and accuracy and to validate the effectiveness of the Corrosion Risk Management toolkit with pipeline operators. SoCalGas believes that continued corrosion research is a necessary step in a good corrosion management process, and this project has the potential to benefit both California ratepayers and stakeholders by validating an advanced corrosion assessment methodology. SoCalGas will utilize the results of this research to evaluate and possibly augment its existing corrosion assessment processes.

Co-Funders: CEC, Others

Start Date: 10/20/2022
End Date: 12/31/2025
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,200,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$1,205,000**
Benefits:

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

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

The objective of this project is to develop Level 1 and Level 2 metal-loss assessment criterion that are easy to use and covers all pipe grades and construction eras. 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 project integrates and builds on work completed in prior research, which developed a criterion for metal-loss assessment demonstrated in an independent evaluation to significantly reduce data spread and address bias in contrast to the American Society of Mechanical Engineers (ASME) B31G and Modified B31G. These assessments will have less scatter and conservatism than ASME B31G, Modified B31G, and other assessment models without compromising pipeline operational safety. The project has four phases. Phase I was completed by developing a burst pressure predictive model for isolated metal loss that captures the effects of length, depth, width, planar shape, and longitudinal profile with the results provided in an interim report. Phases II and III are ongoing and are developing criteria to quantify interaction and coalescence for adjacent metal loss features, with the criteria to be evaluated relative to existing full-scale burst test data. In 2022, the project team continued finite element analysis of adjacent and nested metal loss features and started developing interaction and stacking rules for multiple metal loss features. The outcome of this effort will provide SoCalGas with a comprehensive and representative assessment of failure pressure in areas of corrosion damage.

Co-Funders: PRCI Members

Start Date: 04/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
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 (5.22.j)

This project will review existing practices and perform comparative testing on vent-limiting service regulators to determine installation requirements. Many utilities use the "minimum distance to a source of ignition" requirement for indoor and outdoor regulators listed in the National Fuel Gas Code. It is based on the venting characteristics of standard internal relief valve (IRV) regulators and not for vent-limiting regulators. This project will determine if vent-limiting service regulators offer more options for outdoor installation by having a smaller footprint and reduced clearances. The project team will review current industry practices for vent-limiting regulators, perform testing to quantify the amount of vented gas from vent-limiting and IRV regulators and provide recommendations on safe location and clearance requirements for the indoor and outdoor installation of vent-limiting regulators. The project team will measure the quantity of gas vented from regulators during various operating flow conditions and failure modes, including diaphragm ruptures. In 2022, the project team identified currently available vent-limiting service regulators, selected the regulators to be tested, and finalized the test plan. The project team is now testing regulators and building the test rig for measuring vented gas. The project team expects the testing and final deliverables to be completed by mid-2023. This research will benefit the natural gas industry by providing more regulator installation options once PHMSA establishes new space guidelines for vent-limiting regulators.

Co-Funders: OTD Members, PHMSA

Start Date: 11/19/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$4,858**
Total Project Cost: **$489,629**
Total SCG Cost: **$4,858**
Total Co-Funding: **$484,771**
Benefits:

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

Digital MTR and Steel Pipe Traceability Pilot (8.23.g)

The objective of this project is to conduct a pilot project with manufacturers and operators to test the process of delivering, receiving, and retrieving digital Material Test Report (MTR) data. Most steel asset manufacturers apply a barcode that contains a serial number or another identification number. Some barcodes have asset attributes such as heat number, manufacturer, grade, diameter, and wall thickness. Each manufacturer defines the content and format of these barcodes, making them non-standardized. This lack of standardization makes it difficult for operators to use the data contained in the barcode consistently. The project goal is to start the process of achieving industry adoption of recently published American Petroleum Institute Recommended Practice 5MT - Pipeline Inspection Documents for Material Traceability and Electronic Test Reports (API 5MT) for digital MTRs and Global Standards 1 (GS1) for traceability barcodes for steel pipes. The project kicked off in Q4 2022. The project team will work on developing a GS1 standard, a barcode printing kit for manufacturers and coating mills, and a digital portal to link MTR from the barcode to the portal. If the pilot project is successful, the team will propose the next steps to continue the process of achieving industry adoption. With a digitized MTR process for collecting material data and properties, SoCalGas can improve efficiency and productivity during the MTR review in the quality assurance/quality control process.

Co-Funders: OTD Members, JIP Members

Start Date: 11/10/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$320,000**
Total SCG Cost: **$35,000**
Total Co-Funding: **$285,000**
Benefits:

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) impacts of H2-NG blend H2 concentration on meter accuracy; and 3) feasible H2-NG blend limits for gas meters and service regulators. In 2022, the team finalized the bill of materials for three potential testing rig options. Sponsors chose to have two rigs set up, each with nine regulators and nine meters. The team received most of the meters required for this project, while nine regulators are still needed. The project team initiated the purchasing and subcontracting activities, delivery of parts for the testing rig setup, and construction of the testing rigs through the subcontractor. Project delays were due to project rescoping and supply chain issues on parts delivery. The next step is for GTI Energy to initiate purchase orders. The construction of the rigs is expected to begin in the first quarter of 2023, and completion is expected in the second quarter. The primary project deliverable will be a final report. SoCalGas could use the results from this research to contribute to creating a statewide hydrogen injection standard.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$14,166**
Total Project Cost: **$550,000**
Total SCG Cost: **$50,757**
Total Co-Funding: **$499,243**
Benefits:

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

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

The objectives of this project are to 1) assess the effect of end treatments on the velocity profile and the resulting ultrasonic meter (USM) performance, 2) develop an optimized end treatment design, and 3) evaluate the performance of a clamp-on USM in experimental testing. This project aligns with the Pipeline Research Council International (PRCI) goal to increase measurement accuracy. End treatments can cause distortions in the flow to USMs that can result in a reduction of flow meter performance and an increase in lost and unaccounted for (LAUF) gas. Currently, there are no public data for guidance or comparison of end-treatment designs. The primary benefits of this successful project are improved measurement uncertainty of USMs and reduced LAUF gas volumes from optimized end-treatment designs. The project team created computational fluid dynamics (CFD) models of six end treatments. The project team identified four end treatments for optimization and testing in 2020. Project sponsors voted to add two end treatments in optimization and testing and the collection of clamp-on USM data in the test plan in 2021. The project team started and completed experimental testing in 2022. The project team published a final report on the PRCI website for members. They will also give a webinar as the project's final presentation in early 2023. SoCalGas requested the performance testing of the new clamp-on USM model be added to the project scope to save the cost and time of conducting its evaluation. This approach allows for approved use at SoCalGas utility and customer sites.

Co-Funders: PRCI Members

Start Date: 11/01/2018
End Date: 04/28/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$236,000**
Total SCG Cost: **$4,971**
Total Co-Funding: **$231,029**
Benefits:

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 an online Gas Chromatography-Ion Mobility Spectroscopy (GC-IMS) siloxane sensor for biogas with a second field test. The development of a low-cost, low-maintenance online analyzer capable of meeting the sensitivity and precision needs of the industry will allow more timely monitoring for compliance with regulations compared to offline analysis. This project is in partnership with Operations Technology Development's 7.16.g.2 project, where the project team completed laboratory and field testing of the GC-IMS at a landfill site. The project team will further evaluate the online GC-IMS analyzer at a second site that differs in digester feedstock (i.e., wastewater treatment plant) and geographic location from the initial test for a more robust dataset. Following the American Society for Testing and Materials D8230 Standard Test Method for Measurement of Volatile Silicon-Containing Compounds in a Gaseous Fuel Sample Using Gas Chromatography with Spectroscopic Detection, the project team will take periodic grab samples during the test period and have these samples analyzed at independent laboratories for comparison of online data to offline analytical techniques. The project kicked off in early 2022, and the team is working through equipment issues that have delayed the schedule for field site selection and planning and analyzer field testing. The project team will disseminate the second field test results in a final report and presentation to members. SoCalGas requested to be the candidate site for the second field test of the GC-IMS Analyzer. SoCalGas hopes to test the analyzer at its Engineering Analysis Center before installation at one of its biogas producer sites.

Co-Funders: PRCI Members

Start Date: 08/31/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$118,000**
Total SCG Cost: **$14,603**
Total Co-Funding: **$103,397**
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 Pipeline and Hazardous Material Safety Administration (PHMSA) co-funded project was a comprehensive overview of approaches in collecting, normalizing, and utilizing data for decision support. The project objective was to develop state-of-the-art data analytics and Bayesian network approaches for assessing and managing complex system 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 procedures 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) was developed and tested to analyze distribution assets. This tool enables users to explore multiple threats and 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 covering in detail a wide range of concepts, approaches, and tools to provide a basis for evaluating how to apply the techniques to risk assessment/management efforts. A de-brief Webinar was held to disseminate the project findings. SoCalGas may use this research to support the risk decision-making process supplementing the Transmission Integrity Management Program.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 01/01/2020
End Date: 01/31/2022
Status: Completed
2022 Funds Expended: **$8,567**
Total Project Cost: **$1,739,097**
Total SCG Cost: **$56,567**
Total Co-Funding: **$1,682,530**
Benefits:

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

This project validated commercially available online analyzers in two phases. The goal was for operators to use a single online analyzer to measure multiple contaminants in a natural gas stream instead of one analyzer measuring one contaminant. This approach reduces capital, operations, and maintenance costs. The project team completed Phase 1 in 2020 by evaluating the measurement ranges, accuracy, and reliability of three online analyzers. The project team used the analyzers to measure CO2, O2, H2S, and H2O in three field samples and four blended in-house gases with varying contaminant levels. The Pipeline Research Council International (PRCI) published Phase 1 results in a final report for members and a redacted final report for the public for a fee. Both final reports are available on the PRCI website. In Phase 2, the project team conducted a field trial of two online analyzers at a compressor station. The field test could not provide definitive conclusions due to 1) manufacturer specifications not stated in universal terms, 2) test analyzer precision capabilities two orders of magnitude better than the reference analyzer, 3) inconsistent calibration treatments, samplings, and ambient conditions for the test and reference analyzers, and 4) unknown true measurement process gas values. Despite these constraints, the project team concluded the performance and stability of the two analyzers were reasonable and would improve monitoring in more typical conditions. The Phase 2 final report is available on the PRCI website for members. SoCalGas will evaluate and field test the more promising of the two online analyzers.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 11/02/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$141,600**
Total SCG Cost: **$15,000**
Total Co-Funding: **$126,600**
Benefits:

- 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)

This Pipeline Research Council International (PRCI) project developed guidelines for better pipeline welding process control by investigating the impact of welding procedures on factors that directly control weld properties, such as self-shielded flux-cored arc welding (FCAW-S). FCAW-S is an alternative to traditional welding that offers reduced cost advantages but suffers from toughness and reliability variability. In this project, the team identified the mechanisms responsible for weld toughness variations and tested the impact of changing weld practices and welding variables. The project team then used the test results to develop guidelines for improving semi-automatic FCAW-S welding practices to optimize weld properties and improve weld reliability in high-strength pipeline construction. PRCI published the results in a final report identifying these mechanisms and the guidelines to achieve optimal weld properties and reliability. This final report is available on the PRCI website. SoCalGas will use the results to evaluate whether FCAW-S is a viable welding option for its operations to support pipeline integrity and reduce the cost of pipeline construction and repair.

Co-Funders: PRCI Members

Start Date: 01/01/2016
End Date: 09/15/2022
Status: Completed
2022 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

NYSEARCH's Natural Gas Interchangeability Project, completed in 2012, produced a spreadsheet-based interchangeability model, "NYSEARCH RANGE," which projects the performance of in-service residential appliance populations when new gas supplies are introduced. The project objectives under this Phase II-a project were to 1) improve the ability of the NYSEARCH RANGE model to establish interchangeability boundaries for 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 negative performance and maintenance impacts for combustion equipment. The team completed RNG flame lifting research through residential appliance burner testing and updated the RANGE model with new correlation coefficients determined from these studies. Phase II-a investigated a concentration limit for siloxane that will prevent significant performance and maintenance impacts for combustion equipment. During the first round of testing, the team selected representative residential appliances with a high concentration of siloxane to assess the impacts. If performance issues were detected in the first round of testing, then systems were re-tested with a low siloxane concentration. SoCalGas is using the research to support the new Upper Action Limit for Siloxanes. The study also confirmed the current Lower Action Limit for Siloxanes. A white paper was distributed to SoCalGas stakeholders indicating the lower limit of siloxane.

Co-Funders: NYSEARCH Members

Start Date: 09/28/2018
End Date: 04/30/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$543,869**
Total SCG Cost: **$66,080**
Total Co-Funding: **$477,789**
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 issue has long been a common concern between the pipeline industry and electrical utilities. The goal of this project was to develop a field manual that provides guidance on the minimum safe distances between NG transmission pipelines and AC grounding systems without the need for a time-consuming and costly grounding study. Established minimum safe distances in different soil resistivities/types would provide a filtering criterion that could be universally applied. Utilities could apply the criterion during design to avoid conflicts between utilities and in the evaluation of existing shared rights-of-way. Limited laboratory tests showed that the model appears to capture the general arc behavior. However, the simulation requires tuning and more testing, which a future phase could address. The next step is for project sponsors to evaluate the findings and determine if the group should pursue the next phase.

Co-Funders: PRCI Members

Start Date: 01/31/2017
End Date: 03/18/2022
Status: Completed
2022 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, cathodic protection is not a reliable back-up to coating protection. Therefore, it is important to specify and apply the most appropriate and best-performing coating system. There are unique and promising coatings available in the market that have the potential to substantially reduce wet and dry aboveground corrosion in a wide variety of applications. Unfortunately, the supplier discontinued the NeverWet technology, so it could not be included in the field trials. Although the field exposure started at the end of 2019, the team is continuing field testing with the application of three coatings per the protocol. The project is in the planned "field exposure" phase, with the coatings logging exposure time at their respective application sites. The plan was for the field test to include four seasons of exposure and then to assess performance. The team extended the field trial due to COVID-19 restrictions. The extra time of exposure will benefit the meaningfulness of the assessments. In 2022, the applied systems will continue to age in the field. Operators could use coatings found to provide long-term protection to support their efforts to avoid or mitigate corrosion on aboveground assets.

Co-Funders: OTD Members

Start Date: 09/06/2017
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$217,000**
Total SCG Cost: **$4,347**
Total Co-Funding: **$212,653**
Benefits:

Gas Composition and Quality

For 2022 this project included the HYREADY joint industry project (JIP) Program, which was created to 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, subsurface storage, which covered capacity, operation, and gas conversion processes, the three aspects of storing hydrogen in natural gas underground storage, and hydrogen injection facility design, which established the minimum requirements for components and materials. In 2022, the HYREADY JIP gathered information on hydrogen separation technologies, including pressure swing adsorption (PSA) membrane separation and cryogenic separation, and 100% hydrogen distribution networks for various steel and plastic pipeline components. SoCalGas will use HYREADY work packages to understand better if specific parts of the system would be compatible with different percentages of hydrogen. In 2023, SoCalGas participation in this JIP transfers out of the GasOps RD&D program.

Co-Funders: N/A

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

Gas Machinery Research Council (GMRC)

With more than 77 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 its members and the industry an opportunity to exchange information and ideas and to 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. Products most often evaluated by GMRC improve operation or performance, specifically related to pulsation dampening, compressor efficiency, or throughput. In 2022, GMRC's active projects included: Dry Gas Seal Reliability (Phase 5), Implementing the Virtual Orifice Standardization, Hydrogen Blending on Compressor Stations, Reciprocating Compressor Lube Oil Optimization, and Lube Oil Gas Entrainment. Four projects were completed in 2022, and the results were shared with members. The GMRC benefits SoCalGas, and the industry in one of three ways (1) basic research useful to support other research or product development, (2) establish design criteria, or (3) develop and evaluate products that it will use.

Co-Funders: GMRC Members

Start Date: 01/01/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$4,000**
Total Project Cost: **$1,464,000**
Total SCG Cost: **$20,160**
Total Co-Funding: **$1,443,840**
Benefits:

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

Gas Turbine Component Research Roadmap (CPS-5-12)

The projective objective is to develop a roadmap to guide future PRCI research in centrifugal components for gas turbine-driven centrifugal compressors. The last roadmap was created in 2016. That research map does not reflect the current state of technology. The team will perform a literature review under this new road map and survey the current state of gas turbine-driven centrifugal compressors. They will also identify gaps that will improve gas turbine-driven compressors' safety, reliability, and performance. Once the team develops the road map, they will use it to identify and prioritize research to benefit gas utilities and the ratepayers.

Co-Funders: PRCI Members

Start Date: 12/14/2022
End Date: 12/14/2023
Status: Active
2022 Funds Expended: **$8,872**
Total Project Cost: **$59,000**
Total SCG Cost: **$8,872**
Total Co-Funding: **$50,128**
Benefits:

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

This project developed processes and procedures to assess the risk of girth weld incidents for in-service pipelines. Girth weld incidents (i.e., leaks and ruptures) have occurred during hydrostatic proof tests and in newly constructed in-service pipelines in recent years. The project team developed guidance documents on recommended practices to assess girth welds and pipelines, improve pipeline and weld assessment testing processes and procedures, and prevent girth weld failure. These recommendations will help minimize the risk of girth weld incidents for near-term and future pipeline construction. The improved testing procedures for pipeline assessments and recommended welding practices should lead to more strain-resistant girth welds and more pipelines resistant to welding-produced anomalies, such as corrosion and mechanical damage. SoCalGas has implemented recommendations to minimize weld failures and will continue to review the results to see if additional changes to welding procedures are needed to improve the safety and integrity of its pipelines.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 09/15/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$743,402**
Total SCG Cost: **$20,292**
Total Co-Funding: **$723,110**
Benefits:

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

This project's objective was to develop a test for the susceptibility of low-carbon steel in the Heat-affected zone (HAZ) of a weld. Unexpected girth weld failures can occur in newly constructed pipelines, with time elapsed from construction to rupture ranging from several weeks to a few years. Most failures arise in service and some during preservice hydrostatic testing. HAZ softening is one of the contributing factors leading to the loss of the mechanical strength or softening of the pipe around the weld that produces the HAZ, where the base metal experiences thermal cycling. The team developed a test for susceptibility of low carbon or carbon equivalent steel to characterize the loss of mechanical strength in the HAZ of the base metals by mapping the HAZ area and its strength profile. The project also developed recommendations on welding procedures that could prevent HAZ softening. The team published the results in a final report in 2022. This new test could be submitted to a standard organization so that they could adopt it into an existing or new standard. Pipe manufacturers could also use the new test to determine HAZ softening susceptibility of their products for existing pipes. SoCalGas could benefit from the results of this project to assess the HAZ softening in its existing pipes. If SoCalGas identifies HAZ risk, it could mitigate it by preventing the material from entering service or mitigating weld-induced HAZ softening through weld development and control of welding practices. These efforts will lead to better design and safer operations of pipelines benefiting ratepayers with a more reliable and safer energy source.

Co-Funders: PRCI Members

Start Date: 07/24/2020
End Date: 05/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$218,300**
Total SCG Cost: **$7,400**
Total Co-Funding: **$210,900**
Benefits:

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

Hot Tap Branch Connections, JIP

Start Date: 12/16/2019
End Date: 6/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,050,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$1,020,000**
Benefits:

Hot tap branch connections have long been an important aspect of pipeline and piping system operations. This joint industry project (JIP) aims to develop industry best practices for welding stub-on branch connections onto live gas mains (i.e., hot taps) and to provide a guideline that enables the least-complicated procedure to be selected for a given application. Developing and using 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 2022, the team completed the final version of the PRCI Pipeline Repair Manual. Additionally, revisions were made to the 22nd edition of API 1104, which is a global standard that supports industry-wide requirements for gas and arc welding used in the construction and in-service repair of pipes to improve pipeline safety, structural integrity, and efficiency by providing detailed welding procedures for qualified professional welders, inspectors, and engineers. The project team continues to work on qualifying procedures using a mechanized system for in-service welding, which can make longitudinal seam welds and circumferential fillet welds. The results of this JIP may aid SoCalGas in identifying instances where in-service welding may be acceptable or prohibited. It could also allow it to realize significant economic and environmental benefits.

Co-Funders: JIP Members

HyBlend Collaborative Research Partnership (5.21.k)

Start Date: 09/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$25,000**
Total Project Cost: **$15,050,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$15,000,000**
Benefits:

This project is a joint effort of natural gas (NG) operators, research consortia, and four national labs: Sandia National Lab; Pacific Northwest National Laboratory; Argonne National Laboratory; and National Renewable Energy Laboratory, to evaluate technical and economic considerations related to transporting hydrogen (H2) blends and other low carbon fuels using existing NG infrastructure. The efforts to increase H2 knowledge can lead to reduced greenhouse gas (GHG) emissions, such as when coupling energy efficiency and decarbonized fuels. The project team is addressing high-priority research topics, including 1) H2 compatibility with metals and polymers, 2) life-cycle analysis (LCA), and 3) techno-economic (TE) analysis. The project team will develop general principles for the operation of HyBlend delivery systems regarding structural integrity, assess the role of NG impurities in the degradation of metal pipelines and HyBlend for plastic pipeline degradation and lifetime predictions, perform an LCA on the technology pathways for H2 and NG blends and alternative routes, and quantify the costs and opportunities for H2 production and blending with an NG network, and the alternative paths. In 2021, the project team established the test conditions and materials. In 2022, the project team published the literature review and gap analysis report and completed the TE analysis. Next, the project team will complete the LCA study and develop a TE model to assess opportunities to blend H2 at varying levels into NG pipelines using the findings of their review. SoCalGas will use these results to support the development of an H2 blending standard and 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: 10/31/2022
Status: Completed
2022 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 for sustainable, reliable, and cost-effective energy. The overall project objective was to conduct physical testing to assess the impacts of 5% hydrogen-blended fuel on metallic materials in the natural gas pipeline system. The project also developed engineering tools to perform integrity assessments and determine safety margins for hydrogen blended gas use. In this project phase, the team focused on completing 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 for a future phase. The project deliverables included a comprehensive literature review with references to studies documenting hydrogen embrittlement in metals, journal articles and research studies from the last 20 years, and a Design of Experiment test plan. The project team coordinated with other research efforts, HyBlend and Low Carbon Resource Initiative, to leverage results generated under different projects and to prevent duplication of efforts. The final task for the project was issuing a request for a proposal in preparation for the next phase of the research. SoCalGas will use this knowledge to understand the effects of hydrogen embrittlement on steel pipe and to direct additional research efforts.

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 and 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 material's behavior in the hydrogen/natural gas blend and to develop the lifetime prediction and risk models. Aldyl-A and HDPE Pipe samples have been collected, and the Oxidation Induction Time, Cross-Polarized Light Microscopy, and Tensile tests have been completed. The construction and shakedown of the testing apparatus for the Long-Term Hydrostatic Strength tests took some time due to resource issues, which delayed the tests. Testing of Aldyl-A samples has been completed. HDPE testing is planned for the beginning of 2023.

Co-Funders: OTD Members

Start Date: 04/08/2021
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$100**
Total Project Cost: **$867,800**
Total SCG Cost: **$408,646**
Total Co-Funding: **$459,154**
Benefits:

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

The project objective is to characterize the Fatigue Crack Growth Rate (FCGR) behavior of different steel pipe grades in a range of hydrogen-natural gas blends. The team will determine the FCGR for base metals, longitudinal seam welds, and girth welds at both the 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, the project team completed Phase 1a. The results showed that the FCGR accelerated for the various microstructures in the environments (i.e., hydrogen blends) caused by hydrogen embrittlement mechanisms. This finding expanded the project's scope to include testing for microstructural characterization since defects in microstructure strongly influence crack initiation processes. The team performed a complementary microscopy study for new API X65 steel samples. In 2022, the project team completed the testing for Phase 1b, the microscopy study, and Phase 2. The new X52 testing baseline results of the base metal showed similar trends as X70 and X65 pipes. The team delivered the final report for Phase 1B in December 2022, and they expect the final reports for the microscopy study and Phase 2 in January 2023. SoCalGas will use this knowledge to understand the effects of hydrogen embrittlement on steel pipes and to direct additional research.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 01/20/2023
Status: Active
2022 Funds Expended: **$254,850**
Total Project Cost: **$1,096,160**
Total SCG Cost: **$1,096,160**
Total Co-Funding: **$0**
Benefits:

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

The overall goal of this project was to find a robust measurement method that could detect Siloxanes in renewable natural gas (RNG). 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 the 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 the efficiency of industrial equipment. The Phase II objective was to identify a suitable portable technology that can measure low levels of siloxane concentrations (~0.1 mg Si/m3) and to test the instrument in a wide range of applications. Previously, in phase I of this project, the team evaluated analyzers in the laboratory and the field to provide the technology options for Phase II. During phase II, the team gathered data and information on the presence of siloxanes in RNG that can be used to develop a standard on acceptable siloxane levels. The team chose five analyzers, and testing was conducted 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 in the next step during field testing.

Co-Funders: NYSEARCH Members

Start Date: 01/31/2021
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$256,203**
Total SCG Cost: **$28,940**
Total Co-Funding: **$227,263**
Benefits:

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

Impact of Blended H_2 on Threaded Connections (M2021-007)

This project aims to determine if hydrogen blends in natural gas cause any change in the presence or absence of leaks and 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 include tests to assess the change in a leak or leak flow rate with a 20% hydrogen blend. In Task 4, the project team will evaluate the impact of various pipe dopes and sealants and if hydrogen blends influence this variable. The team will also perform tests on non-NPT threaded connections. The project established procedures for creating threaded connection leaks and methods to measure leak flow rates with hydrogen blends. In the first round of testing, the project team tested sealants with NPT versus out-of-specification threaded connectors with both natural gas and a natural gas-hydrogen blend of 20%. The results showed that the natural gas-hydrogen combination does not appear to create more leaks than natural gas alone. SoCalGas will use the research study to support the determination of a hydrogen blend limit for natural gas distribution systems that could contribute to a statewide hydrogen injection standard.

Co-Funders: NYSEARCH Members

Start Date: 08/09/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$2,260**
Total Project Cost: **$238,517**
Total SCG Cost: **$21,271**
Total Co-Funding: **$217,246**
Benefits:

Impact of Hydrogen/Natural Gas Blends on LDC Infrastructure Integrity (M2020-002 PhII)

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 gaskets for flanges in joining pipes and fittings. The need for more 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 I, the team performed exploratory tests using a limited set of test gas mixtures. Phase II focuses on carrying out a complete and systematic test program leveraging the Phase I findings and testing new and vintage materials with a wide range of hydrogen blends (up to 20%), pressures, and temperatures. To date, virgin NBR and SBR tests are complete, with results showing the impact on the elastomers with the various hydrogen concentrations at 5%, 12%, 20%, and 30%. During Phase I of this project, the team saw an impact on the elastomers during the creep test. In Phase II, they observed no effect, likely due to the more accurate data from the thermomechanical analyzer purchased for this project phase. This project will help SoCalGas 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: 04/22/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$689**
Total Project Cost: **$425,024**
Total SCG Cost: **$31,910**
Total Co-Funding: **$393,114**
Benefits:

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

The objective of this study is to identify trace constituents that act as odor-masking agents. Natural gas contains numerous chemicals that are removed at gas processing plants before 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 industry will use the study's results to determine how to mitigate the masking effect of these agents. The effort will lead to safer gas operations for utility workers and their customers. In early 2021, the team developed an odor masking test method to examine seven common masking agents found in gas processing plants. The team completed testing, and they identified the trace constituents of concern. Volunteers in laboratory sniff tests were to be employed to test those trace constituents. However, the project team delayed this last stage of the project due to health protocol concerns. The team is actively addressing the issues and anticipates that they will complete the sniff test in Q1 of 2023, along with the final report. Once SoCalGas receives the results, it will use them to determine if it needs to change its odorant program to protect ratepayers.

Co-Funders: OTD Members

Start Date: 03/01/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$2,578**
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)

Start Date: 12/14/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$8,000**
Total Project Cost: **$255,000**
Total SCG Cost: **$12,554**
Total Co-Funding: **$241,169**
Benefits:

American Petroleum Institute (API) Standard 5L is the standard for transmission pipes used in the natural gas and petroleum industries. This project aims to develop a standard data interchange template for transmitting a completely digital Material Test Report (MTR) in compliance with API 5L Recommended Practice RP-5MT. API Standard 5L is the standard that 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. Project deliverables include creating a digital template to make the report available to customers electronically and a method for verifying that the report is from the pipe manufacturer. This approach will improve traceability by providing an electronic signature that ties the test report directly to the manufacturer. The team held a kickoff meeting in the second half of 2022. SoCalGas will benefit from the operational efficiency of electronic test reports for pipes by decreasing the time for materials approval and management.

Co-Funders: OTD Members

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

Start Date: 10/13/2021
End Date: 10/13/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$177,000**
Total SCG Cost: **$13,587**
Total Co-Funding: **$163,413**
Benefits:

The objective of this Pipeline Research Council International (PRCI) project is to 1) investigate the Heat-Affected Zone (HAZ) softening associated with welding when installing Type-B sleeves and performing hot taps for pipeline repairs; 2) determine how HAZ softening affects pipeline integrity of welds (i.e., girth welds) and modern pipeline materials; 3) and use the results to update current welding procedure guidelines for a vintage pipe to include best practices for welding modern micro-alloyed pipe during repairs to improve pipeline integrity. The team will perform tests using various welding and installation procedures to minimize the loss of mechanical strength in the HAZ. Softening occurs in the HAZ during welding, where mechanical strength decreases and creates a mismatch of mechanical strength between the HAZ and the unaffected pipe. Girth welds are not only used in pipeline construction, which will enhance pipeline integrity by minimizing pipeline failures, but also in pipeline repairs. SoCalGas will use the results of this project to evaluate if it needs to change its pipeline repair program involving Type-B sleeves and hot taps to improve pipeline integrity.

Co-Funders: PRCI Members

Investigate CLSM to Manage Axial Soil Loads on Buried Pipelines

Start Date: 09/01/2020
End Date: 10/31/2022
Status: Completed
2022 Funds Expended: **$25,050**
Total Project Cost: **$130,000**
Total SCG Cost: **$75,000**
Total Co-Funding: **$55,000**
Benefits:

Ground displacements may produce pipeline strains well over the levels produced under normal operating conditions. These excess loads are caused by the movement of the pipe relative to the soil, as the pipe restricts the movement of the soil. The project's objective was 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. CLSM could significantly reduce the need for costly mitigative measures to repair or replace damaged pipeline sections due to ground displacement events. This project investigated the effectiveness of using CLSMs to prevent pipeline damage from soil friction loads. The project team performed experimental tests involving CLSM cast around pipes with various coatings to measure the bond strength at the pipe-CLSM interface and on pipes with a CLSM backfill buried in the soil to determine the axial load that could be gained by using CLSM as a backfill. The team compared the test results to those predicted using the Pipeline Research Council International (2009) guidelines. The project team found that the ultimate measured load closely matched the expected. This finding indicates that the equations currently used to determine the ultimate loads on pipelines are meaningful and potentially usable for pipes encased in a CLSM backfill.

Co-Funders: PG&E

- 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 volume percentages (i.e., 25%-35%) by evaluating the safety, maintenance, and emergency response changes on gas distribution infrastructure. This project by SoCalGas is co-funded by NYSEARCH. The Living Lab demonstration aims to validate the feasibility of blending 25%-35% hydrogen by volume into the existing natural gas infrastructure by simulating system operations with steel and plastic pipelines and components, a pressure regulator station, and a compressor. The project will also test the sensitivity and check the performance of several leak detectors. The project started with developing a test plan and requesting that sponsors begin collecting plastic and steel pipeline components for testing. The team is currently working on the design, estimating they will commission the Living Lab in late 2023. Testing will start afterward and will run for two years. SoCalGas will deliver a final report with results from all testing and material analysis to project sponsors. This project will yield valuable data to SoCalGas on hydrogen blending impacts on pipeline integrity, measurement, regulation, and procedures for safety and maintenance.

Co-Funders: NYSEARCH Members

Start Date: 12/13/2021
End Date: 06/28/2024
Status: Active
2022 Funds Expended: **$30,412**
Total Project Cost: **$1,222,402**
Total SCG Cost: **$300,000**
Total Co-Funding: **$922,402**
Benefits:

Managing Stress from Uneven Supports and Settlement (CNST-2-2A)

The objective of this project is to develop guidelines and procedures to manage strain and stress from uneven support and soil settlement in the design, construction, and maintenance of pipelines. High strain and stress could lead to fractures in pipelines causing failures and disruption to services for ratepayers. This project will investigate current utility practices in addressing external strain and stress. The project team plans to examine excavation and backfill practices that cause high strain and stress by analyzing utility data. The team will use models to simulate and quantify the strain and stress to develop best practices to minimize strain and stress on pipelines. In 2022, the project completed a literature review of PHMSA incident reports from uneven supports and conducted a members' survey on current practices. In 2023, the team will follow up with members to gather In Line Inspection and bending strain data and maintenance records, and then will analyze the collected data. The final deliverable will be a report with recommended practices and procedures to prevent pipeline failure from uneven supports. The project team will also hold a workshop to train utilities on implementing the best methods to minimize strain and stress on pipelines. The results of this project will be better integrity management of gas pipelines to prevent failures from uneven support and settlement of pipelines, making the pipeline system safer and more resilient. SoCalGas supports this project in anticipation that the guidelines and procedures for best practices could improve design, construction, and maintenance to minimize strain and stress on its pipelines.

Co-Funders: PRCI Members

Start Date: 03/25/2022
End Date: 03/25/2024
Status: Active
2022 Funds Expended: **$7,617**
Total Project Cost: **$188,000**
Total SCG Cost: **$15,234**
Total Co-Funding: **$172,766**
Benefits:

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

The project objective is to provide software tools to assist operators in complying with the maximum allowable operating pressure (MAOP) and materials verification requirements in the proposed rule on the Integrity Verification Process (IVP). The proposed guideline allows using Engineering Critical Assessments (ECA) instead of a hydrotest, derating, or pipe replacement. The pending rule also allows pipe surface-based non-destructive measurements instead of cutouts and reduces the number of destructive tests. The team has developed a set of models using the ASME B31G-modified (wall loss defects) and the Maxey-Folias Leak-Rupture Boundary model and shared them with the Specified Maximum Yield Stress Boundary Project. The design work continues with the development of modules for the ECA tools. The project team has also identified a new compiler/computer language to replace Fortran/Ruby language-based tools and improve computer performance for new and existing models. The project team has made significant progress in importing the ten-million-point dataset and using it in model calculations with resulting output in spreadsheet format. The team plans to continue the development of additional modules for the ECA tools. Project deliverables will include the developed modules along with a final report. SoCalGas could use this tool to comply with the proposed IVP Rule.

Co-Funders: OTD Members

Start Date: 09/08/2017
End Date: 2/28/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$116,000**
Total SCG Cost: **$11,364**
Total Co-Funding: **$104,636**
Benefits:

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

Odor Detection Study for Blended Hydrogen (M2021-005)

The objective of this project is to determine if hydrogen blends can mask common gas industry odorants. Federal regulations require odorant injection into natural gas to provide the 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 of this study to adjust odorant levels in hydrogen blends to maintain the ability of consumers to detect gas leaks.

Co-Funders: NYSEARCH Members

Start Date: 07/29/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
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)

The objective of this project is to understand how the introduction of conditional factors of odor adaptation and odor-masking agents affect the detection and recognition thresholds of human senses. This project is Phase 2 of the natural gas odor detection threshold study and uses the odorant thresholds of human detection levels determined in Phase 1. The team studied the two phenomena in parallel, but they provided the results independently to understand each variable's effect better. This study can potentially inform decision-making regarding the odorization of natural gas. The contractor completed the odor adaptation task of the project. The study of odor-masking effects on odorants by masking agents, Limonene and Ammonia, was delayed in early 2021 due to the impacts of the COVID-19 pandemic. It established preliminary thresholds for Limonene in late 2021. In 2022, the team set the testing threshold for Ammonia. The study on Ammonia impacts will follow the Limonene study. The contractor was planning to perform the last stage of the project using volunteers to establish detection thresholds. However, this final stage was delayed since the contractor failed to meet the health protocols required by regulators. In the 3rd quarter of 2022, the contractor successfully met the required health protocols, and the last stage of the project is planned for late 2022. Once the team completes the last phase, they will publish the results in a final report. SoCalGas plans to use the study's results to evaluate if its odorant levels are adequate in its gas supply to safeguard the safety of ratepayers.

Co-Funders: NYSEARCH Members

Start Date: 11/16/2019
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$468,950**
Total SCG Cost: **$48,100**
Total Co-Funding: **$420,850**
Benefits:

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

For many years, Pipeline Research Council International (PRCI) member companies have been interested in the effect of upstream piping configurations on ultrasonic meter performance. Many manufacturers have conducted testing based on International Organization of Legal Metrology (OIML) R137-1 because the 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 comparison of meter performance. Access to the manufacturer's required calibration lab results for the new generation of ultrasonic flow meters will enable SoCalGas to better assess meter model performance for currently installed models and those purchased in the future. This project organized and compared non-public-domain data from eight different ultrasonic meter manufacturers' OIML R-137-1 testing programs to data from current multipath model ultrasonic meters. The provided OIML R-137-1 compliant data sets were valid and useful for determining meter performance relative to various upstream piping configurations. As a result, the data presented in the final report are applicable for determining the potential meter error for multiple combinations of upstream piping disturbances, flow meters, and upstream straight piping lengths, both with and without flow conditioning. SoCalGas will review the final report to identify any newer generation models that could be acquired as field test evaluation meters, saving the time and cost required to conduct a lab and test rack evaluation. The final report is available to PRCI members. This project was re-mapped from the Operations Technology Subprogram to the System Design & Materials Program.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 04/20/2022
Status: Completed
2022 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

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

In past phases of this project, the team performed validation testing of several on-line biomethane analyzers to identify which would have the potential to detect unconventional trace constituents (TCs). Phase III aims to perform product development on the selected analyzer and to test the modified analyzer for the monitoring of unconventional trace contaminants. These unconventional TCs are sometimes found in biomethane if cleanup technologies fail and are not routinely monitored by on-line instruments. Utilities need technologies to provide real-time data for these TCs since they impact gas quality. In this phase, the analyzer manufacturer will work to modify their system, incorporating changes identified in Phase II to commercialize the analyzer. The analyzer will be tested with continuous gas streams 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 arsenic, halogenated hydrocarbons, and n-nitro-so-di-n-propylamine. In 2022, the sponsors selected the analyzer, and GTI contracted with the manufacturer for product development. The project encountered delays as the project team attempted to procure the main calibration gas. The calibration gas is now on order. The project schedule will be updated once the gas is received and product development can proceed. SoCalGas needs to continuously monitor TC levels to determine the variability of the TC concentration. If it exceeds the limits, SoCalGas may require biogas quality monitoring systems to make sure the gas quality is consistent.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$17,439**
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 in mechanical damage (MD) research and to produce a comprehensive set of guidelines and tools for managing the threat of MD. To date, the SRP has funded two projects 1) Analysis of Pipeline Operator and Prior Research & Development Data (MD-2-5) and 2) 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
2022 Funds Expended: **$9,762**
Total Project Cost: **$2,042,507**
Total SCG Cost: **$13,447**
Total Co-Funding: **$2,029,060**
Benefits:

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 (PRCI) established the Strategic Research Priority (SRP) to coordinate efforts across all technical committees (e.g., Compressor Pump Station, Design Materials Construction, Surveillance Operations Monitoring, Measurement, and Underground Storage). The SRP provides a roadmap of research projects to understand further and efficiently and effectively manage cracks in pipelines. The research will focus on four core areas: susceptibility, inspection, management, and assessment and remediation. In 2022, the project team continued work on the Improvement of ILI Capabilities Joint Industry Project (PHASE II) (NDE-4-12), and a new project was funded and started Recent Pipeline Failures Where Hydrogen Was Identified as a Contributor (MAT-8-3B). The team completed one project: Understanding Why Cracks Fail (MAT-8-3). MAT-8-3 uses public reports on crack failure and PRCI member incident reports to find root causes of pipeline failures from cracks. The team used the root causes to identify research gaps that will guide future research. The final report is available on the PRCI website.

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$26,762**
Total Project Cost: **$5,193,400**
Total SCG Cost: **$49,464**
Total Co-Funding: **$5,143,936**
Benefits:

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

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 (PRCI) MAT-8A fracture mechanics model and its input parameters. The final product will be a cloud-based software that uses probabilistic fracture mechanics (PFM) with the updated MAT-8 model. The new software enables operators to optimize resources by evaluating different mitigation scenarios. In 2022, the project team conducted training sessions for sponsors on fracture mechanics, probability concepts, and the cloud-based software. Evaluation of the methodology to analyze populations of non-detected defects against PRCI methodology is ongoing. 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 various applications such as general fitness for service, maximum allowable operating pressure reconfirmation, and In-Line Inspection (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 because of the Gas Transmission Safety Rule.

Co-Funders: PRCI Members

Start Date: 09/01/2019
End Date: 3/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$621,695**
Total SCG Cost: **$67,645**
Total Co-Funding: **$554,050**
Benefits:

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

The project objective is to develop weld acceptance test criteria to verify acceptable weld strengths and use the results to propose revisions to current welding standards - the American Petroleum Standard 1104 and Canadian Standard Association Z662. This project continues the work from previous research projects (MATH-5-3B and MATH-5-3C) that identified the cause of many failures at girth welds on modern high-strength pipes. The reasons identified involved undermatching (where the weld is weaker than the adjoining pipe) and Heat Affected Zone (HAZ) softening due to welding coupled with axial loads. The revisions associated with this project will improve pipeline integrity, safety, and reliability by updating the standards with new testing methods and procedures for minimizing HAZ softening and undermatching weld strength. In 2022, the project team made steady progress toward completing Phase 1 out of 2. The project team collected a total of over 100 girth welds. Donated and fabricated weld samples have been used in tensile strain capacity analysis to determine weld performance and weld strength. Once Phase 1 is completed, Phase 2 will evaluate the tensile strength capacity of welds experiencing HAZ softening. With the completion of Phase 2, the team plans to develop acceptance criteria for girth welds that meet performance standards and improve pipeline integrity. The project's final deliverable will be the final report with recommendations and acceptance criteria for girth welds. SoCalGas will evaluate the results and recommendations to determine if changes are needed to welding practices to improve its pipeline integrity program.

Co-Funders: PRCI Members

Start Date: 10/05/2021
End Date: 04/05/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$212,400**
Total SCG Cost: **$14,350**
Total Co-Funding: **$198,050**
Benefits:

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

PRCI Emerging Fuels Institute

Pipeline Research Council International (PRCI) established an Emerging Fuels Institute (EFI) in April 2021 to address the challenges of transitioning to clean fuels. The EFI will focus on infrastructure related to hydrogen, renewable natural gas (RNG), carbon capture and sequestration, ammonia, and biofuels in the following areas: pipeline system integrity, steel, and non-steel components, compressor stations, pressure control, and over-pressure safety devices, electrical classification and fire safety, and underground storage. In 2022, the EFI funded eight new projects: Change Management for Introducing Hydrogen at Compressor Stations (JEFI-01-01), EWI JIP – Development of an Optimized Material Qualification Approach for New Steel Pipelines for Hydrogen Service (JEFI-04-01), HYtap-stopple – Experimental Hydrogen Hot Tap and Stopple Safe Operation Process Development (JEFI-04-03), Welding Hot Tap Fittings and Sleeves in H2 Blend Environment (JEFI-04-05), DNV JIP – Guidelines for Material Selection for Underground Hydrogen Storage (JEFI-05-01), EFI Talking Points (EFI-00-01), Electrical Area Modeling and Risk Assessment of Hydrogen-Natural Gas Blends (JEFI-01-02), and Evaluate Gas Pacification to Prevent or Mitigate Hydrogen Embrittlement (JEFI-04-04). Work continued: RNG Trace Components Database (EFI-02-01); NewGasMet/PRCI Collaboration; Hydrogen Blending Projects: DNV Joint Industry Project on Guidelines for Integrity Management of H2 Pipelines (JEFI-03-01); Material Capability Assessment for the Safe Transportation of Hydrogen via Pipeline, HyBlend CRADA (EFI-MAT-9-2); PHMSA/ASU KAI-MAP for hydrogen transport; GMRC analysis of compression; Solar turbine retrofit solutions; and Sandia/PRCI risk study.

Co-Funders: PRCI Members

Start Date: 06/15/2021
End Date: 01/31/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$2,000,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,500,000**
Benefits:

Product and Process Validation Program (5.20.m)

This project tested common natural gas utility industry products to validate that they met industry performance standards. For yearly testing, utility members selected products based on material type, configuration, size, and supplier. Rather than bearing the entire cost of evaluating these products themselves, participating utility members benefitted from cost savings through the project's collaborative financial approach. Four identical electrofusion assemblies from three manufacturers, including a SoCalGas supplier, were tested using industry standards. The test results showed that the selected products from the three manufacturers met industry performance standards. SoCalGas viewed the results as confirmation that its supplier still produced high-performance products and gained information on alternative suppliers that could meet performance specifications.

Co-Funders: OTD Members

Start Date: 09/01/2020
End Date: 08/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$8,491**
Total Co-Funding: **$171,509**
Benefits:

Reserve Strain Capacity Determination (PHMSA)

This project aims to develop a model for measuring accumulated strain on existing pipelines. The team will accomplish this by developing and demonstrating a model network for predictive modeling with decision nodes to show a decision path's outcome (diagrams). The project will also employ the following: 1) scenario analysis for strain interventions, 2) satellite-based ground movement data, 3) causal models for pipeline modes of failures, and 4) metallurgical influences on pipeline properties, which are all required to develop a model to measure accumulated pipeline strains. Satellite data can be used to assess the strains on existing pipes. Metallurgical influences can help reveal the behavior of the steel pipeline and damage propagation in the steel under interacting threats. This Pipeline and Hazardous Materials Safety Administration (PHMSA) co-funded project will provide the necessary modeling and data analysis framework to correlate satellite-based ground movement data to strains on pipelines of interest. In 2022, the project team identified potential sites where satellite and standard data correlate with pipe movement and strain measurement. The development of causal models for multiple pipeline modes of failure and the identification of metallurgical influences on pipeline properties are ongoing. The initial modeling feedback gave the team further insight to focus on a more complete and robust collection of modeling parameters and approaches. SoCalGas intends to use the model as a guide to determine the amount of strain on a pipeline due to ground movement.

Co-Funders: OTD Members, PHMSA

Start Date: 03/30/2022
End Date: 09/14/2024
Status: Active
2022 Funds Expended: **$500**
Total Project Cost: **$1,936,008**
Total SCG Cost: **$2,500**
Total Co-Funding: **$1,933,508**
Benefits:

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

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. Using the USR could allow operators to monitor and control district regulator stations remotely. In 2022, the team developed the Products and System Needs and Requirements document, and Utonomy started investigating how to adapt its smart regulator actuator to work with the Fisher Y600 and 161 pilot regulators. Utonomy continues to seek OTD sponsor input for specific requirements such as set-point accuracy against the flow or lock-up conditions for utility system regulators. SoCalGas also provided data and regulator information to Utonomy to assist in its regulator design. The project team will prepare an interim report after the laboratory testing is complete to determine whether the project should proceed with field trials. This project has the potential technical links to company efforts to bring remote monitoring and control to SoCalGas's 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: 07/31/2023
Status: Active
2022 Funds Expended: **$35,144**
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's (PRCI) Hot Tap 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 kinds of metal could enable a clear understanding of the cooling aspect of the different materials. The project team has updated the model and incorporated it into the software. Although the team completed programming during testing, they encountered issues with the software's graphical user interface (GUI). The team is actively working on the challenges, and progress continues. Unfortunately, the GUI issue has delayed project completion, scheduled to be completed in 2022, to the first quarter of 2023. Once the team finishes the GUI, the Hot Tap Model V5 will be available to PRCI members. The updated software will allow SoCalGas and other utilities to predict weld properties better, thereby enhancing the safety and reliability of pipelines.

Co-Funders: PRCI Members

Start Date: 08/17/2020
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$69,620**
Total SCG Cost: **$19,946**
Total Co-Funding: **$49,674**
Benefits:

RNG Blending Skid Study

The objective of this project is to develop a process and skid design supporting new renewable natural gas (RNG) Interconnections in achieving pipeline gas quality specifications per SoCalGas Rule 45. This effort intends to perform a field demonstration to qualify RNG blending equipment and configurations that will 1) meet Rule 45 requirements, 2) maintain existing pipeline integrity requirements, 3) mitigate the risk of allowing substandard gas from entering the pipeline system, 4) help RNG interconnectors provide RNG to SoCalGas, and 5) help SoCalGas meet company goals in accepting more RNG in its pipeline system. The project team will develop a computational fluid dynamics model and validate it via demonstrations and equipment testing to provide results. The project team will deliver the results in a final report that includes experimental data, analysis of data, resemble data, and blending guidelines and recommendations. SoCalGas intends to procure and implement the proven method and plans to allow for blending Rule 45 RNG with pipeline gas before it enters the pipeline system.

Co-Funders: N/A

Start Date: 11/17/2022
End Date: 11/30/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$400,000**
Total SCG Cost: **$400,000**
Total Co-Funding: **$0**
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 aim to develop seismic risk assessment software tools using different risk models. SoCalGas is involved in both projects. Slate Geotech and UC Berkeley were awarded the first project to produce an open-source analysis tool easily usable by regulators and utilities. The software will utilize updated methodologies for assessing seismic risk to underground and aboveground natural gas infrastructure. The tool will be able 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. The project team will host a User Workshop in January 2023 to launch the developed software and demonstrate how to use the features of the OpenSRA tool effectively. SoCalGas provided data and technical expertise for this project. UCLA was awarded the second project. This endeavor considers four hazards: Earthquake ground shaking, fault displacement, landslides, and liquefaction. It will develop a comprehensive set of pipeline fragility curves and an open-source risk assessment tool based on a probability-based methodology. The project team has developed several fragility models, with a final report expected at the end of 2023. SoCalGas is participating in the TAP for this project.

Co-Funders: CEC, LBNL

Start Date: 06/01/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$500**
Total Project Cost: **$5,207,752**
Total SCG Cost: **$13,000**
Total Co-Funding: **$5,194,752**
Benefits:

Steel Transmission Pipeline System Analysis

The objective of this project was to evaluate the failure susceptibility of operating gas transmission pipelines with hydrogen blending concerning the risk associated with the current operational characteristics of the pipeline with purely natural gas. SoCalGas intended the initiative to position it as a leader in California and the nation, promoting environmentally responsible energy while maintaining the integrity of the pipeline system. SoCalGas worked to establish a roadmap for maintaining pipeline safety and integrity on steel transmission pipelines while transporting hydrogen blended with natural gas (hydrogen blending) through existing transmission pipeline infrastructure. The project team adapted its probabilistic fracture mechanics software for applications unrelated to hydrogen blending. The project team completed a failure susceptibility analysis of the SoCalGas transmission piping system to prioritize candidate pipelines and pipeline segments for a pilot hydrogen blending project. The team delivered the final report to the sponsors. SoCalGas could apply this research to its established strategic demonstration program, which focuses on blending hydrogen with natural gas in select transmission and distribution pipelines.

Co-Funders: N/A

Start Date: 05/24/2021
End Date: 12/30/2022
Status: Completed
2022 Funds Expended: **$394,689**
Total Project Cost: **$600,000**
Total SCG Cost: **$600,000**
Total Co-Funding: **$0**
Benefits:

Study on Changing Accuracy and Variability of Therm Zones Affecting Metering of New Gas Supplies (M2022-002)

Blending hydrogen in natural gas and renewable natural gas (RNG) will change gas properties, such as density, viscosity, and energy content. These altered gas properties may affect the flow measurement performance of natural gas flow meters and interfere with meeting the California Public Utilities Commission (CPUC) requirement of ±2% accuracy in gas delivery to customers. The objective of this project is to characterize the impact of varying hydrogen blend contents up to 20% by volume with natural gas and RNG on different types of residential and commercial natural gas meters. First, the project team will experimentally gather gas property data required to calculate a mass flow rate output from a gas flow meter, compare the results with existing equations of state (EOS), and provide recommendations for best practices and setting appropriate values of uncertainties with various EOS. Secondly, the project team will evaluate the suitability and integrity of common metering devices by determining measurement errors and trends when hydrogen content varies with natural gas and RNG. The result of these two tasks will be communicated via a final report. It will inform gas utilities on determining an accurate and repeatable way to measure and bill the energy delivered to their customers with varying gas supplies. The project kicked off in June 2022. Both tasks will be completed, and the draft final report will be released to project sponsors for review in early 2023. Pending comments and final approval, the final report will be issued mid-2023.

Co-Funders: NYSEARCH Members

Start Date: 04/22/2022
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$32,640**
Total Project Cost: **$367,250**
Total SCG Cost: **$32,640**
Total Co-Funding: **$334,610**
Benefits:

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

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

The project objective 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 will include a literature search and study of all TCs in RNG to identify any gaps and will perform preliminary laboratory testing on those gaps to identify set limits for six TCs of concern. These limits will assist SoCalGas in determining whether RNG specifications need modification. The team will deliver the results in a whitepaper. In 2021, the team modified the scope to include an impact study on critical TC concentrations. The team has completed the literature review, gap analysis, impact study, and testing has started. The testing includes: 1) volume swell testing, 2) visual inspection and dimensions, 3) mass change, 4) Shore D Hardness, and 5) tensile testing. Testing of consumer gas appliances has been delayed due to procurement issues. Presently, the search for a US supplier is still in progress. If the project successfully determines 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: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$606,810**
Total SCG Cost: **$71,390**
Total Co-Funding: **$535,420**
Benefits:

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

The goal of this project was to provide a summary of and recommended practices and standards for the current state of knowledge of mechanical damage focusing on four areas: 1) formation and behavior, 2) detection and characterization, 3) assessment and management, and 4) remediation and repair. The team has developed a range of integrity management tools, from conservative easily-applied empirical equation screening tools that identify features that are non-injurious (benign) to detailed numerical-modeling-based assessment procedures. These tools have been developed to consider a large portion of mechanical damage features; however, the need remains for tools or processes for the other less common features. The project team delivered a final report that consolidated the review of previous mechanical damage research over the past 20 years, covering the four aforementioned areas, including achievements, opportunities for improvement, and a mechanical damage bibliography to support further research. The report provides an overview of the treatment of mechanical damage in existing regulations and standards, which identifies opportunities for improvement. Gaps in current mechanical damage understanding or tools are also identified as targets for further research. SoCalGas is using the research to support industry-wide efforts to update the regulations in mechanical damage management. Current regulations are conservative, and it is expected that this project and the MD-5-2 project team's efforts will result in regulations that are based on research and engineering analysis of the physical properties of cracks and dents. The final report is available on the Pipeline Research Council International website.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 07/28/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$493,982**
Total SCG Cost: **$1,766**
Total Co-Funding: **$492,216**
Benefits:

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

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

Building on previous research, this project supports PHMSA's Tracking and Traceability initiatives. The objective for Phase 4 was to develop a counterfeit screening process for natural gas piping system components and a mobile system software that communicates quality control (QC) concerns about parts directly to the component manufacturer in near real-time. Despite components used to construct natural gas delivery systems passing initial hydrotesting, failures within a few years of service have been linked with counterfeit parts. Tools are needed to confirm component authenticity and to verify their QC test reports are representative of the use requirement for the components received. To achieve these goals, GTI -Energy, formerly known as Gas Technology Institute, built a mobile computing technology coupled with cloud-based processing to yield information on a component for automatic processing. A single scan of a barcode on a product can verify its identity, its QC test information, product properties, geospatial feature definition for modeling and enable numerous QCs. The project team successfully developed a tool to create barcodes and track components from manufacturer to customer. The team is pursuing the commercialization of the device. This project completed the research efforts from the comprehensive studies of Phase 1 through Phase 4. SoCalGas intends to use the relevant results and recommendations from this extensive research to support its' ongoing Material Quality Management and Material Traceability Company efforts.

Co-Funders: OTD Members

Start Date: 11/01/2021
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$5,763**
Total Project Cost: **$229,000**
Total SCG Cost: **$13,263**
Total Co-Funding: **$215,737**
Benefits:

Targeted Hydrogen Blending in Gas Infrastructure for Decarbonization (GFO-21-507)

The project objective is to shape and develop safety practices for blending hydrogen into natural gas pipeline systems by identifying the requirements, steps, and procedures involved. The project will address this through 1) a multi-disciplinary team conducting experimental work, 2) model development derived from the experiments, 3) validation of the analyses through component-level testing, and 4) two case studies and a techno-economic analysis. This project should help understand the condition of existing pipeline assets when introducing hydrogen blends, quantify potential safety risks, and update integrity management practices for better risk management. This project will deliver a system-wide quantitative risk analysis model that can be used to improve the safety protocols of the studied cases and provide recommendations to better prepare gas utilities and facility operators for hydrogen blending at larger scales. SoCalGas intends to use this research in cooperation with other California Investor-Owned Utilities by incorporating the findings into a preliminary statewide hydrogen blending standard that the California Public Utilities Commission will regulate. If the project proves successful, SoCalGas can use the results in its pipeline integrity risk assessment program to determine safe pipeline and operating parameters for introducing hydrogen into natural gas infrastructure.

Co-Funders: CEC, Others

Start Date: 12/09/2022
End Date: 03/31/2026
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$7,216,729**
Total SCG Cost: **$15,000**
Total Co-Funding: **$7,201,729**
Benefits:

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. For this phase, a field study on steel material traceability was conducted to develop a standard data model and protocols for transferring material test reports (MTR) and electronic certificate of compliance (CoC) records 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 can reference this recommended practice when purchasing pipes from pipe mills to deliver material traceability data in a standardized, electronic format. The project was closed out in early 2022.

Co-Funders: OTD Members

Start Date: 02/08/2018
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$265,000**
Total SCG Cost: **$31,346**
Total Co-Funding: **$233,654**
Benefits:

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

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 was to enable the capture of the key information required for documenting and geospatially modeling new or repaired gas transmission systems. The goal of these activities was to support the latest Pipeline and Hazardous Materials Safety Administration (PHMSA) regulatory requirements. The objective of Phase II was 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 Energy, formerly known as Gas Technology Institute, completed a pilot with a natural gas utility by barcoding all components at manufacturing facilities, distributors, or stock components from utility storerooms with scan data saved to a PDF report. While the report was informative, it did not support information export for a modern GIS system. This limitation resulted in a complete system re-architecture record all information resulting from a barcode scan digitally. The knowledge gained from the pilot determined the project's next phase and improved the processes. In Phase II, a pilot program was established to demonstrate marking guidelines and to integrate with Global Standards 1 (GS1) synchronization network. Dedicated databases were created to collect product data into the iOS application. SoCalGas intends to use the relevant results and recommendations from this research to integrate into ongoing Material Quality Management (MQM) and Material Traceability (Mat Trace) Company efforts and complement other similar research efforts in these areas.

Co-Funders: OTD Members

Start Date: 01/01/2017
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$645,000**
Total SCG Cost: **$58,707**
Total Co-Funding: **$586,293**
Benefits:

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 the performance of an Interlaboratory Study Program (ILS) within five years of the procedure publication date. In Phase 2, the team will complete the ILS and field-test an online siloxane analyzer. Initially, the scope of work only included one field test, but the team added a second field test in collaboration with Pipeline Research Council International's MEAS-15-04 project. In 2022, the team continued the ASTM D8230 ILS by confirming siloxane components and concentrations in the ILS gas mixture. The team continued to resolve hardware and calibration issues for the online instrument evaluations. The discussions on accommodating the cylinder bank and installation schedules are ongoing. SoCalGas intends to use the research to determine siloxane analysis's repeatability and reproducibility levels. Once approved, SoCalGas will use the ASTM standard to validate the Rule 30 trigger level for siloxanes. This research will also help bridge the technology gap to monitor siloxane concentration levels at RNG sites.

Co-Funders: OTD Members

Start Date: 05/01/2019
End Date: 04/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$253,000**
Total SCG Cost: **$49,608**
Total Co-Funding: **$203,392**
Benefits:

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

SUBPROGRAM: SYSTEM INSPECTION & MONITORING

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

The primary objective of the NDE 2-11 project was to evaluate the use of X-Ray Computed Tomography (XRCT) technology for accurate and precise detection and sizing of crack-like flaws in piping to advance inspection capabilities for the pipeline industry. Validating the XRCT technology would 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 would allow non-destructive testing to characterize crack profiles and can be used on a repeated basis. This methodology was a significant advancement for the pipeline industry and will advance training, technology development, and integrity management programs. An essential element in this program was acquiring pipeline materials. Modern pipeline materials can be used, but the team preferred to use vintage pipe, especially pipes with low-frequency Electric Resistance Welding seam welds. The team's results showed that XRCT measurements did not match well with measured flaw heights for real-world features, yet XRCT measurements matched reasonably well with measured flaw heights for synthetic features. Therefore, additional work for reference standard development using real-world features will be required. This project was built upon NDE-2-12. SoCalGas could add this testing option to its crack management program as part of the validation process for in-line crack detection tools. The final report is available on the Pipeline Research Council International website.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$0**
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 of this project is to advance sensor technology in through-tubing inspection tools, which will increase their ability to detect, measure, and characterize metal loss features. The project team will 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 combination will be capable of acquiring data in a single run without pulling out the production tubing. In 2022, the engineering review, design, and assessment of thru-tubing logging technology was completed. The outcome of this work led to a few key considerations which were included in the lab test design. The development of this technological advancement will save UGS operators significant time and cost by providing the means to evaluate well integrity and effectively plan well intervention activities. SoCalGas is planning to perform a field demonstration of this technology in 2023. Additionally, SoCalGas will utilize the results to manage well integrity as outlined in each field's Storage Risk Management Plan.

Co-Funders: PRCI Members, PHMSA, Others

Start Date: 09/30/2021
End Date: 09/30/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,760,777**
Total SCG Cost: **$272,473**
Total Co-Funding: **$1,488,304**
Benefits:

Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends (7.23.f)

This project aims to understand and advance leak-sensing technologies to detect hydrogen (H2) and natural gas (NG) blends as utilities move towards cleaner gas. Ensuring that leaks are detected quickly and efficiently, mitigating the potential harm caused by undetected leaks, and minimizing misinterpreted leak detection results can reinforce safety as the need for new leak detection sensing schemes for H2 and H2/NG blends increases. The project team, consisting of GTI Energy and SENSIT Technologies, will perform the following tasks: 1) evaluate leak detection equipment currently used by NG pipeline operators; 2) guide new and altered usage protocols; 3) validate the H2 blending threshold at which these devices become ineffective; 4) quantitatively map out the impact of varying amounts of H2 on the calibration and analytics of currently used leak detection equipment, and 5) develop a proof-of-concept H2 detection scheme to remedy technology gaps. Upon completion, the project team will deliver new leak detection sensing schemes, ten detailed statistical analyses of laboratory and field testing, an OTD and PHMSA confidential report, a public paper, and a conference presentation. The results from the literature review, leak detection methodology, and sensing specifications could benefit SoCalGas in refining company leak detection policies.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/1/2022
End Date: 12/1/2025
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,562,946**
Total SCG Cost: **$75,171**
Total Co-Funding: **$1,487,775**
Benefits:

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

Aerial Methane Monitoring of High-Pressure Distribution System

This project aims to conduct and perform a comparative analysis between SoCalGas' current mobile leak survey practice and an aerial-based survey (AMM GML) for high-pressure distribution supply lines. Additionally, it will evaluate the potential operational cost savings associated with utilizing an aerial-based survey for these infrastructure segments. Natural gas transmission lines are tightly regulated, and monitoring transmission pipelines more efficiently and effectively to reduce emissions is crucial for meeting regulatory requirements and SoCalGas safety and environmental goals. The team will simultaneously conduct mobile and aerial-based surveys along 10 miles of a high-pressure distribution main in increments of 1-mile segments. Using an aerial-based survey for high-pressure distribution lines can significantly reduce the time required to survey these assets while also reducing the cost of purchasing, maintaining, and operating mobile-based equipment on fleet vehicles and the number of personnel needed to handle them. Aerial-based surveys could eliminate slower manual tasks and minimize or prevent hazardous, adverse conditions around resources. SoCalGas will utilize the study's results to evaluate potential operational cost savings associated with switching to an aerial-based survey for high-pressure distribution supply line infrastructure segments.

Co-Funders: N/A

Start Date: 12/14/2022
End Date: 6/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$5,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$0**
Benefits:

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

The project's goals are to develop, demonstrate, and validate automated pipeline patrol and surveillance technologies on an aircraft platform to enhance the detection of third-party activities, ground movement, and other interference that poses risks to pipeline infrastructure. The project team generated data from multiple sensors deployed on aerial patrolto assess the capabilities and limitations of the airborne sensing systems for automated pipeline patrol. The project team made significant progress in validating the performance of an automated Right-Of-Way (ROW) monitoring and surveillance system, operating on long-range, long-endurance, and Beyond Visual Line of Sight (BVLOS) unmanned aircraft. The team gathered data through remote sensing in near-real time. In 2022, a Computing Environment System was developed to support flood detection at river crossings and other threat sources (fires, logging, etc.). Additionally, it supports a proof of concept for detecting liquid hydrocarbon leaks using changes in vegetative health. The final report for the PHMSA co-funded portion of the project was published. The final flight campaign is scheduled for Q4 of 2022. It will be conducted over a pipeline corridor testing the InstiMaps Gen-4 system in a conventional aircraft and BVLOS in an unmanned aerial aircraft. Once the final flight is completed and the results analyzed, the PRCI Final Report will be prepared and submitted to sponsors for review and approval. The results of this project will provide pipeline operators with performance data and information on the capabilities and limitations of airborne sensing systems for automated pipeline patrol to improve surveillance of pipeline ROW corridors.

Co-Funders: PRCI Members

Start Date: 11/30/2018
End Date: 1/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$377,683**
Total SCG Cost: **$10,982**
Total Co-Funding: **$366,701**
Benefits:

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

Alternate Crack Sensor (M2016-004 Ph IV)

The third leading cause of pipeline failure and several recent high-profile accidents have been attributed to cracks and crack-like flaws, including those from seam welds (SWs). This project's last phase, Phase 4, aims to improve the existing sensor probe system with revisions to the mechanical design, weld detection capability, and Explorer 20/26 Robot integration and operation. In the first three phases, the project team developed a sensor probe system for crack detection in longitudinal seam welds (LSWs) in 20"-26" diameter natural gas pipelines through concept, prototype, and improvement phases. In Phase 1, the team developed a concept to integrate the crack sensor probe with the Explorer robotic inspection platform, which included a SW sensor probe and a crack sensor probe. In Phase 2, the team built a prototype sensor and field-tested it successfully to identify cracks in all SWs except for electric resistance welds (ERWs). In Phase 3, the team improved 1) weld sensor ride and data quality, 2) Data Analysis Tools, and 3) ERW SW detection. Phase 4 will deliver a revised circumferential magnetic flux leakage (MFL) sensing system able to detect LSW anomalies, an alternative sensor probe for improving the detection of low signature LSWs, and operation specifications. In 2022, the team optimized the sensor for reduced weight configuration, modified housing, and increased SW and material detection. Currently, the project team is testing two robot configurations (with and without dual weld sensors) of the early version of the 20" SW sensor in helical travel. If successfully developed, this improvement will benefit the SoCalGas inline inspection program by increasing the tool options available for assessing longitudinal seams.

Co-Funders: NYSEARCH Members

Start Date: 08/09/2021
End Date: 04/28/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$491,324**
Total SCG Cost: **$70,190**
Total Co-Funding: **$421,134**
Benefits:

Cathodic Disbondment Detector - Phase 2 (4.12.c)

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 before 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 identifying the features, 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 finding aligned with the overall test results, which showed that the data aligned particularly in cases with strong signal current on the pipe and good soil conductivity. In other instances, particularly where the signal current on the pipe was weak, the system could not 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 final report has been issued by the sponsors, which includes the results and recommendations for another phase to evaluate aboveground cathodic disbondment detection tools as they are developed.

Co-Funders: OTD Members

Start Date: 03/24/2017
End Date: 02/15/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$261,000**
Total SCG Cost: **$40,031**
Total Co-Funding: **$220,969**
Benefits:

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

The main project objectives were to 1) establish the relationship between new nondestructive examination (NDE) test measurements and established standardized tests for fracture toughness and 2) determine if X-Ray Computed Tomography (XRCT) is a viable alternative to destructive testing for collecting "truth" data from flaw reference samples. This research compared the performance of lab-based and in-the-ditch XRCT technologies on artificial and natural flaws. The project results illustrate that field teams can use XRCT for in-the-ditch-flaw characterization, but results show that it is subject to the same caveats and limitations associated with all XRCT systems. This approach may reduce the need to perform costly pipeline cutouts and minimize the associated shutdowns involved in preparing machined samples for laboratory tests. SoCalGas will add this testing option to its crack management program. The final report is available on the Pipeline Research Council International website.

Co-Funders: PRCI Members

Start Date: 06/16/2020
End Date: 03/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$311,929**
Total SCG Cost: **$8,687**
Total Co-Funding: **$303,242**
Benefits:

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

Database of All Burst Tests for Corrosion, Cracking, Dent, and Interacting Defects (EC-02-11)

The project's objective is to develop and populate a database of burst and fatigue tests from pipes with corrosion, cracking, dent, and interacting defects. Burst and fatigue tests are usually done to validate improvement in defect assessment or modeling. These tests are time-consuming, expensive, and finding the appropriate pipe samples for testing is also challenging. The project plans to develop a uniform format for burst test data collection and support future defect assessment and modeling efforts. In 2022, the project team developed attributes for corrosion, stress corrosion cracking (SCC), and dents and parsed them as metadata and burst test data. Additionally, data gathering, data entry, and personnel training are underway. This project will provide consistent and relevant data for future Pipeline Research Council International (PRCI) research in defect assessment and crack growth modeling. The outcome will be a database of burst and fatigue tests with open access to members that could save sponsors, including SoCalGas, money on future research projects.

Co-Funders: PRCI Members

Start Date: 11/19/2021
End Date: 05/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$147,500**
Total SCG Cost: **$8,780**
Total Co-Funding: **$138,720**
Benefits:

Determine the Impact of Human Factors in the Performance of In-Service NDE (NDE-2-7)

This research was a multi-phase project that assessed the potential impact of human factors (i.e., transfer of knowledge, teaching, and learning) on the performance of in-service non-destructive examination (NDE) for pipeline integrity. Accurate damage assessments cannot occur when the accuracy or variability of the NDE is not well understood, especially when a human operator impacts the NDE performance. Phase 1 evaluated the quality of a training program as a source for human factors on NDE performance. Phases 2 and 3 further investigated the effects of human factors on NDE performance for conducting magnetic particle inspections and ultrasonic thickness testing of pipeline components. The last phase of the project, Phase 4, was to deliver an assessment of the human variabilities in performing NDE and standard procedures to assess NDE operator performance. The NDE-2-7 project was delayed for safety reasons due to COVID-19 restrictions on in-person meetings. After much effort and discussion with Pipeline Research Council International leadership, they canceled the last phase of this project. While much work was done to finalize the project, COVID-19 delays did not allow for consistent data collection and participation in evaluating this project. The final report is available to project sponsors.

Co-Funders: PRCI Members

Start Date: 01/31/2017
End Date: 09/29/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$437,878**
Total SCG Cost: **$25,000**
Total Co-Funding: **$412,878**
Benefits:

Develop Guideline for API 1163 Inspections Qualification for Level 1, 2, and 3 (IM-1-06)

This project objective is to develop guidelines and procedures for utilities to implement the three levels of validation as prescribed in API 1163 for the qualification and validation of tools for In-Line Inspection (ILI) systems. The standard covers the selection, reporting, verification, and three levels of validation associated with in-line inspection (ILI) systems. It outlines the complexity and cost increase with each level of validation. The project's emphasis is to develop guidelines and statistical methods for Levels 1, 2, and 3 analyses and will also develop software for Levels 2 and 3 analyses. The results of this project will aid utilities in determining and selecting the validation level that will optimize integrity management resources and reduce overall risk. Ratepayers will benefit from safer and more cost-effective pipeline operations. SoCalGas sponsored this project so that its Integrity Management Department can improve its guidelines for when Level 1, 2, or 3 validations are applicable. The team has completed the project, and as of Q4 of 2022, they have submitted the final draft report to the technical committee for review. The team expects the review to be complete in Q1 of 2023. SoCalGas will evaluate the results, guidelines, and recommendations to determine if improvements could be implemented in its pipeline integrity management program.

Co-Funders: PRCI Members

Start Date: 03/25/2022
End Date: 03/25/2023
Status: Active
2022 Funds Expended: **$6,313**
Total Project Cost: **$154,108**
Total SCG Cost: **$6,313**
Total Co-Funding: **$147,795**
Benefits:

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

Downhole Inspection Tool Performance Evaluation

The objective of this project is to enhance SoCalGas's (SCG) understanding of new downhole inspection tools used to assess the integrity of gas storage well casing and tubing. Inspection tools will be tested by running them inside fabricated tubing and casing pipe with manufactured anomalies. The measured inspection results will be compared with the known anomaly dimensions to evaluate inspection tool performance and accuracy, i.e., "pull testing." A greater understanding of downhole inspection tool performance will enhance future integrity assessments of gas storage well casing and tubing. In 2022, proof of concept work was completed for a novel high-resolution ultrasonic thickness (UT) inspection tool. The tool was run in four gas storage wells, and its results compared well to established UT and magnetic flux leakage tools. The high-resolution UT tool has been added to the list of tools to be pull-tested. In preparation for upcoming pull testing, tubing and casing were fabricated with manufactured anomalies of known dimensions. In 2023, SCG plans to conduct the pull testing and analyze the results. Through this research, SCG will gain a better understanding of new inspection tool performance and limitations

Co-Funders: N/A

Start Date: 1/08/2022
End Date: 8/31/2023
Status: Active
2022 Funds Expended: **$412,506**
Total Project Cost: **$692,506**
Total SCG Cost: **$692,506**
Total Co-Funding: **$0**
Benefits:

Eclipse Scientific Red/Green Light Tool for NDE of PE Pipe Butt Fusion Joints – Phase 1-a (M2019-010)

Pipefusers can join polyethylene (PE) pipes 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 received a portion of the defected BF joint samples developed under the M2019-009 project and completed all the scans of PE pipe standard and defect pipe to continue the integration of automated defect recognition within NDE pass/fail (green/red) characterization. In 2022, additional samples were shipped to the project team to continue the scan of defective samples building the dataset. Artificial Intelligence will use the library of scanned standard and defect pipe samples and the acceptance criteria to base NDE decisions. These scans provide the basis for automated anomaly identification and interrogation of deciding on a pass/fail during an NDE PE pipe inspection. The project team will provide the final report summarizing the tool's performance at the end of the project. The development of this technology will improve the integrity of BF joints constructed by SoCalGas since any defect in the joint would be identified before placing the pipe into service.

Co-Funders: NYSEARCH Members

Start Date: 01/31/2020
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$153,790**
Total SCG Cost: **$13,670**
Total Co-Funding: **$140,120**
Benefits:

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 applying the EM-TDR technique to inspect transmission natural gas pipelines. The project team will perform an initial feasibility evaluation, numerical modeling, EM-TDR system benchtop prototyping, and performance evaluation before a go/no-go milestone review. If the decision is to move forward, the building of a full-scale engineering prototype will begin, which would include a controlled pipeline degradation experiment, numerical model improvements, a pilot scale field demonstration, and a performance comparison with ultrasonic testing and electromagnetic acoustic transducer systems. The results from the initial feasibility evaluation demonstrated the ability to identify features in steel pipe. Still, they became difficult to detect when the damage was small, especially with background noise. The numerical modeling results conducted by the team showed clear responses of the system in all defects in varying degrees. The team conducted a go/no-go milestone review, and the funders determined that the project should continue with the remaining tasks of this project. SoCalGas benefits from this study because it provides the ability to obtain more information on difficult-to-access portions of pipelines that are currently assessed by External Corrosion Direct Assessment (ECDA). EM-TDR could be used to further evaluate carrier pipe within cased segments and crossings where ECDA techniques are unavailable. SoCalGas could use this tool to supplement and enhance its existing ECDA inspection techniques supporting the pipeline integrity program.

Co-Funders: NYSEARCH Members

Start Date: 05/01/2021
End Date: 05/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$339,000**
Total SCG Cost: **$28,850**
Total Co-Funding: **$310,150**
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 aims to conduct 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 effort will provide power to sensory and related devices in areas where utility power is limited or non-existent and remove the need for replacing batteries. In Phase I, the team initiated a feasibility study to determine if energy harvesting using the energy available in the system's environment could be converted to power and identified four potential technologies: (1) vibration energy, (2) fuel cell energy, (3) thermal energy, and (4) fluid flow energy. In phase II, the team will evaluate the technologies for practicality and commercial availability. In 2022, the project team looked at two energy harvesters, the thermoelectric generator and the electrodynamic turbine generator. Field testing was performed in Q4 2022 using a 20-watt thermoelectric generator to convert heat energy from gas burning into electricity and for the electrodynamic turbine generator. Analysis of the test results is in progress, with the Final Report scheduled for release to sponsors in Q1 2023. Once the team completes the project, SoCalGas will analyze and review the results to determine if they should further study the equipment for operations.

Co-Funders: NYSEARCH Members

Start Date: 12/01/2016
End Date: 1/31/2023
Status: Active
2022 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 Ph II)

This project builds on Phase I, in which the project team performed a feasibility study for extending the wireless communication range of the existing Explorer In-Line inspection robot while deployed in the gas pipeline. The project team will implement the recommendations from Phase I and develop a prototype that can be demonstrated in the gas infrastructure. This project consists of six tasks: 1) Concept Review and Detailed Design, 2) Manufacturing and Assembly, 3) Full System Testing, 4) Investigation of Implementation in Other Robot Sizes, 5) Communication Protocol Enhancements, and 6) the Final Report. In 2022, a feasibility study was completed and reported that a significant communication range extension is possible with combinations of wireless technologies and in-pipe antenna deployment via range extender modules (REM). The update to the mechanical design to fit within a 15-inch diameter, meet weight requirements, and provide a more robust and efficient system, is 80% complete. The electrical design is finished. The next steps will finalize the coding and design of the firmware, graphical user interface, mechanical drawings, procurement of mechanical parts, assembly, and testing. The project deliverable will be a report and a prototype that can be commercialized. SoCalGas will benefit from this project by using the commercialized prototype to increase the efficiency of its pipeline inspection and reduce the overall inspection cost.

Co-Funders: NYSEARCH Members

Start Date: 04/22/2022
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$59,675**
Total Project Cost: **$542,400**
Total SCG Cost: **$59,675**
Total Co-Funding: **$482,725**
Benefits:

Explorer Wireless Range Extender (M2021-006)

The results of a previous project—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, the increased range can lead to loss of wireless communication across large distances. The goal of this project was to extend the wireless communication range of the existing Explorer in-line inspection (ILI) robot while deployed in the pipe. The team identified a target distance of about two miles, roughly four times the current range. The project team completed the development of a concept that included a Wi-Fi module, preliminary mechanical design, and analysis of the electrical and network requirements. Wireless network feasibility studies were performed to determine which approach provided the best performance. The results were compiled into a report that includes recommendations for the next phase of work. SoCalGas can benefit from this technology because data can be captured and stored without a wait or delay, contributing to increased efficiency and reduced cost of pipeline inspections.

Co-Funders: NYSEARCH Members

Start Date: 08/09/2021
End Date: 03/22/2022
Status: Completed
2022 Funds Expended: **$0**
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 objective of this project is to perform a feasibility study on the scalability of the Explorer 20/26 Energy Harvesting (EH) system, equipped to function within 20" and 26" diameter pipe, to other platforms and specifically to determine the performance envelope for the Explorer 10/14, 16/18, and 30/36, within 10" and 14", 16" and 18", and 30" and 36" diameter pipe, respectively. This project consists of five tasks: 1) the team will perform an analysis on the robot to determine its power consumption under various operational conditions and the energy and tow force that can be generated for the robot within different pipe sizes; 2) the team will investigate the mechanical design of the EH system and its impact on the overall weight of the robot; 3) & 4) the team will evaluate the amount of power and energy generated for different pipe sizes under different operating conditions, and they will modify the EH system's electronics, if necessary; and 5) will explore the potential impacts of the EH technology in its commercial deployment across various Explorer robot platforms. The team will deliver a report outlining the tasks conducted during the feasibility study, including 1) the key parameters for an EH system for different pipe sizes of the Explorer fleet; 2) remedying technical obstacles that EH systems need to overcome to be successfully developed in future phases, and 3) recommendations on the next steps. The project kicked off in May 2022 but is currently on hold until 2023 due to resource constraints. This project, if successful, will expand the inspection capabilities of the Explorer robotic tools and allow the SoCalGas in-line inspection (ILI) program to collect more data and conduct longer inspections.

Co-Funders: NYSEARCH Members

Start Date: 11/15/2021
End Date: 08/31/2023
Status: Active
2022 Funds Expended: **$0**
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 objective of this project is to do a feasibility study on integrating a high-resolution magnetic flux leakage (MFL) sensor onto the Explorer robot platform, assess multiple commercially available sensors, and optimize the resulting system for maximum efficiency and interchangeability among the various robots. This project has four tasks: 1) determine the best sensor for the application while considering potential solutions to implementation issues (i.e., sensor control, data transfer); 2) identify various concepts for sensor positioning and design schemes, and select the best one; 3) build a benchtop prototype system based on the design selected in Task 2 to validate optimal integration into the magnetic bars and performance (data collection and transfer, sensor resolution, defect sizing resolution, etc.); and 4) summarize the results with a recommendation for implementing the new sensors on the MFL module. The project was kicked off in early 2022, but due to resource constraints, the tasks will begin in early 2023. The next step will be to complete a feasibility study and then build and test the proof-of-concept prototype. The team will deliver a benchtop prototype system along with a feasibility analysis report and recommendations on the next steps. Improving the sensor capabilities of the Explorer family of robotic platforms will be of benefit to the SoCalGas In-line Inspection program because the smaller sensors will allow for higher spatial and circumferential resolution and detectability of smaller defects with higher resolution, therefore, allowing higher confidence levels in the measurements made.

Co-Funders: NYSEARCH Members

Start Date: 11/15/2021
End Date: 12/29/2023
Status: Active
2022 Funds Expended: **$0**
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 and associated causal factors. The distributions will be based on actual data from successive ILI runs provided by Pipeline Research Council International members. The project will develop a probabilistic model for estimating external corrosion growth (ECG) rates via successive ILI runs. The team will analyze in-the-ditch inspection data to determine statistical corrosion depth distributions. They will also perform a literature review for various ECG rate estimation strategies, which will help them decide if any existing models can be utilized. In 2022, the project team collected ILI data from sponsors to refine the Bayesian Network variables. The project team continues to implement key parameters in updating the Multi-Analytic Risk Management (MARVTM) tool, a Bayesian Network approach for statistically quantifying risk and corrosion growth. The software is already developed, but the team will refine it during this project based on recent industry work and input from industry subject matter experts. Local distribution companies will continue to develop and refine the ECG rate probability curves. A better understanding of ECG rates along the pipeline could result in more accurate reassessment intervals, allowing member companies to optimize ILIs for metal loss. SoCalGas will utilize the research study's applicability in increasing the accuracy of ECG rate calculations to determine the remaining life of the pipeline. After evaluation, SoCalGas could benefit from this research by potentially integrating the deliverables into the company-specific Transmission Integrity Management Program.

Co-Funders: PRCI Members

Start Date: 06/23/2021
End Date: 04/07/2023
Status: Active
2022 Funds Expended: **$0**
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 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 to make sure that pipeline infrastructure is safe, reliable, and efficient. The project objective was 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 inline inspection (ILI) dent and interacting feature size variation, and 3) defining dent fatigue life assessment safety factors. The project team evaluated the impact of ILI dent and interacting feature size variations, fatigue life safety factor calculation for dents interacting with metal loss, and sample calculations for restraint parameter dent fatigue life analysis. SoCalGas is using the research to support industry-wide efforts to update the regulations regarding the management of mechanical damage. The current regulations are overly conservative, and it is the expectation that this PHMSA project, as well as MD-5-1, will result in regulations that are based on research and engineering analysis of real-life properties of cracks and dents. The final report is available on the Pipeline Research Council International website.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 08/29/2022
Status: Completed
2022 Funds Expended: **$0**
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)

The goal of this project is to understand the probability of detection by state-of-the-art In-Line Inspection (ILI) tools for internal anomalies in steel pipes. It is important to understand the likelihood of identifying abnormalities in the steel pipe as it 1) can minimize the number of missed defects without increasing the number of false indications, 2) optimize the number of excavations needed for operation pipeline safety, and 3) allow for more efficient utilization of resources. Research outcomes will improve ILI sizing accuracy of cracking, crack-like anomalies, and corrosion anomalies and allow ILI technology developers to improve and adjust sizing algorithms for these anomalies. In addition, developers can re-run tools on test strings with modified sensors, sensor configurations, and sizing algorithms. In December 2021, the ILI Technology Providers completed the delivery of the ILI reports for the initial (blind) test. In 2022, they were asked to detect and characterize a blind set of metal loss anomalies and evaluate detection, identification, and sizing capabilities for each defect type. The ILI performance evaluation and data verifications are in progress, and providers are currently comparing truth data to ILI results. PHMSA has granted a time extension for the project due to extended vendor timeframes for data processing and improvement analysis, and reporting with potential retesting. SoCalGas can use this research to improve ILI vendors' sizing accuracy, which will benefit in targeted excavations toward potentially immediate conditions.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$2,251,100**
Total SCG Cost: **$5,000**
Total Co-Funding: **$2,246,100**
Benefits:

INGAA - Geohazard Management JIP

The objective of this project is to provide a high-level, concise framework for pipeline operators to utilize in managing geohazards considering no best practices or recommended procedures for geohazard data management currently exist. This set of documents will include a detailed recommended practice (RP) and a guide for implementing and executing a geohazard land movement management program. A secondary goal is to support potential rulemaking by the Pipeline and Hazardous Materials Safety Administration (PHMSA) related to geohazard management. The project team will produce a published RP by the American Petroleum Institute (API). The team has reviewed various PHSMA and European data sets addressing gas and liquid incidents caused by Weather-Related Outside Forces and interviewed sponsors about their geohazard integrity management programs. Additionally, the project team is working on a high-level framework paper for geohazard management with an expected completion date in January 2023. A second paper will provide an RP for landslide integrity management, with expected completion in March 2023, and will likely be added to API RP 1187. The team reviewed both draft papers with comments in November 2022. Upon completion, the aforementioned documents could aid SoCalGas with its geohazard management framework and landslide threat evaluations.

Co-Funders: JIP Members

Start Date: 07/18/2022
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$37,996**
Total Project Cost: **$567,996**
Total SCG Cost: **$42,996**
Total Co-Funding: **$525,000**
Benefits:

Innovative Leak Detection Methods for Gas Pipelines (MEAS-2-01)

The objective of this project is to develop 1) improved algorithms to estimate pipeline inventories lacking full pipeline transient modeling applications, 2) a new algorithm for enhanced zone balancing calculations, 3) pattern identification methods that identify how corrected zone balances shift due to changes in system flow, which the project team will use to identify meters that are most likely attributing to measurement flow errors, and 4) recommended practices to troubleshoot facilities with high error probabilities. Computational pipeline monitoring (CPM) systems have technology gaps. For example, 1) balancing zones are minimal in number and encompass too large areas, 2) retrofitted inline flow measurement systems are difficult to install, 3) challenges faced with changes in gas pipeline systems inventory or distinguishing measurement errors from leaks, and 4) unavailable, infrequent, or asynchronous data. Addressing these gaps will enhance CPM leak detection methods by detecting and locating leaks more accurately and quickly. The project team will test the developed algorithms and methods on simulated systems and then validate them on a gas pipeline system. This research could reduce 1) lost, and unaccounted-for volumes of gas, 2) impacts on safety, and 3) impacts on the environment. The results will be presented in a final report and at a public forum. The developed algorithms and methods could be used in SoCalGas measurement accounting systems if successful and compatible.

Co-Funders: PHMSA, PRCI Members

Start Date: 9/29/2022
End Date: 9/28/2025
Status: Active
2022 Funds Expended: **$4,849**
Total Project Cost: **$547,226**
Total SCG Cost: **$13,393**
Total Co-Funding: **$533,833**
Benefits:

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

Internal Corrosion Management

The objective of this project is to review existing processes and data associated with "potentially corrosive constituents" as identified in 49 C.F.R. § 192.478 to evaluate whether changes should be implemented to comply with recent federal regulations. Potentially corrosive constituents include, but are not limited to: carbon dioxide, hydrogen sulfide, sulfur, microbes, and liquid water. In task 1, the project team will review SoCalGas procedures. In task 2, the project team will create a flow diagram for the data currently being collected. The project deliverables will include a report identifying next steps, such as preparing a white paper documenting the known limits for constituents or additional research which needs to be performed.

Co-Funders: N/A

Start Date: 11/17/2022
End Date: 5/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$76,800**
Total SCG Cost: **$76,800**
Total Co-Funding: **$0**
Benefits:

Low Flow EMAT ILI Tool Demonstration (qi II)

The goal of this project is to demonstrate the capabilities of the 12" and 16" free-swimming Electromagnetic Acoustic Transducer (EMAT) tool with a field demonstration inspecting SoCalGas transmission pipelines. Many In-line-Inspection (ILI) technologies use a Magnetic Flux Leakage (MFL) detection method to measure wall loss on metallic pipelines due to internal and external corrosion. Under previous research projects, an EMAT sensor and robotic platform for small-diameter unpiggable pipelines capable of identifying smaller defects than traditional MFL tools were developed for commercialization. Building upon this research, a free-swimming version of the tool has been created. Free-swimming tools are of interest to subject matter experts such that the tools are propelled by the flow of internal pipeline pressures. The demonstration was moved to 2023 to allow Integrity Management to complete a feasibility review of the pipelines. If the demonstration is successful, SoCalGas will have an alternative for performing pipeline inspections on unpiggable pipelines with traditional tools.

Co-Funders: N/A

Start Date: 11/26/2021
End Date: 12/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$0**
Benefits:

MEC Pig ILI Tool Design Study for Multiple Pipe Diameters (NDE-4-21)

The objective of this project was to explore the feasibility of leveraging a Magnetic Eddy Current (MEC)-Pig developed for 8-inch-diameter pipelines with those of other diameters. The MEC-Pig developed for in-line inspection (ILI) has successfully detected small volumetric defects, spots that were hard to inspect, cracks in stainless steel, duplex materials, thick wall small-diameters gas lines, and plastic and concrete-lined pipes. This project studied applying MEC technology in a modular concept to cover a range of pipe diameters: 8-10", 12-16", 18-24", and over 24". The goal was to decrease the number of Pigs needed for utilities with multiple-diameter transmission lines, reducing inspection costs. Since MEC technology can inspect pipes with linings or coatings, the technology has the potential for future application in pipelines converted for hydrogen or emerging fuels that use coatings to prevent corrosion or cracks. If successful, the project had the potential to decrease inspection costs, improve pipeline integrity, and meet future inspection needs. The project faced delays from contractual issues as well as technical challenges. The team could not resolve those issues, so the Pipeline Research Council International and its sponsors decided to cancel the project returning the funds to the sponsors.

Co-Funders: PRCI Members

Start Date: 11/2/2021
End Date: 5/2/2022
Status: Canceled
2022 Funds Expended: **$0**
Total Project Cost: **$95,969**
Total SCG Cost: **$0**
Total Co-Funding: **$0**
Benefits:

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

Microbial Influence Corrosion (MIC) Detection (GFO-21-506, Group 2)

The project objective is to develop and pilot a self-contained portable microbial detection kit that will allow fast detection and identification of various corrosion-related microbes from raw samples with minimal hands-on time. Microbial testing is an essential component in detecting, controlling, and mitigating microbiologically influenced corrosion (MIC) in natural gas systems. Current testing approaches are hampered by long wait times, the inability of rapid tests to identify specific corrosion-related microorganisms, and complex sample preparation and testing processes that require laboratory equipment or highly specialized personnel. The team has scheduled the project to begin in February 2023, with field pilot demonstrations performed under various environmental conditions after that. The project deliverables include Test Kit Documentation and a Field-Testing Guide, which will build the foundation for developing new approaches for detecting, monitoring, predicting, and controlling microbial corrosion in California's natural gas pipeline systems. The primary benefit will be the timely detection of specific corrosion-related microbes in pipelines and storage tanks which will provide a basis for developing targeted strategies for the control of microbial corrosion and reduce the use of expensive and environmentally toxic broad-spectrum biocides. SoCalGas intends to use the research and development of the portable microbial detection kit as it will potentially provide a more accessible and lower-cost method to detect and identify the presence of microbiologically influenced corrosion (MIC) in natural gas systems.

Co-Funders: CEC, Others

Start Date: 10/25/2022
End Date: 09/30/2026
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,493,920**
Total SCG Cost: **$50,000**
Total Co-Funding: **$1,443,920**
Benefits:

Modeling and Assessing PE Assets with 3D Scanning Technology

The objective of this project was to evaluate different use cases for 3D scanning technology, specifically to model Polyethylene (PE) fittings and PE failures to support the failure analysis process. SoCalGas identified potential use cases to model 1) components where manufacturer drawings are not readily available, 2) pipe or fittings in situ, and 3) failures as an alternative to destructive testing. The project team completed a laboratory and field pilot identifying both limitations and benefits of the 3D scanner system and the post-processing analysis and creating a measurement protocol to compare data from the 3D scanner with traditional measurement tool data. The main limitation of this technology is the clearance needed for the sensors to capture surface attributes. In 2022, the team performed in-situ modeling of failed plastic components before asset removal, successfully capturing deviations from the axis on fused plastic components. In addition, the team performed bend strain analysis on the plastic assets before/after removal from belowground. The resulting heat map indicates that below-ground plastic assets experience stress/strain that may lead to plastic fusion failures. The outcome of this research demonstrated the deviation from the axis of belowground failed plastic components. This research has the potential to support specific PE failure measurements and analysis of in-situ modeling of failed plastic components. SoCalGas will use this research to add to the Failure Analysis Process for Gas Systems process.

Co-Funders: N/A

Start Date: 10/30/2020
End Date: 10/31/2022
Status: Completed
2022 Funds Expended: **$13,847**
Total Project Cost: **$29,445**
Total SCG Cost: **$29,445**
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 and risk assessment tools used for managing the integrity of pipeline crossings over waterways. The project tasks include field verification of scour and erosion prediction from hydrology hydraulics and fluvial geomorphology; field validation of Vortex-Induced Vibration (VIV) initiation within waterways to determine pipeline limitations and VIV avoidance criteria. The goal is to allow operators to identify crossings that require operational (e.g., monitoring) or engineering (e.g., mitigation) controls to lower the probability of flooding hazards that can lead to containment loss. The project team will build and test a prototype website-based alert dashboard. The dashboard could also be a screening tool to plan new waterway crossings. The results of this project can supplement the guidance provided in API RP 1133, Managing Hydrotechnical Hazards for Pipelines Located Onshore or Within Coastal Zone Areas. To date, the project team has delivered nine of nine final reports to PRCI members. Eight are available on the Pipeline Research Council international website. The team anticipates completing the final project report in early 2023. SoCalGas will use this information as a knowledge base for evaluating and maintaining pipeline water crossings.

Co-Funders: PRCI Members, PHMSA

Start Date: 01/01/2019
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$0**
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 a straying electrical current takes a pathway directly to the ground. This situation increases the 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 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 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. This project encountered contracting and resource issues, so it has been canceled. Since the need still exists, the project will be rescoped and revisited.

Co-Funders: N/A

Start Date: 12/14/2021
End Date: 9/30/2022
Status: Canceled
2022 Funds Expended: **$0**
Total Project Cost: **$96,759**
Total SCG Cost: **$0**
Total Co-Funding: **$0**
Benefits:

NDE Tool for Electrofusion Fittings (M2022-004)

Inspecting Polyethylene (PE) Electrofusion (EF) fitting joints is an important quality control check, confirming that the fusion between the pipe and EF fitting has properly formed, ensuring its long-term performance. Currently, inspection is limited to visual observation of the final exterior joint surface due to the EF joint's internal configuration. Without direct observation of each step in preparing the PE pipe and EF fitting, there is no opportunity to assess a final EF joint internal configuration after the fusion between the PE pipe and fitting is complete. However, there are non-destructive evaluation (NDE) methods available to look beyond the outer surfaces of EF PE pipe fusions. This approach provides high granularity inspection capabilities of the joined material between the PE pipe and fitting. These NDE techniques require highly trained and experienced NDE personnel to perform the testing and interpreting of the results. A method of NDE inspection is desired to enable a non-NDE expert to look within the EF joint internally to observe the general configuration, confirming an acceptable fusion has been obtained. The scope of this project is to develop an NDE technique for visual examination of the internals of a PE pipe EF fitting using a digital x-ray. This research will include 1) an NDE digital x-ray and quality control interpretation method, 2) an application for personnel who are non-experts in NDE methods to perform field procedures, and 3) training guidelines for setting up and performing NDE in a safe, effective, and efficient manner. SoCalGas can use this X-ray system in the field to assess PE EF joint quality before installing fused piping in the ground, which would contribute to pipeline safety and integrity.

Co-Funders: NYSEARCH Members

Start Date: 8/30/2022
End Date: 6/30/2023
Status: Active
2022 Funds Expended: **$16,925**
Total Project Cost: **$156,575**
Total SCG Cost: **$16,925**
Total Co-Funding: **$139,650**
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)

Technology advancements may be useful in assessing the quality of questionable butt fusion (BF) joints and may prevent unnecessary cut-outs of good BF joints with the appearance 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 (NDE) of PE gas pipeline BF joints. Phase II evaluates the THz capability on BF joint samples with inclusions at the acceptance criteria threshold. The team has performed extensive NDE inspections of specific PE joint defects containing a lack of fusion. The birefringent application to the THz NDE process has advanced with improved inspection procedures and analytical signal processing. In 2022, the project team worked on improving signal resolution using the THz inspection process during scan interpretation to identify potential defects, including "cold" or lack of fusion within the BF. The project team will provide a final report, including the results of technical assessments of THz NDE potential for plastic pipes, at the end of the project.

Co-Funders: NYSEARCH Members

Start Date: 07/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$10,035**
Total Project Cost: **$693,547**
Total SCG Cost: **$59,615**
Total Co-Funding: **$633,932**
Benefits:

Numerical Modeling and Full-Scale Testing to Evaluate the Performance of Large Standoff Magnetometry (NDE-3-5)

This project builds upon the research performed in NDE-3-4. The challenge with the current state-of-the-art Large Standoff Magnetometry (LSM) technology is the lack of validation data and fundamental analysis to support its use. The research program evaluated the performance of LSM for pipeline integrity inspections using a test rig that introduced various loading combinations into a pipe sample and could simulate a variety of factors, including internal pressure, axial tension/compression, and bending to simulate what might be encountered in a geohazard condition. In addition to the full-scale testing, this project integrated numerical modeling, laboratory testing, and a literature review of magnetic sensor technologies and commercially available products. SoCalGas envisions this tool as a nondestructive evaluation technique to supplement the traditional approach to establish baseline profiles for pipelines in areas of potential land movement. The final report is available on the Pipeline Research Council International website.

Co-Funders: PRCI Members

Start Date: 06/12/2019
End Date: 03/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$430,405**
Total SCG Cost: **$23,806**
Total Co-Funding: **$406,599**
Benefits:

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. The goal of this project was to develop improved methods for satellite-based tools and technologies to enhance the detection of natural changes, seasonal flooding, erosional effects, channel dynamics, and ground movement affecting pipelines installed near river 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. Satellite imagery, particularly Synthetic Aperture Radar (SAR) and high-resolution optics, have several characteristics that make them meaningful additions to pipeline ROW monitoring programs. The team identified three leading classes of satellites to support pipeline integrity programs, enhance operators' risk mitigation programs through more frequent high-resolution detection of risk factors and ROW surveillance. The team completed the project in 2022 by validating field data against high-resolution optical data at four locations. SAR amplitude was used to detect and classify large-scale and cover/land use change. This project provided a further understanding of the current capabilities and limitations of combined SAR and high-resolution optical satellite imagery for monitoring pipeline ROWs that span river crossings. The complementary information provided by SAR and optical satellite sensors makes them a valuable qualitative addition to existing pipeline monitoring programs with other technologies.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 12/08/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$330,814**
Total SCG Cost: **$10,267**
Total Co-Funding: **$320,547**
Benefits:

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

Pipeline Cleaning Tool for Liquids with Flow (M2017-006 Ph II)

InvoDane will develop and test expanding the capability of the 20/26 Explorer robot, which is capable of inspecting "difficult-to-inspect" pipes while remaining in service, to drive and scan through an accumulated liquid in the natural gas pipelines. When inspection teams find liquids in the pipeline, inspections must stop until they remove the liquids before proceeding with the examination. With regulatory-driven due dates, delays in completing assessments can result in non-compliance. This research, if successful, will allow inspection teams to continue without the need to halt for liquid removal. Pre-commercialized liquid-capable drive tracks and magnet bars will be designed and tested for retrofit onto an Explorer 20/26 robot and included on future-generation robots. In 2022, the project team had the components manufactured, and they completed testing on the magnet bar and drive tracks. The liquid-capable testing of the modules is underway. In early 2023, the project team will perform the final tests to verify the validity of the design. After this project, InvoDane plans to build several sets of liquid-capable drive tracks and magnet bars to incorporate into other robots. SoCalGas could potentially use this new Explorer robot for inspections where there is a risk of liquids in the pipeline improving data quality and inspection performance.

Co-Funders: NYSEARCH Members

Start Date: 05/06/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$339,000**
Total SCG Cost: **$79,765**
Total Co-Funding: **$259,235**
Benefits:

Remaining Life Model and Assessment Tool for Dents and Gouges (MD-4-16)

The objective of this project was 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 was the ability to manage the threat of dents and gouges in pipelines in a prioritized manner. This approach reduced the overall cost and bridged a gap in the ability to quantitatively assess fatigue life at dents and gouges in pipelines. A time-delayed failure occurs when a crack grows due to pressure cycling and eventually fails by fatigue, resulting in a surface crack in a dent. Based on available Stress Intensity Factor (SIF or K) solutions for surface cracks in a pipe and finite element analysis (FEA) results, the team developed an engineering approach and pragmatic fatigue model for predicting fatigue lives of pipelines containing dents and gouges. An equivalent stress method was developed for estimating the K solutions for a crack in a dent. The proposed fatigue model was evaluated and validated with Pipeline Research Council International (PRCI) full-scale fatigue test data for line pipes containing dents and gouges. The final report is available on the PRCI website. 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: 10/31/2022
Status: Completed
2022 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 periodically monitor the cathodic protection (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. The project objective was to 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 project team planned to set up the network and measuring device at GTI Energy or a member utility facility for testing. A final report intended to provide procedures for integrating a remote CP monitoring system with an AMI/or LoRaWan network would have been the deliverable. This project experienced delays due to bids from project contractor(s) coming in at a significantly higher cost than the original proposals. Project sponsors discussed the options of rescoping or canceling the project and decided on cancellation. There is still high interest amongst utility members, so a new re-scoped project proposal is being developed in the future. SoCalGas will re-evaluate the new proposal once it becomes available and assess to see if it meets SoCalGas's needs.

Co-Funders: OTD Members

Start Date: 1/31/2021
End Date: 4/29/2022
Status: Canceled
2022 Funds Expended: **$0**
Total Project Cost: **$157,000**
Total SCG Cost: **$0**
Total Co-Funding: **$0**
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 bond-line 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. However, these MFL tools generally cannot differentiate between SSWC and coincidental corrosion. As technologies and analysis processes have improved, ILI vendors are now 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 2022, the vendor completed acid etching to create test samples with SSWC and corrosion. They delivered documentation that addresses raised edges of electrical discharge machined (EDM) notches and adjacent corrosion. SoCalGas can use this research's results and identified tools to detect SSWC in its pipelines better, thereby improving safety and reliability.

Co-Funders: PRCI Members

Start Date: 10/06/2020
End Date: 9/1/2023
Status: Active
2022 Funds Expended: **$14,159**
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)

This project aimed to produce a polyethylene (PE) pipe butt-fusion (BF) joint sample library of joints with known defects. The gas industry will use the sample library to validate current and future non-destructive evaluation (NDE) technologies claiming to be capable of detecting PE butt fusion defects. NYSEARCH members have invested considerable resources into NDE development through extensive testing with The Welding Institute. The sample library provides resources to validate any NDE tool purported to be capable of identifying defects that would impact the integrity of BF joints. In 2022, the team continued fabricating PE joint defect samples and shipping the defective samples to NYSEARCH for distribution to various projects where different NDE technologies are being developed and validated. The project team constructed a total of 41 butt-fusion joints with high-density and medium-density PE pipe of two and eight-inch diameters. The team made samples to represent the range of fusion joint qualities that might be encountered, including: no imperfections, fine particulate contamination, coarse particulate contamination, grease contamination, cold fusions, and planar lack-of-fusion flaws. The team performed mechanical tests, computed tomography (CT), and phased array ultrasonic testing on identical joints to make sure the joints performed as expected per appropriate industry standards. This project concluded when all samples were constructed and received by NYSEARCH. SoCalGas is benefiting from this library of defective PE butt-fusion joints since the defective pieces are being used to evaluate NDE technologies in other projects that SoCalGas is sponsoring.

Co-Funders: NYSEARCH Members

Start Date: 10/10/2019
End Date: 02/28/2022
Status: Completed
2022 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

Subsidence Study

This project will perform analytical modeling to estimate levels of relative displacement between a transmission pipeline and five tap locations, validating the results of earlier studies. Buried natural gas pipelines can be damaged by soil displacement resulting from sudden extreme events, such as floods, landslides, earthquake fault rupture, and gradual ground deformations caused by land subsidence. Causes of vertical or horizontal land subsidence include extraction of water, oil, or gas; sinkholes; mining activities; and natural consolidation. A previous study evaluated the potential hazard to natural gas transmission pipelines from subsidence resulting from water withdrawal in the San Joaquin Valley. The results supported the conclusion that long-term subsidence from water withdrawal does not pose a significant threat to steel gas transmission pipelines at general locations. However, the study concluded that relative axial displacements at some tap locations could be a concern in the future. The study recommended that efforts be taken to discern if there are signs of relative displacement or distress at tap points identified as having the largest relative axial displacements. The project tasks include modeling a section of transmission pipe and five tap locations and analyzing various scenarios affecting tensile and compressive strain as a function of axial displacement. The team will perform the analyses using simulation software with typical pipe elements and non-linear springs to represent soil restraint. This study could help to pre-emptively manage the subject tap locations and significantly reduce the need for costly mitigative measures to repair or replace damaged pipeline sections due to subsidence displacements.

Co-funders: N/A

Start Date: 11/25/2022
End Date: 1/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$18,850**
Total SCG Cost: **$18,850**
Total Co-Funding: **$0**
Benefits:

Technology Development Center (TDC-1-1 & 1-A)

This project supports 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 key issues they face to enhance 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 pipeline safety and integrity goals. The TDC enables efficient and timely access to industry samples in support of technology projects and programs. The TDC continues to be utilized by PRCI projects, for example, NDE-4-18 Validate ILI Capabilities to Detect and Characterize Mechanical Damage. In 2022, an Open House showcased the value and capabilities of the TDC. This event highlighted how PRCI members advance safety and integrity within the industry through the TDC.

Co-Funders: PRCI Members

Start Date: 01/01/2015
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$7,358**
Total Project Cost: **$3,440,727**
Total SCG Cost: **$42,709**
Total Co-Funding: **$3,398,018**
Benefits:

Tools and Methods to Assess Pipe Materials from Inside the Pipeline (NDE-4-23)

The objective of this project is to perform a State-of-the-Art literature review of existing in-line inspection (ILI) and in-ditch tools to identify techniques with the potential to inspect the mechanical properties of steel pipe without the need for excavation. Technology companies have made a significant effort to develop in-ditch tools to measure mechanical properties. However, these technologies are used on the external surface of the pipeline and require exposure. An in-line tool option that characterizes mechanical properties, including fracture behavior and metallurgical properties, would be invaluable in confirming maximum allowable operating pressure (MAOP) and allow operators to approve these pipelines for hydrogen transport. This project will: 1) identify technologies that exist in the public domain from a variety of sources, including: ILI service providers, sensor, and surface hardness technology companies; 2) assess the status of each of the technologies from various sources and potential for application onto in-line tools; 3) evaluate and analyze the findings; 4) discuss technologies that exhibit potential; and 5) develop a comprehensive report summarizing the findings. SoCalGas could benefit from this project because obtaining precise information regarding pipe material properties is essential for MAOP verification and understanding the impacts of hydrogen blending on the transmission pipeline system. Additionally, this project could provide an option to gather information on pipeline materials at a lower cost due to excavation not being required, which will support SoCalGas in meeting pipeline regulations for integrity management.

Co-Funders: PRCI Members

Start Date: 07/28/2022
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$15,265**
Total Project Cost: **$59,000**
Total SCG Cost: **$15,265**
Total Co-Funding: **$43,735**
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. The project will generate data to support the Pipeline Research Council International's (PRCI) research and development projects pursuing the development of revised dent response criteria. 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. In 2022, four vendors performed trial runs with their tools through mechanical damage test strings built at PRCI's Technology Development Center. The systems employed mechanical calipers and ultrasonic technologies for dent geometry. Ultrasonics were also used for metal loss and crack identification and sizing. The team used Magnetic flux leakage technology for metal loss. All vendors performed trials at multiple speeds, and they duplicated some of the speeds to collect various data sets, which they used to show repeatability and consistency, as well as provide backup data. The post-processing analysis is still pending, so PHMSA approved a project extension into mid-2023. The next steps are to finalize the data analysis and potentially perform more pull tests. SoCalGas can benefit from this research if the project results in revised dent response criteria based on engineering knowledge of the pipe conditions. It can then target excavation to pipe segments that meet the revised response criteria.

Co-Funders: PRCI Members, PHMSA, Others

Start Date: 09/30/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$1,524**
Total Project Cost: **$3,012,542**
Total SCG Cost: **$25,722**
Total Co-Funding: **$2,986,820**
Benefits:

Validation of NDT Technology for PE Pipe (5.20.p)

In this project, the team is evaluating 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, service tees, etc.) pipe joining methods. Industry stakeholders need to understand the capabilities and limitations of the various NDT technologies to determine whether the technologies are reliable for determining joint integrity. Previously, the team gathered information on sponsors' current use of NDT technologies on PE fusion joints with a survey. The project team held a workshop with stakeholders to review the capabilities of existing NDE technologies and to develop a roadmap for the next steps in evaluating them. Following the roadmap developed by stakeholders in the workshop, the types of test samples were chosen. Several NDT technology vendors have shown interest in participating in this study. Based on recent project team communications with vendors and the methods they use, however, it was determined that appropriate acceptance criteria for test samples should first be developed. In 2022, the project team worked on revising the project scope to include developing acceptance criteria, upgrading the control software on the butt-fusion machine that is used for the project, and preparing butt-fusion samples for testing. Once the project is completed, the team will deliver a final report detailing the NDT technologies identified, the validation test results, and supporting documentation for each pipe joining method, NDT technology, and NDT vendors. Additionally, the team will identify potential technology enhancements that would make the NDT technology for PE pipe more reliable.

Co-Funders: OTD Members

Start Date: 10/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$17,054**
Total Co-Funding: **$182,946**
Benefits:

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

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 (CT) are complementary to terahertz (THz) methods in different aspects of PE pipe inspections. The objective of Phase II was to advance Iowa State University THz and X-ray non-destructive evaluation (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 was performed, and defective BF samples were developed under the research project Standard Library of PE Joint Samples with Embedded Defects for NDE Tool Validation - Phase I-a (M2019-009) to be used for scanning, evaluating, and further developing the 2D and 3D scan data interpretation for each defect type. In 2022, the project team continued working on the tasks planned for the project. However, due to a similar effort in another project (M2018-009 PhII), the team decided to close out this project. The team provided a final report documenting the research findings.

Co-Funders: NYSEARCH Members

Start Date: 01/20/2021
End Date: 12/30/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$407,019**
Total SCG Cost: **$45,400**
Total Co-Funding: **$361,619**
Benefits:

CLEAN TRANSPORTATION

SUBPROGRAM: 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

Start Date: 08/31/2021
End Date: 2/10/2023
Status: Active
2022 Funds Expended: **$25,000**
Total Project Cost: **$409,500**
Total SCG Cost: **$409,500**
Total Co-Funding: **$0**
Benefits:

This project aimed to develop the 2040 vision for zero-emission ground and air vehicles operating at and near Ontario International Airport ("the ecosystem"). This case study defined three future scenarios for technology adoptions ("Baseline," "Balanced," and "High Hydrogen"). For each of these scenarios in the ecosystem, the researchers then 1) reviewed vehicle use cases, duty cycles, energy demand, and fuel consumption, 2) derived hydrogen infrastructure needs and costs, and 3) calculated relative emissions (CO_2 and NOx). The study included input from a technical advisory committee composed of industry experts, utilities, city and community leaders, and local, state, and federal agencies. The study produced several key insights. First, 92% of the ecosystem's total energy demand comes from aircraft. However, ground support equipment (GSE) accounts for 82% of energy use, excluding aircraft and passenger vehicles. Decarbonizing just the top 3 most utilized GSEs could result in a 52% decrease in CO_2 and an 89% decrease in NOx. Transitioning commuter aircraft to zero emissions could decrease total air emissions by 22%. Transitioning medium-haul aircraft would reduce the total by an additional 62%. Finally, under the High Hydrogen scenario, the ecosystem would require over 580 kilotons of hydrogen annually in 2040, roughly equal to 6% of the total U.S. hydrogen consumption in 2020. However, this scale would reduce levelized production costs to $2.29/kg (liquid) and $2.65/kg (gaseous). The project team produced a final report summarizing the findings in 2022. The team is scheduled to present the results at the FCHEA Hydrogen and Fuel Cell Seminar in 2023.

Co-Funders: N/A

CALSTART Hydrogen Zero Emission Tugboat Design

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$100,000**
Total Project Cost: **$623,309**
Total SCG Cost: **$100,000**
Total Co-Funding: **$523,309**
Benefits:

CALSTART has assembled a consortium of leading maritime stakeholders to design a hydrogen fuel-cell-powered zero-emission tugboat and support 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 Management District. This project was awarded CEC grant funding through 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 currently 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 emission reduction goals. To achieve the project objectives, the team will develop a design for a fuel cell-powered tugboat that they will use to inform future production and deployment. The team will also assess the economic feasibility, conduct a cost-benefit analysis, identify technology and regulatory barriers to using hydrogen in the maritime industry, and develop plans for the necessary refueling infrastructure – including hydrogen production and delivery pathways. The team completed the tugboat design, safety requirements, and economic feasibility analysis in 2022.

Co-Funders: CALSTART, CEC

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

GTI Energy Doosan Hydrogen Drone Demonstration

The project's goal was to advance hydrogen use in aviation by demonstrating Doosan Mobility Innovation's (DMI) hydrogen fuel cell drones for various applications. Hydrogen drones offer significant benefits compared to their battery-electric counterparts. DMI's hydrogen fuel cell drones have longer flight times (2 hours) and drastically reduced refueling. Throughout the project, GTI Energy worked with DMI to showcase the technology at various conferences, including ACT Expo and CES. The drone was also demonstrated at two SoCalGas facilities and in Austin, Texas, as part of H2@Scale. These demonstrations highlighted the drone's extended flight time, efficient fuel tank swapping procedure, package delivery, and ability to conduct various infrastructure inspections. In addition to the demonstrations, GTI Energy also worked with DMI to assess the product design and operational procedures. This analysis included a review of pertinent codes and standards for the safe operation of the drone.

Co-Funders: N/A

Start Date: 09/30/2020
End Date: 1/31/2023
Status: Active
2022 Funds Expended: **$80,000**
Total Project Cost: **$250,000**
Total SCG Cost: **$250,000**
Total Co-Funding: **$0**
Benefits:

GTI Energy Hydrogen Fuel Cell Switcher Locomotive Demonstration

GTI Energy 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 result will improve local air quality and eliminate corresponding greenhouse gas emissions. The team will demonstrate the locomotive 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. Integrating advanced fuel cell and battery technologies represents a new platform that will enable commercialization within a few years. The project team completed the high-level design, identified key components, and began ordering materials in 2022. Detailed design and hydrogen safety reviews also started in 2022.

Co-Funders: Ballard/Ricardo, CEC, GTI Energy, Railpower, Sierra Northern Railway, SMAQD, UCD, ValleyVision

Start Date: 01/01/2021
End Date: 12/31/2025
Status: Active
2022 Funds Expended: **$179,167**
Total Project Cost: **$5,964,876**
Total SCG Cost: **$537,500**
Total Co-Funding: **$5,427,376**
Benefits:

GTI Energy 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 project was the first of its kind and has paved the way for similar future technologies in this space. Hydrogen fuel cell vehicles have been gaining attention in transportation as manufacturers and legislators 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 has been an extensive technology showcasing effort to maximize the impact of the demonstration. Yard trucks are the largest emissions source in all cargo handling equipment classifications. This project aims 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 a demonstration project with TraPac. The team commissioned a temporary refueling station to replace mobile refueling, which offers higher efficiency and operational uptime. Initial operator feedback has been positive, and the project team will continue collecting performance data into 2023. Upon completion of the demonstration, the team will report its findings.

Co-Funders: CARB, BAE, Ballard, TraPac, Capacity, Frontier, HTEC

Start Date: 01/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$136,226**
Total Project Cost: **$11,877,913**
Total SCG Cost: **$372,500**
Total Co-Funding: **$11,505,413**
Benefits:

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

ZEI Harbor Craft Demonstration

In this project, Zero Emission Industries (ZEI) aims to develop and demonstrate a small, fast, hydrogen fuel cell-powered, rigid inflatable boat for various harbor craft use cases. ZEI will operate the vessel for six months in the San Francisco Bay and Long Beach harbor. 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. 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 various 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 team will fuel the ship through novel mobile, portable systems developed by ZEI for marine vessel fueling and built through the project. These systems will use hydrogen sourced from California's retail hydrogen stations. ZEI will apply their knowledge and experience from an existing CARB-funded 84-passenger hydrogen ferry project to this endeavor. In 2022, the project team completed the initial designs of the vessel arrangement and fuel cell power system, as well as the mobile refueler. They also started building sub-components, purchasing critical equipment, and drafting safety procedures.

Co-Funders: CEC, Ocean5 Naval Architects, ZEI

Start Date:	01/01/2021
End Date:	12/31/2025
Status:	Active
2022 Funds Expended:	**$48,938**
Total Project Cost:	**$3,401,178**
Total SCG Cost:	**$200,000**
Total Co-Funding:	**$3,201,178**
Benefits:	

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

SUBPROGRAM: ONBOARD STORAGE

GTI Energy Advanced On-board Hydrogen Storage Technology Assessment

This project aims to identify and test state-of-the-art onboard hydrogen storage technologies for transportation. Current vehicle hydrogen storage consists of high-pressure gaseous hydrogen, which requires a high volume to achieve the required runtimes. This project will be conducted in two phases. In Phase 1, GTI Energy will conduct a market assessment of advanced onboard storage technologies. This market assessment will identify the most promising state-of-the-art technologies to be evaluated in Phase 2. In Phase 2, following the market assessment, GTI Energy will evaluate, analyze, and support the technical development of three advanced onboard hydrogen storage technologies. These technologies are important for advancing fuel cell electric vehicles (FCEVs) because fuel storage systems are typically the largest individual cost component. The development of these technologies could yield the following benefits: increased volumetric energy density; reduced storage vessel costs; lower weight, resulting in increased payload; and improved fueling efficiency. The project was contracted in 2022.

Co-Funders: N/A

Start Date: 12/19/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$225,000**
Total Project Cost: **$225,000**
Total SCG Cost: **$225,000**
Total Co-Funding: **$0**
Benefits:

Sandia National Labs Metal Hydride Composite Hydrogen Storage for Heavy-Duty Vehicles

This project aims 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 regenerate fully following hydrogen desorption at pressures much lower than 700 bar. For example, metal amides considered in this project can be revived at 100 bar, much lower than current onboard high-pressure hydrogen storage tanks (350 bar or 700 bar). 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 developing material-based storage for stationary applications such as microgrids and backup power for data centers. Sandia National Laboratory is still conducting its analysis. The team expanded the scope to include exploring material-based hydrogen storage for rail. In 2022, the team identified and focused on a promising material for the remaining modeling and testing.

Co-Funders: N/A

Start Date: 11/30/2020
End Date: 12/30/2023
Status: Active
2022 Funds Expended: **$0**
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)

This project aims to develop and demonstrate a next-generation natural gas vehicle (NGV) driver information system that provides an accurate miles-to-empty estimate for the vehicle. This hurdle is particularly challenging in gaseous-fueled cars because the gas experiences a wide range of temperature fluctuations 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 Energy 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 Energy will model the thermodynamics of the vehicle tank(s), the key technical hurdle for this project. Argonne National Lab will adapt a previously developed NGV fleet navigation application to utilize the miles-to-empty data to optimize fleet efficiency. After the DOE project, the team will engage potential commercial partners for licensing opportunities. In 2022, the project team successfully installed and demonstrated the first Driver Information System on a truck. Once the display is validated, the team will install the system in 11 more vehicles. The team has also started discussing deployment in a commercial fleet.

Co-Funders: UTD

Start Date: 07/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$250,000**
Total SCG Cost: **$15,400**
Total Co-Funding: **$234,600**
Benefits:

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

GTI Energy Hydrogen Fuel Cell Switcher Locomotive UTD Technical Support for Clean Transportation Testing, Performance, and Safety (2.21.I)

The objective of this project was 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. The Committee discusses NGV safety incidents and investigates root causes each quarter. Key updates included a Cummins announcement of the industry-changing 15-Liter natural gas engine for North America in November 2021. Safety issues with a Mainstay CNG Module led to a safety bulletin by the Technology and Development Committee. The team released a best practices guidance document for time-fill CNG fueling stations. GTI Energy supported activities related to CSA NGV 5.1 (Technical Subcommittee on Residential Fueling Appliances) and CSA NGV 5.2 (Technical Subcommittee on Vehicle Refueling Appliances). GTI Energy also focused on CSA NGV 4.3 (Temperature compensation guideline for compressed natural gas vehicle fueling). GTI Energy served as vice-chair of the Committee. UTD issued a final report in August 2022 documenting these efforts in detail.

Co-Funders: UTD

Start Date: 07/01/2021
End Date: 08/09/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$2,200**
Total Co-Funding: **$122,800**
Benefits:

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

SUBPROGRAM: ON-ROAD

A1 Alt Fuels Fuel Cell Electric Paratransit Shuttle Demonstration

A1 Alternative Fuel Systems will develop and demonstrate two fuel-cell electric vehicles at Sunline Transit for 12 months. The fleet includes two class 4 medium paratransit shuttles, a low-floor (kneeling) Ford F-53, and a standard-floor Ford E-450s. The paratransit shuttles will be capable of a 175 – 250 mile range per fill. In addition to the demonstration, A1 Alternative Fuel Systems will test and certify the shuttles at the Altoona Test Center and 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 time frame. The project team started designing and building both shuttles in 2022 and plans to complete the builds and start testing in 2023. The team developed the high-pressure fuel cell system used for the shuttle 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 they can configure as a wide variety of vehicle types, such as delivery trucks, work trucks, shuttles, and vans.

Co-Funders: A-1 Alternative Fuels, Hometown, U.S. Hybrid, SCAQMD, Sunline Transit, Turtle Top, Luxfer

Start Date: 05/20/2021
End Date: 02/29/2024
Status: Active
2022 Funds Expended: **$28,666**
Total Project Cost: **$2,086,608**
Total SCG Cost: **$531,166**
Total Co-Funding: **$1,555,442**
Benefits:

CALSTART Class 8 Hydrogen Fuel Cell Truck Commercialization Roadmap

The objective of this project was 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. CALSTART worked with a technical advisory committee (TAC) to develop the roadmaps, including the Technology Commercialization Roadmap and the Medium- and Heavy-Duty (MD/HD) Hydrogen Fueling and Infrastructure Roadmap. The Technology Commercialization Roadmap provides market projections and describes market scenarios for the new truck technology. It also compares 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 recommends strategically locating hydrogen fueling infrastructure and estimating future demand for the medium- and heavy-duty trucking industry. It also analyzes the viability of various hydrogen production and delivery pathways to compare centralized production with trucked hydrogen, pipeline delivery of hydrogen, and distributed or onsite production. The team issued a draft document containing both roadmaps to the TAC in Q4 2022, and they will publish it in 2023.

Co-Funders: N/A

Start Date: 04/30/2020
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$25,000**
Total Project Cost: **$216,000**
Total SCG Cost: **$216,000**
Total Co-Funding: **$0**
Benefits:

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

CALSTART CNG Hybrid Class 8 Truck Demonstration

This study was part of a larger California Energy Commission (CEC) project for Kenworth Truck Company that identified the business case for heavy-duty electric trucks with range extenders. This configuration 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 near the corridor. The project team has identified the roll-out plan, early adopters of near-zero-emission heavy-duty trucks, and strategies for expansion into other applications. This study updates 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 various 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 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 are recommended.

Co-Funders: SCAQMD, California Energy Commission, DOE

Start Date: 06/16/2015
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$20,259,820**
Total SCG Cost: **$250,000**
Total Co-Funding: **$20,009,820**
Benefits:

CTE Fuel Cell Electric Delivery Van Demonstration

The Center for Transportation and the Environment (CTE) will develop and demonstrate 15 fuel-cell electric delivery vans with UPS in Ontario, CA. UPS's existing battery electric fleet vehicles meet approximately 70% of UPS route range requirements. Currently, there are no hydrogen fuel cell medium-duty vehicles for goods movement. The team expects the delivery van to meet almost 95% of UPS's service needs when configured with the fuel cell electric propulsion system. The project will show that a fuel-cell electric van can provide fleet operators with a zero-emission vehicle capable of meeting route range requirements while matching the performance characteristics of its existing fleet vehicles. According to Fleet DNA data compiled by the National Renewable Energy Laboratory (NREL), a delivery van with a 125-mile range will meet 97% of Class 3–6 daily delivery driving distances. Meeting CARB's desired 150-mile range threshold increases the attractiveness of zero-emission trucks to fleet operators and increases the commercial viability of fuel-cell electric conversion kits. The team will operate all fifteen fuel cell vans in routine UPS service for at least 5,000 hours. During this period, the project team will provide maintenance and operational support. The team will collect and report all critical operational data throughout the period. In 2022, all vehicles were built and delivered. UPS also conducted an extensive hydrogen safety review. As a result of the evaluation, a few minor modifications are being made to the vehicles. The delivery vans are planned to go into service in Q1 2023.

Co-Funders: DOE, SCAQMD, CEC, CARB, UPS

Start Date: 01/05/2022
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$250,000**
Total Project Cost: **$15,229,320**
Total SCG Cost: **$750,000**
Total Co-Funding: **$14,479,320**
Benefits:

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

Cummins Integrated Fuel Cell Electric Powertrain Demonstration

Cummins will develop and demonstrate a modular, scalable, fully integrated heavy-duty fuel cell prototype design. It will also collect operations and performance data on the units. Data will be collected and analyzed by CALSTART for two different applications – a HD class 8 truck and a transit bus. The HD class 8 truck demonstration will utilize a Cummins HD architecture with two fuel cells. The 40-foot transit bus demonstration will include one fuel cell. Each fuel cell consists of two stacks that together produce 90kW of power. The project's overall goal is to demonstrate the feasibility of this modular, scalable platform that utilizes a plug-and-play design for ease of installation. The project seeks to demonstrate that truck and bus applications can meet a 300+ mile range and exceed the current mileage limitations of pure battery electric HD vehicle solutions. The fully integrated powertrain that includes the fuel cell, battery, motor, inverter, and optimized controls will be installed as a vertically integrated solution on both demonstration platforms, allowing for overall cost reductions. The project team plans to demonstrate the truck in Southern California with a port drayage or in a regional delivery fleet and the bus with a transit property in Ohio. In 2022, Cummins finalized the system architecture and completed 30% of the truck and bus design. They also began procuring key components.

Co-Funders: DOE, Cummins, SCAQMD, Gillig, SARTA, Navistar, Werner

Start Date: 02/01/2022
End Date: 12/31/2025
Status: Active
2022 Funds Expended: **$24,000**
Total Project Cost: **$7,208,624**
Total SCG Cost: **$240,000**
Total Co-Funding: **$6,968,624**
Benefits:

GTI Energy CNG Plug-In Class 8 Hybrid Truck Development and Demonstration

The goal of this project was to design, develop and demonstrate a prototype control system integrated into a Natural Gas (NG) – Hybrid Electric Class 8 truck, optimized to achieve both near-zero oxides of nitrogen (NOx) emissions and significant greenhouse gas (GHG) savings. The vehicle used a 239kW 8.9-liter near-zero natural gas engine, a 222kW electric motor, a 31kWh lithium-ion battery pack, and electric accessories to provide equivalent performance to a larger 15-liter diesel engine while adding a 20-mile zero-emissions range. By comparing the emissions test results to engine emissions tests on similar platforms, the research team found that a hybridized near-zero powertrain can offer a 36% improvement in fuel economy and NOx emissions 22x lower than the current 0.02g/bhp-hr standard. Moreover, the team has found that 90% of NOx emissions are attributed to cold-start operations. Further research, optimization of the system, and support from the component manufacturers could yield additional improvements and offer NOx emissions rivaling well-to-wheel emissions of battery-electric vehicles. However, the NG HD-HEV technology would provide the range, reliability, and refueling convenience advantages over battery-electric alternatives. The team recommends further refinement and deployment of this technology, and they issued the final report to the CEC in Q4 2022.

Co-Funders: CEC, Cummins, FEV, U.S. Hybrid

Start Date: 11/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$32,250**
Total Project Cost: **$1,764,631**
Total SCG Cost: **$161,250**
Total Co-Funding: **$1,603,381**
Benefits:

GTI Energy Symbio Class 8 Long-Haul Hydrogen Fuel Cell Truck Demonstration

The project aims to design, develop, and demonstrate an advanced hydrogen fuel-cell class-8 truck operating on a 400-mile route between Fontana, California, and Lathrop, California, along the I-5 corridor in the San Joaquin Valley. The truck will match the performance of a 15-liter diesel vehicle utilizing proven pre-commercial core technologies, including a 400kW high power density Symbio fuel cell featuring stainless steel stacks, Faurecia's 60+ kg 700bar onboard hydrogen storage, and Michelin's advanced e-tires integrated into a widely adopted Freightliner Cascadia truck. The project intends to demonstrate the feasibility of fuel-cell vehicles on demanding regional haul routes where battery-electric trucks cannot meet the range or operational requirements. The vehicle will be fueled at public hydrogen fuel stations and from a mobile fueler deployed as required at one of the Michelin Commercial Service Networks along the route. The powertrain will handle challenging duty cycles such as the Tejon Pass ("the Grapevine") and extended freeway speeds in the San Joaquin Valley. Over the 12 months, the vehicle will travel over 60,000 zero-emission miles, most of them in disadvantaged communities across 7 California counties. Technical targets include a fuel cell system lifetime of 25,000 hours or 10 years/1,000,000 miles, at least 1.9x fuel economy improvement over equivalent internal combustion engine-powered vehicles, and total cost of ownership reduction of at least 30% compared to current fuel cell technology. The team will conduct a techno-economic analysis to compare TCO of the next-generation fuel cell truck to existing technology. The project was contracted in 2022.

Co-Funders: CEC, Symbio, Michelin, Faurecia, UTD, TTSI

Start Date: 11/1/2022
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$100,000**
Total Project Cost: **$5,128,158**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,628,158**
Benefits:

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

SCAQMD and WVU Alternative Fuel Vehicle Maintenance Study

This project aims to study maintenance-related efforts and costs of medium- and heavy-duty vehicle engines powered by various alternative fuels across multiple vocations. The alternative fuels considered in this study are natural gas, propane, electric, and high biodiesel blends. This maintenance cost assessment incorporates the link between the operational characteristics of alternative fuel vehicles and how they affect maintenance and repair activity. The team will also 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, which the industry often uses in goods movement and delivery vocations. The project team will use vehicle maintenance costs of available fleet information, real-world vehicle activity, and in-use emissions data from another study upon which this project builds. The team will further leverage emissions and activity data previously collected and pre-established relationships from previous research. The project team managed and analyzed digital and paper records from fleets throughout 2022. They have also started building a model that will account for vocational and duty cycle inputs to provide vehicle recommendations.

Co-Funders: DOE, SCAQMD

Start Date: 01/01/2020
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,335,682**
Total SCG Cost: **$150,000**
Total Co-Funding: **$1,185,682**
Benefits:

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. 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 original plan was for three companies to develop and test engines. However, only one company, Agility Fuel Solutions, completed the project. Agility completed the development and certification process as of the summer of 2022. Agility developed all the hardware required to operate the Ford 7.3L engine on CNG and LPG fuel. After successfully demonstrating the ability to achieve a 0.02 g/bhp-hr NOx needed to meet the Low NOx standard requirements, Agility applied for certification with US EPA and CARB. Additional testing showed the ability to meet 0.01 g/bhp-hr NOx using only engine calibration and OEM ford exhaust systems. Durability testing was also performed, which demonstrated that Agility's modifications do not cause the Ford 7.3L engine to exceed any of Ford's established durability limits or not exceed thresholds. These are the first medium-duty class engines to reach near-zero emissions and will likely be widely adopted into Ford medium-duty truck platforms. The team is in the process of reviewing the final report, which will be finalized in 2023.

Co-Funders: SCAQMD, Agility Fuel Systems (CNG)

Start Date: 11/30/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$20,413**
Total Project Cost: **$940,000**
Total SCG Cost: **$320,413**
Total Co-Funding: **$619,587**
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, along with improving emissions inventory estimates. In-use emissions remain a critical component for measuring the effectiveness of engine, fuel, and after-treatment technologies and 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 vehicles. 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 showed 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. In 2022, subsequent testing identified a need for follow-up testing and analysis, which is ongoing. Once the results are confirmed and finalized in 2023, a final report will be published. 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: 03/31/2023
Status: Active
2022 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

The goal of this research is to provide data to justify the initiation of extensive validation work to increase the hydrogen limit for near-zero emission natural gas engines. This research project is assessing the criteria pollutant and greenhouse gas impacts of hydrogen-natural gas fuel blends on near-zero NOx emission heavy-duty natural gas engines. Past studies have shown that adding hydrogen to natural gas may result in lower engine emissions when combined with optimized engine calibration. The University of California Riverside'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 study's first phase focused on the emissions impacts of H-CNG blends compared to the baseline on regulated engine test duty cycles. CWI provided the test engine, after-treatment systems, engineering and data analysis support, and oil sample analysis. A 2005 comprehensive study 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. In 2022, UCR set up the engine on the engine dyno and started developing the blending system and identifying hydrogen sources and safety considerations.

Co-Funders: SCAQMD

Start Date: 11/21/2019
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$534,000**
Total SCG Cost: **$304,000**
Total Co-Funding: **$230,000**
Benefits:

UC Riverside Hydrogen Blended Natural Gas Engine Durability Test

This project aims to evaluate the impact of hydrogen content in natural gas on the performance and durability of one end-use technology, 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 based on typical natural gas composition. Since the limit is part of the Cummins specification, using natural gas with a hydrogen content greater than 0.03% could void the engine's warranty. The University of California, Riverside research team will operate the motor on hydrogen blended natural gas for 500 to 1,000 hours, simulating normal heavy-duty truck and transit duty cycles. After completing the 500 to 1,000 hours of testing, the research team will disassemble the engine to identify and analyze impacts on the components, fluids, and performance. The research will provide data to justify the initiation of extensive validation work to increase the hydrogen limit for near-zero-emission natural gas engines. Increasing the hydrogen limit in CNG engines will help reduce CO_2 emissions. In 2022, UCR set up the engine on a dyno and started developing the blending system and identifying hydrogen sources and safety considerations.

Co-Funders: PG&E

Start Date: 03/06/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$200,000**
Total Project Cost: **$489,977**
Total SCG Cost: **$364,977**
Total Co-Funding: **$125,000**
Benefits:

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 along with additional benefits if run on renewable natural gas. The team will use the truck as a demonstrator for fleets and events. The team will complete emissions and performance analysis through dynamometer and road-testing to assess the PHET design's overall advantage and emissions reduction. The truck is currently in operation with a host fleet. The truck has been operating for approximately one year and has received positive reviews from the independent operator. The team will publish a final report at the end of the demonstration.

Co-Funders: SCAQMD, CEC, DOE, U.S. Hybrid, Clean Energy

Start Date: 03/31/2021
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$3,233,836**
Total SCG Cost: **$250,000**
Total Co-Funding: **$2,983,836**
Benefits:

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

SUBPROGRAM: REFUELING STATIONS

Frontier Energy MC Formula Protocol for H35HF Fueling Demonstration

This project aims to develop and test the MC Formula method for fueling heavy-duty-hydrogen-fuel-cell trucks at 5,000 psi using H35HF (high flow) dispensers. The MC Formula Method is a lumped heat capacitance model that calculates end-of-fill gas temp. Hydrogen refueling stations and protocols are fully responsible for the safe fueling 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 refuel vehicles safely. The MC Formula method uses the 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 dynamic feedback controls. This method allows for high-flow scenarios and faster and more accurate filling of fuel cell vehicles. In 2022, the team, led by NREL collected information on H35 fueling stations and vehicles and updated NREL's fueling model. NREL has also developed an MC Formula validation tool that allows the team to evaluate if the dispenser pressure data from an actual station is accurately controlled with the MC Formula logic. The next steps are to finalize H35HF MC Formula fueling tables and install them in NREL's HD dispenser to confirm the fueling process works. Eventually the team will validate the reliability of the fueling method at commercial stations.

Co-Funders: DOE, Frontier Energy/CAFCP, SCAQMD, Shell, Sunline, Worthington Cylinders

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$572,500**
Total SCG Cost: **$80,000**
Total Co-Funding: **$492,500**
Benefits:

GTI Energy CNG Smart Station Demonstration

This project aims to address natural gas vehicle total-cost-of-ownership by developing and demonstrating a smart fueling system that includes a full suite of necessary technologies that enables 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 and compressor. This combination of technologies solves the technical challenges of dispensing uncertainty and compression heat that results in underfilled natural gas vehicles. By eliminating under-filling, it may be possible to reduce the volume, weight, and cost of the CNG fuel system by approximately 25% while increasing fuel economy, cargo capacity, safety, and driver experience. The project team consisting of GTI Energy and University of Texas Center for Electromechanics (UT-CEM) will perform system design, testing, and techno-economic analysis. The project team has completed the detailed design and is constructing the system for testing.

Co-Funders: DOE, CEC, UTD, UT-CEM

Start Date: 01/31/2019
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$53,754**
Total Project Cost: **$3,346,356**
Total SCG Cost: **$268,754**
Total Co-Funding: **$3,077,602**
Benefits:

GTI Energy Cost-Effective Pre-Cooling for High-Flow Hydrogen Fueling Demonstration

The goal of this project is to develop a high-flow pre-cooling system suitable for heavy-duty hydrogen fueling applications. The design will target the most cost-effective pre-cooling method possible by using commercially available components. The team will design the system to achieve the DOE target of 6 minutes, or 10 kg/min average fueling rate. Current chillers require more than 300kw of power. This project will target a peak power consumption of less than 200kW. The team will execute the project in three phases 1) preliminary design; 2) sub-scale prototype development and economic analysis; and 3) performance testing of the sub-scale system, economic analysis updates, and commercialization plan. The team has identified performance and economic metrics and included them in stage gates between phases. By the end of the project, the team targets having a performance-validated full-scale chiller design and commercialization plan in place with a manufacturing partner.

Co-Funders: DOE, UTD, GTI Energy

Start Date: 12/19/2022
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$150,000**
Total Project Cost: **$2,783,098**
Total SCG Cost: **$268,750**
Total Co-Funding: **$2,514,348**
Benefits:

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

GTI Energy H2 at Scale Hydrogen Refueling Demonstration

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 project will include the demonstration of co-located multiple hydrogen generation and use applications at the University of Texas at Austin. Activities include 100% renewable hydrogen generation (steam methane reforming and electrolysis), a 100kW fuel cell powering a data center, and vehicle and drone refueling. In the second track, the project will leverage the experience from this demonstration and research and outreach to develop a framework for additional H2@Scale pilot opportunities. The project team started construction in 2022 and received most of the critical components.

Co-Funders: DOE, Industry Partners

Start Date: 11/01/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$30,000**
Total Project Cost: **$11,287,021**
Total SCG Cost: **$483,750**
Total Co-Funding: **$10,803,271**
Benefits:

Immaterial Low-Cost Liquid Hydrogen Boil-Off Capture and Utilization Assessment

Immaterial, a research, experimental development, and engineering firm built at the University of Cambridge (UK), have a unique technology, providing a step-change in the performance of Metal-Organic Framework (MOF) materials. This project aims to develop a computational fluid dynamics model of a cryo-adsorbed hydrogen boil-off management system and initial demonstration design. Simultaneously, Immaterial will develop second-generation optimized materials for boil-off conditions and a high-level techno-economic model. Immaterial will also identify target applications for their MOF technology. Boil-off – a phase change from liquid to gas – occurs when fluid, in this case, liquid hydrogen (LH2), is warmed by the energy transfer with the environment during vessel-to-vessel transfer. Boil-off is common along the LH2 supply chain, including vehicle refueling. Using MOFs to capture hydrogen boil-off can help reduce GHG emissions by capturing and using this otherwise wasted hydrogen. This approach can improve total costs by reducing hydrogen losses. First-generation Immaterial MOFs have demonstrated world-leading volumetric capacity, reaching storage capacities of 45g/L at 25 bar and 77 K as validated by the National Renewable Energy Laboratory (NREL). This strategy is already a 22% enhancement over the DOE record of 37 g/L at 100 bar and exceeds the current EU Horizon target of 40 g/L at 100 bar. The project started in 2022 and has completed the initial modeling effort.

Start Date: 01/01/2022
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$150,000**
Total Project Cost: **$254,571**
Total SCG Cost: **$254,571**
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 approach will allow for safer, fuller fills of NGVs while also enabling fleets to track a vehicle's fuel consumption more accurately. To date, the project team has completed the design and bench scale development of a smart dispenser module that can communicate with the smart vehicle to improve full fills and completed lab testing of the smart dispenser components. The team also began the integration of the smart components with GTI Energy's CNG station to conduct testing with precooling to guarantee full fills of CNG vehicles. The team will share the final results with UTD members after the project.

Co-Funders: CSA, DOE, UTD Members

Start Date: 09/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
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 were 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) guide tracking methods to monitor station leakage performance to maximize operational efficiency and minimize leaks and losses. As CNG vehicles begin to replace increasing numbers of diesel and gasoline-powered vehicles, it is prudent to understand how associated methane leaks might contribute to criteria pollutants and GHG emissions. The team leveraged results from other studies and additional data collection efforts throughout the project to identify several sources of methane emissions at CNG stations, with compressor emissions being the most important to address. Other sources included leaks in piping and other equipment, which are easier to identify and handle than the compressor emissions resulting from faulty or worn-out compressor rod seals. The team compiled full project results in a report issued to UTD members.

Co-Funders: UTD Members

Start Date: 06/01/2017
End Date: 07/20/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$75,000**
Total SCG Cost: **$7,500**
Total Co-Funding: **$67,500**
Benefits:

UTD Mitigating Methane Emissions from CNG Stations – Phase 2 (2.17.H.2)

The goal of this project was to identify and quantify sources of emissions from compressed natural gas (CNG) fueling stations to support efforts to prioritize planning and strategies to mitigate these losses. In addition to the economic importance of minimizing losses from CNG fueling stations, addressing these methane emissions will help reduce GHG emissions from CNG fueling. The team built on the results from Phase 1 in this Phase 2 project by investigating the nature of methane emissions from compressors. The project team conducted experiments to measure methane emissions reductions from rod seal replacement on reciprocating compressors most commonly found at CNG fueling stations. Using the best available seal technologies, they found significant potential for emissions reductions through regular rod seal replacements. They also evaluated advanced compression technologies for the potential to reduce emissions further and found that modern sealed crankcase compressors have lower overall emission profiles. In addition, the team identified emissions monitoring equipment that could help CNG fueling station managers better monitor their emissions to implement better, more effective maintenance plans. The team compiled full project results in a report issued to UTD members.

Co-Funders: UTD Members

Start Date: 06/01/2017
End Date: 07/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$75,000**
Total SCG Cost: **$10,300**
Total Co-Funding: **$89,700**
Benefits:

Yankee Scientific Strategies for CNG and Hydrogen Infrastructure Assessment

Yankee Scientific's goal for this project is to develop technical strategies to incorporate compressed hydrogen refueling capabilities at existing CNG refueling stations. The results of this project will allow for the accelerated deployment of hydrogen-fueled vehicles, thereby enhancing the use of renewable resources, reducing the generation of greenhouse gases, and improving air quality. In addition, this proposed program will support Transit Agencies as they develop strategies to meet the goals of the California Innovative Clean Transit (ICT) Regulations. Yankee Scientific will investigate methods to implement off-the-shelf components or to convert and share existing CNG station equipment for hydrogen refueling. This approach allows fleets to refuel CNG and hydrogen vehicles as they transition to zero emissions. The team will compare the economics of these technologies with tube-trailer transport of hydrogen from regional generation facilities or large industrial hydrogen suppliers. The team will identify strategies for adding equipment to the existing CNG refueling station. When applicable, these studies will consider installing structures and equipment using standard site construction methods and prefabricated modular add-on systems. In addition, the team will evaluate each selected strategy's total station conversion and fuel delivery costs and complete a safety assessment. The team will develop recommendations for the best methods for incorporating hydrogen refueling. The team finished the preliminary investigation and system design efforts in 2022, with plans to complete the safety and cost assessments in 2023. At that time, they will publish a final technical report.

Co-Funders: N/A

Start Date: 05/20/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$50,000**
Total Project Cost: **$148,100**
Total SCG Cost: **$148,100**
Total Co-Funding: **$0**
Benefits:

CLEAN GENERATION

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

SUBPROGRAM: DISTRIBUTED GENERATION

Bloom Energy Coupled Electrolyzer and Fuel Cell Demonstration

This project aims to demonstrate the coupling of Bloom Energy's new solid oxide electrolyzer cell (SOEC) with an existing Bloom solid oxide fuel cell (SOFC). A 240kW SOEC will utilize grid electricity to generate hydrogen, to be blended with natural gas to fuel Bloom SOFCs. Hydrogen blending will occur downstream of the SoCalGas meter at a manifold that feeds multiple existing SOFC units on the Caltech campus. The tentative blending is 30% hydrogen by volume. The project includes SOEC product development, hydrogen blending design, permitting, and 15 months of operating costs. The project team will validate the performance of Bloom's SOEC and demonstrate the benefits and ability to blend hydrogen into the fuel cells for reliable lower carbon electricity production. In 2022, Bloom completed the SOEC development, designed the blending system, and received all critical components. The team will continue fully integrated system testing into Q1 2023 and start construction.

Co-Funders: Bloom Energy

Start Date: 04/19/2021
End Date: 06/30/2024
Status: Active
2022 Funds Expended: **$150,000**
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 has identified key factors dictating project economics, life-cycle costs, and opportunities for improvement and optimization that could lead to further market adoption and improved economics. The team installed a commercially available ORC system at a SoCalGas customer site for monitoring and verification. After experiencing technical issues during the initial commissioning, the team put the project on hold. Following that, due to COVID-19 travel restrictions, the manufacturer could not troubleshoot the system in person, so it was removed and shipped to the manufacturer. The ORC system was reinstalled at the customer site and commissioned in Q4 2022. The project team will characterize system performance in a final report they will issue in 2023.

Co-Funders: CEC, EPRI, SoCalGas Emerging Technologies

Start Date: 12/01/2015
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$25,000**
Total Project Cost: **$1,146,739**
Total SCG Cost: **$75,000**
Total Co-Funding: **$1,071,739**
Benefits:

GTI Energy Aisin Residential Fuel Cell Laboratory Testing

This project aims to evaluate a residential solid oxide fuel cell (SOFC) for commercialization and widespread deployment in California. SoCalGas acquired two 700W SOFC units from Aisin to be assessed by GTI Energy. The units were modified versions of the commercially available systems in Japan. Modifications include tuning for U.S. gas composition and adding an external transformer for electrical connectivity in the lab. GTI Energy worked with SoCalGas and Aisin to develop and execute a test plan. Lab testing took place over nine months and included a variety of performance measurements and functional characterizations. GTI Energy has issued a final report to SoCalGas documenting the lab test results and has shipped the fuel cells back to Japan for post-testing evaluation. Aisin will evaluate the units and issue a report to SoCalGas illustrating their findings in 2023.

Co-Funders: N/A

Start Date: 12/14/2020
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$31,119**
Total Project Cost: **$343,702**
Total SCG Cost: **$343,702**
Total Co-Funding: **$0**
Benefits:

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

GTI Energy Kyocera Residential Fuel Cell Laboratory Testing

The ultimate goal of this project is to develop a residential fuel cell for commercialization and widespread deployment in California. To help achieve this, SoCalGas will acquire two 400W SOFC units from Kyocera to be evaluated by GTI Energy. The units will be modified versions of the commercially available systems in Japan. Modifications will include tuning for US gas composition. The team will operate the systems with an external transformer for lab testing. GTI Energy will work with SoCalGas and Kyocera to develop a test plan, which will, at a minimum, assess the following items: power characteristics (I-V data), power capacities and efficiencies of the system at various loads, system endurance, and stack degradation, load following capabilities, system cycling, start-up and shut-down times, emission rates, heat recovery potential, and stand-alone operation. Upon completion of the testing, GTI Energy will issue a final report to SoCalGas RD&D documenting their findings. The team finalized the test plan, and fuel cells were shipped to GTI Energy in 2022.

Co-Funders: Kyocera

Start Date: 12/19/2022
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$200,000**
Total Project Cost: **$330,000**
Total SCG Cost: **$300,000**
Total Co-Funding: **$30,000**
Benefits:

GTI Energy 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—to certify both systems under the CARB Distributed Generation Certification Program (CARB-DG). The team has completed the first phase of the project. During the first phase, GTI Energy worked with the manufacturers to conduct performance and emissions testing of the system in its lab. Working with a third party, GTI Energy, confirmed both systems' ability to meet CARB-DG emissions requirements. GTI Energy installed and commissioned the EC Power system at a commercial bakery within SoCalGas' service territory in 2022, and are in the process of commissioning the M&V equipment. The Marathon system will be installed, and commissioned at a location to be determined in 2023.

Co-Funders: CEC, Marathon Engine Systems, AO Smith Corporation

Start Date: 07/01/2018
End Date: 12/31/2023
Status: Active
2022 Funds Expended: $0
Total Project Cost: $1,667,006
Total SCG Cost: $100,000
Total Co-Funding: $1,567,006
Benefits:

GTI Energy Mobile Hydrogen Fuel Cell Generation System Demonstration (CEC MORBUGS)

This project aims to design and build four easily transportable, integrated hydrogen fuel cell backup generators. Each system will consist of a hydrogen fuel cell, hydrogen storage, battery energy storage, power conversion system, customer and grid interconnection resources, energy management, safety, and monitoring systems. The system, built by Renewable Innovations, will self-sufficiently support a minimum of 10 kW, with 35 kW of continuous load for more than 24 hours, with a peak load capacity of 180 kW. The system will be fueled by hydrogen, providing an opportunity to replace high-emitting diesel backup generators with fuel cell systems that virtually have no emissions and little noise. The units will be deployed for emergency response in disadvantaged communities and Tier 2 and 3 Fire Threat Zones throughout California. The systems will also be capable of supporting other customer functions during non-emergency conditions, including battery electric vehicle charging, peak shaving, and replacement for fossil-based backup power. The project was contracted in 2022.

Co-Funders: CEC, EPRI

Start Date: 12/21/2022
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$300,000**
Total Project Cost: **$2,632,074**
Total SCG Cost: **$300,000**
Total Co-Funding: **$2,332,074**
Benefits:

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

GTI Energy Upstart Residential SOFC Lab Evaluation

This project aims to evaluate the performance of the Upstart Upgen 10 residential solid oxide fuel cell (SOFC) system at GTI Energy's lab. The technology was originally designed to operate on propane, but it was modified for testing with natural gas. Unlike other SOFC systems, Upstart claims they designed the system to achieve fast start and stop times while maintaining cyclic durability. SOFCs can improve customer energy reliability while reducing GHG and pollutant emissions. The project intended to assess 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 early on during testing and was decommissioned and sent back to Upstart for evaluation and troubleshooting. After extensive troubleshooting and parallel product development efforts by Upstart, the team decided to wait for the next-generation system to be produced before pursuing further testing. The new system will be specifically designed to operate on natural gas.

Co-Funders: N/A

Start Date: 08/17/2020
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$206,481**
Total SCG Cost: **$206,481**
Total Co-Funding: **$0**
Benefits:

LBNL Metal-Supported SOFC Development

This project aimed to demonstrate LBNL's metal-supported solid oxide fuel cell (MS-SOFC) technology operating with natural gas and determine future technical improvements required for commercialization. LBNL has developed MS-SOFCs with unique symmetrical architecture that offers 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. LBNL performed testing at the single-cell level. The team operated the cells at 700 °C and 0.75 V due to the efficient and durable performance at that temperature and voltage. The project team successfully ran the cells for over 1,000 hours with over 40 rapid cycles while meeting or exceeding technical targets. The group derived these benchmarks from a literature review and assumptions about residential backup generators. The team demonstrated that the MS-SOFC cells tolerate very rapid start-up and the presence of sulfur when using reformed natural gas as fuel. Furthermore, the process avoids carbon deposits during long-term operation. This feature can enable a rapid-start backup generator to utilize pipeline natural gas. Commercial production of natural gas-based backup generators can be informed and advised by single-cell results. Still, future research should include scale-up to commercial-size cells and evaluation of stack performance, lifetime, and durability. Project results were published by LBNL and shared in an RD&D Public Webinar in October 2022.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 01/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$375,000**
Total SCG Cost: **$375,000**
Total Co-Funding: **$0**
Benefits:

Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration

The goal of this project is for Mainspring Energy to demonstrate its linear generator in a real-world setting. The demonstration occurred 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 produce electricity efficiently with near-zero nitrogen oxide emissions. The project achieved its desired performance targets over a more than nine-month monitoring period. The system provided dispatchable power 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 unit's efficiency was greater than forty percent over the building load range, which occasionally dropped below 150 kW. Low-emission operation was achieved and verified by a third party across the building load range. This project and parallel research and development have led to several design improvements that the team will incorporate into future systems. During the project, Mainspring received significant market interest from national and multinational corporations and raised sufficient capital for a successful and sustained market launch. The project team has issued the final report, pending acceptance and publication by the CEC.

Co-Funders: CEC, Mainspring Energy

Start Date: 01/01/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$2,381,873**
Total SCG Cost: **$100,000**
Total Co-Funding: **$2,281,725**
Benefits:

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

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. Researchers at the University of California (UC), Berkeley, developed the APC. It utilizes an internal combustion engine operating in a closed loop, with argon as the working fluid (instead of air) in conjunction with a membrane gas separation unit. The closed-loop nature of the system 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 project has progressed according to plan, with only minor delays due to supply chain issues. The team has completed the development of the fully integrated system model, 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. The project team is in the process of building the integrated system for testing. The team will operate the unit for 18 months after commissioning.

Co-Funders: DOE, Private Investors

Start Date: 08/14/2020
End Date: 10/31/2023
Status: Active
2022 Funds Expended: **$75,000**
Total Project Cost: **$5,279,034**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,779,034**
Benefits:

QSI Nano-Power Generation System Proof-of Concept

This project aims 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. The reactions occur on an EED's nano-surface, where hot electrons are generated. QSI's foundational research shows that direct conversion of chemical energy from gas-phase catalytic reactions can achieve 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. QSI relocated their lab during 2022 and is in the process of obtaining permits, at which point testing will resume.

Co-Funders: N/A

Start Date: 09/09/2019
End Date: 6/30/2023
Status: Active
2022 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

This project aimed to develop Scaled Power's 40kW Turbogenerator and perform emissions testing. 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 – providing a low-cost option for reliable distributed generation or backup power. The Turbogenerator was re-designed and fabricated based on lessons learned from a prior project phase. The team also integrated the system with a low-emissions combustor, which utilized Low Swirl Burner technology developed by Lawrence Berkeley National Laboratory in an attempt to meet CARB-DG emissions requirements. Once the team integrated the design with the new burner in 2022, third-party emissions testing was performed and compared to CARB-DG's requirements. Unfortunately, measured emissions were higher than desired. Scaled Power identified several potential reasons for the elevated emissions and will explore these reasons in the future. The emission results and future system development opportunities were summarized in a final report and issued to SoCalGas in Q4 2022.

Co-Funders: U.S. Air Force

Start Date: 07/01/2019
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$52,000**
Total Project Cost: **$516,000**
Total SCG Cost: **$232,000**
Total Co-Funding: **$232,000**
Benefits:

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

UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing

This project aimed to investigate the impact of hydrogen-blended natural gas on the performance of selective catalytic reduction (SCR) units for the 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 differ from those that contain carbon. Introducing a flue gas with a different composition into the SCR unit affects the chemistry occurring on the catalyst and, hence, its performance. It was thought that this might cause a change in the resulting NOx emissions downstream of the SCR unit, which would be released from the stack. The team completed testing with a commercial SCR catalyst in 2022. Blending hydrogen with natural gas was shown to have a negligible effect on the catalyst performance. It was shown to be beneficial in terms of the resistance of the catalyst to sulfur dioxide that might be present in natural gas. The team presented the results at two conferences and is working on producing a final report.

Co-Funders: N/A

Start Date: 10/05/2020
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$40,000**
Total Project Cost: **$210,000**
Total SCG Cost: **$210,000**
Total Co-Funding: **$0**
Benefits:

UCI Fuel Flexible Rotary Engine MicroCHP Development

The objective of this project was to demonstrate the operations of an existing micro rotary-engine-based (~30kW) combined heat and power (CHP) unit supplied with hydrogen-natural gas mixtures. The project specifically focused on 1) the robustness of operation and 2) the extent of low emissions performance. Demonstrating hydrogen tolerance in distributed generation technologies provides a pathway to decarbonization for flexible and reliable electricity when preserving air quality. This project leveraged prior CEC-supported development of a rotary engine operating on natural gas, integrated with a generator and heat recovery systems. The team tested the engine at the University of California, Irvine. Issues with several system components, including the alternator and heat exchanger, were observed and remedied during durability testing. The project team conducted performance testing on hydrogen blends up to 20% and found that impacts to CO and NOx emissions resulting from the increased hydrogen were typically controllable by adjusting settings on the engine ECU. The team summarized the results in a final report, and UCI is planning to share the results at an industry conference in 2023.

Co-Funders: N/A

Start Date: 07/01/2019
End Date: 09/28/2022
Status: Completed
2022 Funds Expended: **$7,500**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

UCI Low-Cost Sensors for Smart Burners Research

The objectives of this project were to evaluate the robustness and accuracy of low-cost sensors (<$500) for emissions and fuel composition that the industry can integrate into the overall control systems of low-emissions devices (e.g., nitrogen oxides (NOx) from microturbines "smart" appliances). The project team explored two areas of interest: 1) sensors for monitoring exhaust emissions (particularly NOx and O_2) and 2) sensors associated with monitoring the hydrogen content of hydrogen-natural gas mixtures. The project team compiled possible sensors that they could use to improve the performance of combustion devices in light of variable fuel composition. The team created a summary of possible sensors, and several candidates for evaluation were selected. Off-the-shelf, low-cost sensors were not available for pipeline measurement of hydrogen content. As a result, components associated with electrochemical and acoustic principles were selected for fuel composition and modified to incorporate them for use in a flowing pipeline. The team identified low-cost automotive sensors for evaluation of NOx and CO monitoring, though the design ranges of the devices available are for relatively high emissions (> 100ppm). The team developed testbeds to evaluate the candidate sensor performance. Regarding fuel composition, both technologies responded appropriately to flowing hydrogen and natural gas mixtures. Electrochemical-assessed sensors were limited to less than 3.5% hydrogen in natural gas. The acoustic sensor did not have limits, but the team did not establish a formal concentration range. The results were promising in general, but additional work is needed to evaluate accuracy and robustness. The group gathered results in a final project report.

Co-Funders: N/A

Start Date: 08/01/2019
End Date: 10/30/2022
Status: Completed
2022 Funds Expended: **$7,500**
Total Project Cost: **$136,500**
Total SCG Cost: **$136,500**
Total Co-Funding: **$0**
Benefits:

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

UTD Capstone C200S Microturbine Laboratory Evaluation (2.18.E)

This project aims 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 90%. In 2020, efforts shifted to testing gas turbines at customer sites. Discussions proceeded with customers at specific locations in Florida and Pennsylvania. In 2021-22, the team finalized a testing and data collection agreement and executed the necessary non-disclosure agreements. The project group obtained performance-characterization data. They then discussed characterizing the C200S microturbine for ambient temperature during measurements, turbine electrical power output, turbine fuel input, and other factors. The team expects to produce a final report in 2023.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$160,000**
Total SCG Cost: **$19,800**
Total Co-Funding: **$140,200**
Benefits:

UTD Emerging Rescom Fuel Cells - Laboratory Evaluations (1.20.F)

This project aims to evaluate the merits of at least six residential and small-commercial scale fuel cell systems (<50kW), prioritize them based on fitness for the North American market, and conduct lab testing of select designs. GTI Energy assessed sixteen fuel cell configurations, including alkaline, solid oxide, and polymer electrolyte technologies, all identified for residential or commercial combined heat and power applications. The project team evaluated the merits of the methods based on electrical efficiencies, manufacturer reputation, successful field demonstrations, and North American market fit. Based on this prioritization, GTI Energy identified seven systems for potential evaluation in the lab. So far, GTI Energy has evaluated two systems in the lab to characterize their power and thermal capacities, efficiencies, and qualities, as well as modulation and cycling capabilities. In 2022, GTI Energy completed the daily operation of two identical 700W solid oxide fuel cell (SOFC) mCHP systems in their fuel cell laboratory. After ten months of operation, results indicate a sustained electrical efficiency of about 45% HHV with overall CHP efficiencies above 90%. These are commensurate with the manufacturer's expected performance.

Co-Funders: UTD Members, PERC

Start Date: 07/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$190,000**
Total SCG Cost: **$27,789**
Total Co-Funding: **$162,211**
Benefits:

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. The project team tested these units in the laboratory, and their development was supported by validating performance and other competitive analyses. 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 site now being GTI Energy's lab. In 2022, BRASH informed GTI Energy that they have a prototype ready for laboratory evaluations. However, the prototype seems to have different specifications than originally proposed. The team is working on a path forward for the project.

Co-Funders: UTD Members, BRASH, EnviroPower

Start Date: 07/01/2019
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$190,000**
Total SCG Cost: **$22,588**
Total Co-Funding: **$167,412**
Benefits:

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

UTD GRIDIRON Micro-CHP System Demonstration - Phase 2 (2.16.H.2)

This project aimed to evaluate and support GRIDIRON (formerly M-Trigen) in developing cost-effective, self-powered, and uninterruptible space and water heating in the laboratory. GTI Energy examined GRIDIRON's PowerPlant H24 system, a smaller version of the HA65 explored in Phase 1 of this effort. The H24 does not produce cooling, which results in significantly lower costs. Due to COVID-19-related delays and supply chain issues, GTI Energy will work with GRIDIRON to remotely test the system at their facility in Texas. In 2021, the project team installed the H24 system and GTI Energy's measurement instrumentation. In 2022, the project group conducted testing and, in October, released a final report. GTI Energy completed Phase 2 of this project, focused on system performance characterizations and developing a solution for emissions control. The team conducted testing that showed the NOx and CO emissions levels of the PowerPlant H24 being well below CARB limits. Overall efficiencies were less than 60% higher heating value (HHV). At the time of evaluation, the system did not include a secondary exhaust gas heat exchanger due to sourcing challenges. Simple implementation of a secondary heat exchanger would greatly improve overall efficiency and emissions.

Co-Funders: UTD Members, M-Trigen, New Jersey Natural Gas

Start Date:	07/01/2019
End Date:	06/30/2022
Status:	Completed
2022 Funds Expended:	**$0**
Total Project Cost:	**$230,000**
Total SCG Cost:	**$22,737**
Total Co-Funding:	**$207,263**
Benefits:	

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

SUBPROGRAM: INTEGRATION & CONTROLS

Blue Frontier Fuel Cell Integrated Air Conditioning System Dynamic Lab Testing

This project aims to expand the development and testing of the Blue Frontier air conditioning (BFAC) system. This liquid-desiccant air conditioner 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 an extensive analysis of the benefits of the BFAC, which showed significant energy, cost, and emissions savings when paired with a fuel cell combined heat and power (CHP) system. This phase of the project expanded the scope and variety of testing performed at the University of California, Davis, Western Cooling Efficiency Center (WCEC). The team at WCEC has expertise in this type of testing. Duplicate tests showed good agreement and similar efficiencies to the testing performed by NREL, strengthening the project's conclusions. The project team also tested the system in new operational modes, such as being the building's sole source of ventilation air. These new modes increase the system's capacity by up to 50%, pointing to exciting new opportunities for coupling with fuel cells. For instance, the system can now be combined with larger fuel cells due to the increased capacity, thus larger waste heat needs. The team is in the process of finalizing the final report.

Co-Funders: CEC

Start Date: 10/18/2021
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$40,000**
Total Project Cost: **$495,635**
Total SCG Cost: **$250,000**
Total Co-Funding: **$243,635**
Benefits:

Blue Frontier Fuel Cell Powered HVAC Development

This project aims to develop the Blue Frontier Air Conditioning (BFAC) system further and investigate its integration with a fuel cell combined heat and power (CHP) system. Using an Enhanced Liquid Desiccant Energy Storage technology originally developed by NREL, the BFAC recovers and stores the waste heat from the fuel cell 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 tested it at NREL. The team tested both the system's waste heat regenerator (converting waste heat into concentrated liquid desiccant) and conditioner (converting concentrated desiccant into air conditioning) under various operational and climate conditions. Thermal regeneration testing showed an efficiency of 78% (fraction of heat directly used to evaporate water), which outperformed the target of 75%. Additionally, the conditioner utilized the concentrated desiccant to deliver between 5 and 10 tons of air conditioning consistently. The combined system shows impressive results when coupling it with a 5 kW fuel cell to provide the waste heat for desiccant regeneration. A fuel cell electrical efficiency of 50% rises to 79% when accounting for the electricity displaced from the pre-existing air conditioner. The team is in the process of finishing the final report.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$10,527**
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 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 team split the project into two phases: 1) market and technology shortcoming analysis; and 2) lab evaluation of the Energy Switch technology. During the project's first phase, Energy Switch announced that it would no longer be pursuing the commercialization of its technology. The team completed Phase 1, identified several other potential options, and evaluated them. The team may pursue lab testing of one of these alternative systems as a separate follow-on project. This project aimed to help overcome custom microgrid solutions that are expensive and prohibitive to widespread adoption. Simplifying the integration of small-scale gas-distributed generation can pave the way for increased fuel cell adoption.

Co-Funders: N/A

Start Date: 01/01/2021
End Date: 01/31/2022
Status: Completed
2022 Funds Expended: **$2,000**
Total Project Cost: **$135,000**
Total SCG Cost: **$135,000**
Total Co-Funding: **$0**
Benefits:

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

NREL GKN Metal Hydride Storage Integration with Renewable Energy and Fuel Cells Demonstration

This project will validate and demonstrate the dynamic operation of GKN's HY2MEGA metal hydride hydrogen storage system integrated with NREL's ARIES platform. The H2MEGA, to be constructed at NREL's Flatirons Campus, will be the largest known metal hydride storage system (520 kg H2 / 17.2 megawatt-hour). It will leverage ARIES resources: 1.25 MW PEM electrolyzer, 1.0 MW PEM fuel cell, 600 kg compressed hydrogen, 6.3 MW controllable grid interface, battery, and renewable power assets. The project will use renewable electricity to produce green hydrogen via electrolysis, which will then store in the HY2MEGA system and a compressed storage system. The project will use hydrogen to generate electricity via the fuel cell. Simulated energy production and consumption via the controllable grid interface will enable the team to validate the HY2MEGA performance in various real-world scenarios. These simulated use cases will include data centers and remote communities. This project will help advance the proven, at a smaller commercial scale, HY2MEGA technology. It will also help to understand and address the challenges of connecting multiple megawatt scale engineering systems and the subsequent performance of the integration. The team kicked off the project in 2022. Design and construction of the HY2MEGA storage system and the integrated energy system at NREL is ongoing and planned for commissioning in 2023.

Co-Funders: DOE, GKN

Start Date: 01/01/2022
End Date: 06/30/2025
Status: Active
2022 Funds Expended: **$100,000**
Total Project Cost: **$2,983,229**
Total SCG Cost: **$400,000**
Total Co-Funding: **$2,583,229**
Benefits:

NREL Grid Forming Inverters for Fuel Cells Research

This project aims to develop interconnection and interoperability standards for grid-forming fuel cell inverters. Grid-forming inverters are critical to maintain and regulate voltage and frequency for parts of the grid without traditional rotational assets (which typically perform this function). The industry has successfully integrated grid-forming inverters with battery storage systems in the past few years. The operational differences between fuel cells and batteries require standards specific to fuel cell integration with grid-forming inverters. This project utilizes NREL's cutting-edge ARIES research platform, capable of integrated systems modeling and testing at scales up to 20MW. The team will perform the tasks in three phases: 1) hardware-in-the-loop modeling, 2) interconnection and interoperability requirement evaluation, and 3) testing and validation of the developed standards in the ARIES platform. The project has three technical goals: 1) demonstrating the ability of fuel cell inverters to transition between grid following and grid forming modes, 2) interconnection standards (how fuel cells connect to the grid), and 3) interoperability standards (how fuel cells communicate with other assets).

Start Date: 01/01/2022
End Date: 03/31/2025
Status: Active
2022 Funds Expended: **$150,000**
Total Project Cost: **$1,689,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,189,000**
Benefits:

UCI Fuel Cell Supported Nanogrid Controls Evaluation

This project aims 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 net zero energy in a residential setting with a solid oxide fuel cell (SOFC), PV array, and battery storage. The University of California, Irvine (UCI) will work with two microgrid control vendors to evaluate and further develop its control platform(s) capabilities. The microgrid controllers will be installed in UCI's laboratory nanogrid, which includes a 1.5kW SOFC, 5kW rooftop solar array, and a 9.8kWh battery. The team will test the control platforms for their ability to meet the dynamic operating requirements developed in the previously mentioned supporting project. In addition to 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 residential demands of various California climate zones. In 2022, UCI completed the construction and electrical wiring of the demonstration infrastructure in their lab and began working with two control manufacturers to integrate their technology for testing.

Co-Funders: Microgrid Control Companies

Start Date: 10/18/2021
End Date: 04/30/2023
Status: Active
2022 Funds Expended: **$125,000**
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 Fuel Cells in Data Research

The objective of this project is to explore the real-world feasibility of using Solid Oxide Fuel Cells (SOFCs) integrated to provide power, cooling, and dehumidification to a data center. The project was conducted in a University of California, Irvine laboratory. For testing, Microsoft provided a standard 42-slot server rack. To meet the 12kW power requirements of the server rack, the project team used eight 1.5kW Solid Power Blue-GEN fuel cells. The waste heat from the SOFCs was used to drive the absorption chilling and liquid desiccant dehumidification (LDD) processes. The project team conducted both physical lab testing and modeling for the individual components and integrated systems. The team evaluated the system's annual hourly dynamic performance for powering the demand of a single server rack (~12kW) and a row of servers (~240kW) in different data centers around the United States. The researchers found that the integrated system could produce waste-heat-based cooling and dehumidification, power the servers, and maintain server operating temperatures and humidity in the safe range for different weather conditions. They also determined the yearly desiccant storage capacity required for each location to meet the demand of the data center for the entire year. In 2022, researchers completed the optimal design for the integration of the SOFC and absorption chiller to minimize annual carbon emissions intensity and levelized cost of utility and maximize the primary energy savings (PES) ratio. The team will compile complete project results in a final report in 2023.

Co-Funders: Microsoft

Start Date: 10/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$540,000**
Total SCG Cost: **$190,000**
Total Co-Funding: **$350,000**
Benefits:

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 low-cost and renewable power supply on the electric grid—provide the best techno-economic and long-term solution to meet both 100% renewable energy 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. University of California, Irvine (UCI), 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. In 2022, UCI began work identifying and characterizing the dynamics of various critical infrastructure and optimizing system sizing for hydrogen production, transmission and distribution infrastructure, and reconversion equipment for critical infrastructure. UCI also began investigating hydrogen system coupling with other societal infrastructure grids.

Co-Funders: Microsoft

Start Date: 11/22/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$75,000**
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 project was to assess the viability of incorporating a hydrogen-based energy storage system on the University of California, Irvine (UCI) campus to decarbonize the campus' energy consumption, primarily in the existing natural gas-fueled combined heat and power plant. The assessment included 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 also conducted a techno-economic 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. The team identified several technology gaps and outlined the next steps in the final report issued to and published by the DOE in 2022.

Co-Funders: DOE

Start Date: 06/01/2021
End Date: 05/31/2022
Status: Complete
2022 Funds Expended: **$0**
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 is 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 has 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. The team considered various metrics for achieving ZNE in the analysis, including "Site," "Source," and "Time Dependent Valuation (TDV)" metrics. The project results have shown that the All Electric: PV + Battery scenario results in impractical surface area requirements for PV to achieve ZNE. The research showed that ZNE could be more practically completed 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 meeting ZNE requirements. UCI also used the open-source energy system techno-economic optimization model DERopt to develop utility and equipment cost scenarios for 2025, 2035, and 2045. The SOFC has proved to be beneficial by locally producing electricity at high efficiency while simultaneously cogenerating heat. The project results show a need to develop control strategies and systems to manage energy production, storage, and export dynamically. Results have also shown that the overall energy cost for a utility customer will decrease over time due to the availability of lower-cost onsite generation options. The team will document the full project results in a final report in 2023.

Co-Funders: N/A

Start Date: 10/01/2019
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
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)

Researchers reviewed available demand response (DR) programs and demand-side management (DSM) options in this project. The project team also evaluated the potential for life-cycle cost savings for distributed generation (DG) or combined heat and power (CHP) systems. The objective was to develop a technical and economic assessment of opportunities for peak electric DR that can be achieved from DG and CHP installations. The evaluation of DR and DSM opportunities identified operating strategies and other approaches that provide economic benefits for DG and CHP systems. Growth in DG units and micro-grids could 1) improve the resilience of individual facilities and 2) support the reliability of the electric infrastructure by boosting its ability to react to increasingly intermittent generation from renewable energy. The team issued a final report in June 2022. The demand response programs vary in their details and implementation from one organization to another. However, they can be grouped into three general categories: load curtailment, onsite distributed energy resources, and time-of-use pricing. Load curtailment involves the customer reducing the load in response to a signal from the ISO or the utility. In some programs, onsite generation can be used to reduce load demand to meet this requirement. Incentives can be paid on the amount of the load reduction and for a commitment to participate, regardless of whether any curtailment signal is sent. Onsite distributed energy resources allow the customer to respond to calls to operate their grid-tied power generation equipment in response to signals from the ISO or utility. These signals are generated to support grid stability during high-demand periods.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 06/30/2022
Status: Completed
2022 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)

This project aims 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. The objective of this approach is to improve efficiency, reduce greenhouse gas emissions, reduce operating costs, and increase resilience. GTI Energy has successfully operated the nanogrid to achieve self-powered hybrid residential HVAC and water heating using the mCHP system and thermal and electric energy storage to power the combi system and air source heat pump (ASHP). The nanogrid controller manages 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 Energy is targeting annual coefficients of performance greater than 1.0 serving heating loads down to 5,000 BTUs per hour. GTI Energy 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
2022 Funds Expended: **$47,769**
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)

This project aims to perform a laboratory evaluation of an EC Power/Lochinvar XGRi25micro combined-heat and power (mCHP) unit in a multi-family scenario coupled with best-in-class electric heat pumps (EHPs) responding to heating and cooling demand. With integrated smart thermal storage and management capabilities, the XGRi25 and advanced EHPs operated as an advanced gas-fired integrated system with annual gas efficiencies greater than 100% for heating, cooling, and hot water loads. The project integrated 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. The team has designed, procured, and commissioned all system components. In 2022, the group kicked off the integrated system evaluation, at which point GTI Energy identified several obstacles. These issues were associated with 1) an exhaust gas leak in the venting installation, 2) a low-refrigerant charge in EHPs, and 3) challenges with the data collection system control. The team got a no-cost time extension approved to collect data on the 2022 heating season, and the project will extend into 2023.

Co-Funders: UTD Members

Start Date: 06/01/2021
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
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)

This project aims to leverage the results of Phase 1, which integrated a Lochinvar combined heat and power (CHP) system, distributed air source heat pumps, and thermal storage in an integrated energy system (IES). This project will expand the system's capabilities to further test and demonstrate the capabilities of the IES in a multifamily setting. The project team will integrate electric vehicle charging, PV arrays, 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. For phase 2, GTI Energy has been working with the installation contractor on details associated with permitting and as-built drawings. Supply chain and permitting issues have delayed the installation of the solar panel infrastructure and EV charging stations. The team will finalize these installations in 2023.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$69,249**
Total Project Cost: **$480,000**
Total SCG Cost: **$139,249**
Total Co-Funding: **$340,751**
Benefits:

CUSTOMER END-USE APPLICATIONS

SUBPROGRAM: ADVANCED INNOVATION

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

METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration

Start Date: 08/31/2020
End Date: 09/30/2023
Status: Active
2022 Funds Expended: **$164,259.00**
Total Project Cost: **$481,460**
Total SCG Cost: **$481,460**
Total Co-Funding: **$0**
Benefits:

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 fewer than 12 months, and up to 15% total energy savings (electric and gas combined). The goal is to test and 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, third party measurement & verification of the 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 guarantee a successful demonstration rather than three. During the site analysis, the project team identified several pathways for significant energy savings including modifications to parameters that affected the electricity, steam generation, vacuum pump, compressed air, expansion, and incinerator processes. In 2022 the team worked on the instrumentation and connectivity of the steam generation and incinerator processes. The energy optimization software has been installed at the host site. The plant managers are familiarizing themselves with the energy dashboard which has high-level control over the plant's operation. The team is working to bring online more variables in the system.

Co-Funders: N/A

UTD Gas Fired High-Efficiency Liquid Desiccant Air Conditioning and Humidity Control - Phase 2 (1.15.E.2)

Start Date: 06/01/2018
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$415,000**
Total SCG Cost: **$4,000**
Total Co-Funding: **$411,000**
Benefits:

The goal of this project is to develop a gas-fired liquid desiccant dedicated outdoor air system (LDDOAS) that addresses many of the critical issues facing the HVAC industry. During this project, a research team is collaborating with a manufacturer to compare the current state-of-the-art LDDOAS technology with other advanced systems. The team designed and experimentally evaluated a breadboard LDDOAS test rig rated at approximately 100 CFM 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 upgraded a one-tower test rig and completed liquid desiccant distribution tests. Progress was made on continuous regeneration tests, demonstrating efficiency as high as 70% while sufficiently regenerating the desiccant. 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. The project team discovered that insufficient mixing of water vapor in the air at the exit of the tower was causing the imbalance. To make certain 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 flow velocity and turbulence. In 2022, the team completed plans for building a second packed bed column tower to allow for simultaneous regeneration and conditioning. Construction of the second tower is currently underway. The group purchased a new digital refractometer to measure the desiccant solution's refractive index. The project team plans to begin benchtop tests of the desiccant on different material surfaces in the next reporting period.

Co-Funders: UTD Members, NYSERDA

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

UTD Investigating Multifamily Infrastructure Challenges - Phase 4 (1.14.J.4)

The objectives of this project were to evaluate the current position of the natural gas industry in multifamily new construction and to develop recommendations for improvement. The goals were to establish concrete market transformation and implementation tools and action plans to properly connect with new development decision-makers pertaining to natural gas in new multifamily construction projects. In earlier research, the project team interviewed key national-level players active in the multifamily market, including representatives from industry associations, gas utilities, and the building and development community. In this phase, the team continued dialogues with experts in the multifamily new construction market. It sought to create actionable tools for UTD members to serve multifamily homeowners, architects, and builders better. The project team identified important research to communicate quantifiable 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. The team completed the final case study and development guidance for the relevant low-rise multifamily construction project.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$127,000**
Total SCG Cost: **$1,984**
Total Co-Funding: **$125,016**
Benefits:

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

SUBPROGRAM: COMMERCIAL APPLICATIONS

CSU Hydrogen Blend on a Caterpillar NSCR Natural Gas Compression Engine Research

This engine testing research aims to assess the impact of hydrogen blends 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 fuel-to-air ratio control processes can mitigate impacts. Researchers hypothesize that more advanced systems and controls are needed to accommodate blends with hydrogen content to remain in compliance with air quality requirements. Approximately 1,000 - 2,000 engines are in operation in the SoCalGas service territory, used for water pumping, distributed power generation, and pipeline gas compression. This research could help develop a statewide hydrogen injection standard and a better understanding of hydrogen blending in commercial and industrial (C&I) equipment. The study will also benefit disadvantaged communities because most engines are in municipalities, water companies, and farming areas. Successful project completion will allow the C&I team to work with customers to retrofit their engines before they receive hydrogen blends. In 2022, the research team completed the hydrogen blending system setup, and shortly after, they completed the engine testing. The team is now reviewing the data on hydrogen fuel blending and developing appropriate air-fuel-ratio (AFR) control strategies. The team intends to submit a research paper to the Society of Automotive Engineering's 2023 conference, covering emissions, sustainability, and thermal management topics.

Co-Funders: Caterpillar

Start Date: 09/01/2021
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$34,612**
Total Project Cost: **$203,066**
Total SCG Cost: **$173,066**
Total Co-Funding: **$30,000**
Benefits:

GTI ENERGY Gas Heat Pump Water Heating and Space Cooling in Restaurants Demonstration

The goal of this project is to pilot a low-cost gas-fired heat pump (GHP) for integrated commercial water heating and air-conditioning (A/C). The project team deployed the technology at two restaurant sites in the Los Angeles basin. 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%. The team anticipates having an equipment cost of approximately half that of comparable GHP equipment. To offset A/C energy consumption, the project team modified this GHP 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. Stone Mountain Technologies, Inc. (SMTI) designed this GHP, a startup company specializing in gas-fired heat pumps, with technical support from GTI ENERGY and A.O. Smith. After the project, the research team found that energy savings at both sites were 16%-26% for the Integrated GHP System and 52%-53% for the heat pump. The daily net electricity increase for both sites was 7-8 kWh. The energy 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. The simple payback for the Integrated GHP System ranges from 1.1 to 6.4 years (fuel savings basis). Lastly, the climate impact of the technology yielded a net greenhouse gas reduction 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: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,090,294**
Total SCG Cost: **$226,000**
Total Co-Funding: **$864,294**
Benefits:

GTI ENERGY Model-Based Control Hospital Decarbonization Demonstration

The objectives of the project are to 1) demonstrate an overall 30% reduction in natural gas usage and a simple payback of fewer than three years, 2) advance the technologies integrated with model-based optimal control from TRL7 to TRL9, and 3) showcase the retrofit measures and energy savings through outreach to encourage similar implementation of energy saving measures throughout the state. This project demonstrates an integrated model-based control solution for reducing space heating and hot water loads to decarbonize large commercial buildings. The proposed technology will significantly reduce energy use and greenhouse gas (GHG) emissions. GTI Energy will monitor and report real energy savings and GHG reductions from installing advanced technologies at the Baldwin Park Medical Center. In 2021, the project team held its first technical advisory committee meeting to share project progress. During their meeting, they shared their analysis of the site characterization, including technical information on the boiler and chiller systems used by the medical center. In 2022, the team completed the baseline energy monitoring, expects to complete the system design and engineering by October 2022, and anticipates system installation and commission by Q1 of 2023.

Co-Funders: CEC

Start Date: 12/01/2020
End Date: 03/31/2024
Status: Active
2022 Funds Expended: **$42,000**
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

The project's goal is to optimally deploy a state-of-the-art natural gas heat pump technology into a hotel. This technology holds the potential to reduce greenhouse gas emissions greatly and air quality impacts to local communities and populations collocated with this facility while demonstrating energy savings of at least 35% in the form of natural gas consumption (target 50%). In this project, SoCalGas is leading an effort to deploy and demonstrate the technical and economic viability of high-efficiency natural gas heat pumps. The pilot is located at the Westin Bonaventure, a 1.5 million square foot hotel in a low-income and disadvantaged community. In 2021, the host site decided they could no longer support the technology demonstration. As a result, the project team spent most of the year developing a turnaround strategy, including identifying alternative sites. With the assistance of the CEC, several meetings were held with the project team to narrow down candidates, including a large university and a major television production facility. In 2022, the project team finalized contracting for an alternative site, and the group expects procurement of the GHP components in 2023.

Co-Funders: CEC

Start Date: 06/30/2020
End Date: 12/31/2024
Status: Active
2022 Funds Expended: **$0**
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's objective was to advance a unique technology that uses aerosolized sealant particles to remotely seal leaks in low-pressure natural gas distribution systems downstream of the building pressure regulator. This technology has been commercialized for duct 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 team completed a majority of the tasks. The team built and tested a leakage measurement apparatus in the laboratory, applied the device and protocol to ten systems, built an aerosol sealing apparatus, and applied it to a building piping system. In 2022, the team delivered a final report. The leakage testing methodology was involved in 10 field applications and was used to characterize the leakage encountered in the field and laboratory mock-ups of pipe networks. The conclusions drawn from this work were: 1) eight of the ten gas distribution networks downstream of the gas meter had very low leakage levels (below the 2 ft^3/year detection limit), 2) the team showed the method seals leakage within two orders of magnitude of the maximum leakage measured in the field, and 3) the leakage in pipe joints scales linearly with the pressure differential. The reader should note that the leakage-testing sample size was too small to draw general conclusions about the magnitude of the leakage issue. The sealing methodology holds promise but needs further development for application to the natural gas distribution network.

Co-Funders: N/A

Start Date: 07/01/2020
End Date: 06/30/2022
Status: Complete
2022 Funds Expended: **$25,000**
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)

The overall goal of this project is to develop an advanced burner capable of achieving ultra-low emissions, high efficiency, good turndown, and attractive first costs. In Phase 1 of this project, researchers successfully developed and tested a 3D-printed burner by integrating advanced nozzle prototypes with a commercial water heater's blower, controls, and fuel inlet. The goal of the 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 designed and fabricated prototypes of a nozzle burner. They considered the key features they should adapt for the prototype (e.g., flame stability within the water heater and smooth ignition). Oak Ridge National Laboratory fabricated two to three design iterations. In 2021, the project team reviewed different integration methods for the burner within the water heater. In 2022, the project team further reviewed the water-heater prototype's burner designs for adaptation and flame stability. Researchers studied various methods for adapting the burner within the water heater. Testing showed that ignition was intermittent and the flame was not stable; hence, further changes are being made to the ignition scheme to guarantee that the customer can retrofit the burner without any other modifications. The emissions testing showed that the burner could achieve <9 ppm emissions; however, the project team is addressing ignition and stable operation within the water heater.

Co-Funders: UTD Members, ORNL

Start Date: 06/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$12,000**
Total Project Cost: **$300,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$276,000**
Benefits:

UTD CleanO2 CARBiNX Carbon Capture (1.21.C)

This project aims to evaluate the performance of a CleanO2 CARBiN-X v 4.0 carbon capture device in the laboratory 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. Implementing distributed carbon capture technology such as the CARBiN-X will help reduce greenhouse gas emissions in residential and light commercial and industrial spaces while allowing facilities operators to use natural gas in Zero Net Energy Buildings. The CARBiN-X v 4.0, CleanO2 team is working on more advanced prototypes to further disrupt the distributed carbon capture market. Depending on the progress in developing these prototypes, GTI Energy may perform preliminary regulatory and technical analyses to support the advancement of this technology. In 2022, The project team worked with CleanO2 to fully commission the new production version of the carbon capture unit in the improved experimental test stand for next-round tests. Researchers will complete baseline and advanced testing and provide continued assistance to CleanO2 to refine the new system.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2024
Status: Active
2022 Funds Expended: **$16,000**
Total Project Cost: **$180,000**
Total SCG Cost: **$36,000**
Total Co-Funding: **$144,000**
Benefits:

UTD Commercial Heat Pump Water Heater Field Performance Comparison (1.21.F)

This project compares commercial gas and electric heat pump-based water heater technologies. These tests are being carried out at one or two field locations and in GTI Energy's laboratory using ASHRAE standards. The aim is to establish each technology's cost and energy savings capabilities. The goals are to assess the performance of these technologies under various conditions and to provide comparative information between commercial heat pump technologies. In 2022, the project team executed a contractual agreement with SMTI. The initially-planned host site pulled out from participating in this field study. SMTI is holding discussions with other potential host sites for demonstration.

Co-Funders: UTD Members, PERC, DOE

Start Date: 07/01/2021
End Date: 01/31/2024
Status: Active
2022 Funds Expended: **$1,765**
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 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 service hot water (SHW) generation. 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. The project's primary goal 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 Minnesota by developing custom modeling and assessment tools. The team completed data analyses between the tankless and baseline systems. The findings included full-system efficiencies with 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 uninsulated pipes. For the baseline tank systems, the average efficiency was 60%, and for the CCTWH system, the average efficiency was 66%. For the water-heater-only efficiency, the average baseline tank efficiency was 74% and 85% for the CCTWH. A final report was issued in October 2022. The team found that the CCTWH systems can save energy over tanked storage systems. The evaluation of installations at two sites in MN concluded that CCTWHs saved an average of 12.7% of site energy consumed for water heating, 18.1% at one site, and 7.2% at the other. The annual energy savings were 344 and 168 therms per building, respectively.

Co-Funders: UTD Members, State of Minnesota

Start Date: 06/01/2018
End Date: 04/01/2022
Status: Completed
2022 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 various 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 a techno-economic 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. In 2022, the project team continued to refine hourly performance curves for the Yanmar GEHP VRF system. The team is integrating measured heating and cooling field data from 2021 through 2024 from two UTD GEHP demonstrations to validate Yanmar's GEHP performance curves. Researchers will begin to incorporate National Research Council Canada's laboratory and field data for an eight-ton GEHP to validate the manufacturer performance curves. The team will collect additional GEHP datasets from demonstration projects with the Illinois Army National Guard (2023-2024). The research team continues to explore different modeling approaches for EnergyPlus.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2024
Status: Active
2022 Funds Expended: **$3,100**
Total Project Cost: **$320,000**
Total SCG Cost: **$7,631**
Total Co-Funding: **$312,369**
Benefits:

UTD Gas-Fired Binary Fluid Ejector Heat Pump Water Heater (1.20.E)

This project aims to model, design, and build prototypes of a gas-fired ejector heat pump water heater (GFEHP). 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 first-of-a-kind heat pump uses a novel cycle that combines a binary-fluid ejector and sorption subsystem into one high-efficiency process. The technology integrates several components that are thermally and hydraulically coupled. This new approach will make the unit twice as efficient as the current state-of-the-art technology on a primary energy basis. This method 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. In 2022, the research team completed the initial design of an integrated burner and evaporator design and is currently working on fabricating the assembly. The project team will test it in-house and then ship it to the University of Missouri for integration with the alpha prototype.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2020
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$7,969**
Total Project Cost: **$2,115,000**
Total SCG Cost: **$22,844**
Total Co-Funding: **$2,092,156**
Benefits:

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

UTD High Hydrogen-Content Fuel in Residential/Commercial 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. The aim is to show multiple solutions in a controlled laboratory environment and leverage international developments and technology transfer. The project goals are 1) to build a hydrogen-blend and experimental test station. Then use the test apparatus 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 the technology, including hosting outreach events with a wide range of stakeholders. In 2021, the project team developed a comprehensive review of hydrogen demonstrations in Europe and Asia that included end-users. In 2022, test stands were built and modified for standardized testing of furnaces and water heaters. The project team completed a preliminary literature review on relevant test and certification methods. The research team developed a comprehensive test plan, with testing expected to occur in the first quarter of 2023. As part of the R&D road mapping and outreach efforts under this project, the team prepared a summary paper for the World Gas Conference held in May 2022. Researchers demonstrated that methane emissions decrease with added hydrogen. There are several emerging options for distributed gas quality and hydrogen sensors. The project team is meeting with representatives from several sensor manufacturers.

Co-Funders: UTD Member

Start Date: 07/01/2020
End Date: 06/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$18,900**
Total Co-Funding: **$161,100**
Benefits:

UTD High-Efficiency Thermo Vacuum Commercial Clothes Dryer - Phase 2 (2.17.C.2)

This project aims to develop and test a prototype high-efficiency, natural gas-fired thermo-vacuum clothes dryer and demonstrate the technical and economic benefits compared to the state-of-the-art dryer. A successful prototype would reduce drying time by up to 75%, fuel savings of 50% or more, and significant emissions reductions while lowering operating and maintenance expenses. The project team conducted bench-scale experimentation for the drying of selected fabric samples. These drying curves will serve as a basis for designing prototype units and help inform the development of refined drying curves. The project team assessed and evaluated commercial product lines and contacted major original equipment manufacturers. The team characterized the integrated drying concept to establish the baseline performance. A benchmark unit for the laboratory-scale testing was defined, and the 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 technology's superior performance and provided promising results for moving the technology forward. The team presented a paper that includes the methodology, model description, and process energy analysis 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 continues to review the related U.S. patent application 62/785,769.

Co-Funders: DOE, UTD Members

Start Date: 07/01/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,990,225**
Total SCG Cost: **$15,225**
Total Co-Funding: **$1,975,000**
Benefits:

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

UTD Hydrogen-Blended Gas in ResCom Combustion Equipment - Phase 2 (1.20.H.2)

Specific goals of Phase 2 are to 1) determine the impact of hydrogen blends on efficiency ratings and seasonal performance of appliances, 2) estimate the greenhouse gas reduction potential of hydrogen blending at various levels for U.S. and Canadian blocking stocks, and 3) identify safety, emissions, and efficiency benefits or concerns. This project will support the potential deployment of up to 30% hydrogen blend in natural gas supplied to commercial and residential buildings in North America. The project will assess operational performance, emissions, and safety impacts on at least five standard appliances in a laboratory setting. In 2022, test stands were built or modified for standardized testing of furnaces and water heaters. The team completed a preliminary literature review on relevant test and certification methods. The research team developed a comprehensive test plan, with testing expected to occur in the third or fourth quarter of 2022. As part of the R&D road mapping and outreach efforts under this project, the team prepared a summary paper for the World Gas Conference held in May 2022. Researchers demonstrated that methane emissions decrease with added hydrogen. The response to results was very positive, particularly with high interest from organizations in Latin America. There are several emerging options for distributed gas quality and hydrogen sensors. The project team is meeting with representatives from several sensor manufacturers.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$1,450**
Total Project Cost: **$150,000**
Total SCG Cost: **$4,350**
Total Co-Funding: **$145,650**
Benefits:

UTD Integrated, Self-Powered, High-Efficiency Burner System (1.19.C)

The objective of this project was to develop and demonstrate a grid-resilient, self-powered, fuel-flexible, high-efficiency Advanced Burner Thermoelectric Generator (ABTEG) as an integrated system that a user can drop into many types of residential and commercial building spaces 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 team targeted reducing NOx emissions by more than 70% compared to current designs. The project team performed the following tasks: subsystem specifications and design, burner fabrication and testing, and testing of the integrated ABTEG system architecture. In 2020, researchers performed Computational Fluid Dynamics (CFD) analysis for the fuel-flexible burner and generated a solid model for 3D printing. In 2021, the team tested multiple TEG units of different power levels and physical dimensions to understand the power output. In 2022, the team completed CFD modeling of the burner. Testing results demonstrated that this technology could achieve <5 ppm NOx emissions for the entire firing range with different levels of hydrogen blending with natural gas. The burner will enable a more integrated TEG-burner module design for improved system performance, should this be required in the future. The current storage water heater and the proposed tankless water-heater efforts utilize the conventional burners packaged with the water heater. The project is complete, and the project team continues to engage with its commercial partners to move the technology toward commercialization.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2019
End Date: 07/31/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$1,060,000**
Total SCG Cost: **$36,600**
Total Co-Funding: **$1,023,400**
Benefits:

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

UTD Ionic Liquid Absorption Heat Pump for Commercial Water Heating (1.21.I)

This project aims 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) in partnership with the University of Florida and leading OEMs. The system also uses a mild ionic liquid, providing integrated latent cooling to maximize efficiency. The target efficiency is COPgas, HW≥1.60 if only providing hot water, or COPtotal>1.80 if the system also offers indoor cooling and dehumidification. The prototype will be performance-tested at loads (steady and dynamic) typical of commercial buildings with 100 gallons of storage and nominal heating output at 145 kBtu/hr. The system uses a simple plastic pump; most construction materials are polymers. In 2021, the project team continued to refine the product definition and consider codes and standards implications, and controls specification options. In addition to defining the concept for the target application, the effort leveraged a parallel commercial HVAC effort using a hospital application to consider deep dehumidification applications (defined as a different sensible and latent air-conditioning version) and a compressor-less HVAC version. In 2022, the research team completed the fabrication of the desorber and is prepared to apply instrumentation and complete the test rig assembly for testing. Researchers continue to hold frequent design meetings to discuss product-definition challenges and designs for the desorber and condenser, including results from modeling and analysis and desorber system and component testing.

Co-Funders: UTD Members, PERC

Start Date: 12/31/2021
End Date: 7/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$225,000**
Total SCG Cost: **$2,400**
Total Co-Funding: **$222,600**
Benefits:

UTD Low Emission Efficient Burner for Ovens and Dryers (2.20.A)

The goal is to advance the commercial introduction of a new burner that would reduce emissions, energy use, and operations and capital expenses for many end users. Novel burner technology was previously developed in project No. UTD 2.15.D. This project tested the air-process heating assembly focusing on the burner performance and progress from a laboratory to a field test site. Specific tasks included (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 operations and process conditions. In 2020, the project team completed the burner assembly and the crossflow process-air section fabrication. In 2021, the team installed the air and fuel trains for the burner and the crossflow air for flow, pressure, and temperature measurements. In 2022, an improved second prototype burner design was fabricated based on a computational fluid dynamics analysis that further reduced emissions by improving the mixing by more than 30%. The burner was assembled and installed in the furnace, similar to the previous burner assembly, with pressure and temperature instrumentation and air and fuel plenums. The project team conducted burner shakedown testing and preliminary tests on this improved design. Laboratory testing of the enhanced burner design is currently in progress, and the team expects it to lower emissions and improve turndown. The prototype testing simulates the host site test setup and demonstrates proof of concept. The prototype enables market demonstration while reducing integration risks with the host-site system.

Co-Funders: UTD Members

Start Date: 06/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$23,800**
Total Co-Funding: **$176,200**
Benefits:

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

UTD Membrane-Based Ionic Liquid Absorption Heat Pump for Commercial HVAC (1.20.I)

The objective of this project is to develop innovative thermally driven cooling technology for commercial heating, ventilation, and air conditioning (HVAC) applications. The U.S. Department of Energy (DOE) awarded prime funding to the University of Florida (UF) to lead this technology development effort through project management, technical design and shared laboratory development with GTI. The project team will demonstrate the technology 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 non-crystallizing ionic liquids. This absorption system is built upon a compact membrane-based heat and mass exchanger with no desiccant entrainment. The compact size facilitates retrofitting 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. In 2021, the project team completed a study regarding the impact of direct firing the desorber concerning capacity, hot spots (material reliability), and other factors. In 2022, the project team completed the commissioning and testing of the desorber using a working fluid that simulates the ionic liquid.

Co-Funders: UTD Members, PERC, DOE

Start Date: 08/01/2020
End Date: 08/31/2023
Status: Active
2022 Funds Expended: **$5,493**
Total Project Cost: **$1,800,000**
Total SCG Cost: **$24,033**
Total Co-Funding: **$1,775,967**
Benefits:

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 collaborated 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. This project aimed 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 2022, the project team performed heat-flux measurements for the different conditions and compared them with the performance of traditional IR burners. Researchers reviewed the data from the host site, which looked promising. The team expects more discussions with the manufacturing partner and the host site and more data gathering.

Co-Funders: UTD Members, Solaronics

Start Date: 06/01/2020
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$4,600**
Total Project Cost: **$300,000**
Total SCG Cost: **$9,200**
Total Co-Funding: **$290,800**
Benefits:

UTD Sequestering Non-Condensable Gases for Enhanced GHP Reliability - Phase 2 (1.19.E.2)

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, reliability, safe operation, and reduced cost of any absorption-type heat pump. It is important to minimize the impact of non-condensable gases on long-duration performance and reliability to successfully advance the use of high-efficiency gas absorption heat pumps (GAHP). The project team plans to demonstrate the technology's performance in a prototype GAHP. Phase 1 of this project is complete, and the team is preparing the final report. For Phase 2, the project team will finalize approaches toward novel corrosion inhibitor methods for non-condensable gas management. The project team is reviewing options for the initial procurement of samples for testing, fulfilling an 18-point test matrix in the test vessels.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$1,064**
Total Project Cost: **$240,000**
Total SCG Cost: **$2,364**
Total Co-Funding: **$237,636**
Benefits:

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

UTD Thermoelectric Generator for Self-Powered Water Heater - Phase 4 (1.17.B.4)

This project aims 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 stages to develop the critical components and integrate the design to power a condensing tankless water heater. Three different approaches to integrating the thermoelectric generator with a storage-type water heater were analyzed. Opportunities to leverage UTD's funding with potential prime funding from governmental agencies that are interested in funding research in resilient, high-efficiency water heating were sought, as this research continues.

Co-Funders: UTD Members,

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$3,000**
Total Project Cost: **$240,000**
Total SCG Cost: **$6,000**
Total Co-Funding: **$234,000**
Benefits:

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

SUBPROGRAM: COMMERCIAL FOOD SERVICE

GTI ENERGY SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration

Start Date: 11/01/2019
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$2,052,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$1,852,000**
Benefits:

The project objective is to demonstrate at least 25% NOx emission reduction by optimizing the combustion process in a multi-zoned commercial baking oven within a South Coast Air Quality Management District environmental justice area. The team estimates a 10% reduction in carbon dioxide emissions 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. The project team will follow this step by testing and performing data collection over a wide range of operating conditions to illustrate 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 team was delayed in completing field engineering and demonstration system installations until mid-2021. Fortunately, the team turned the project around in August of 2021 when they installed the demonstration system (i.e., the modified combo-burners and oven control system). In 2022, the team was able to successfully startup and shakedown the demonstration system. They are now actively collecting data and monitoring the performance of the EcoZone burner.

Co-Funders: SCAQMD, Kroger, SoCalGas Energy Efficiency

UCI Hydrogen Blend Commercial Stove Low NOx Catalytic Burner Development

Start Date: 11/01/2021
End Date: 11/01/2023
Status: Active
2022 Funds Expended: **$55,000**
Total Project Cost: **$305,000**
Total SCG Cost: **$305,000**
Total Co-Funding: **$0**
Benefits:

The goal of the proposed work is to design and build an ultra-low NOx catalytic burner to combust natural gas and hydrogen blends (up to 50%) for commercial cooking applications. This work will be phase one of a two-phase study. After burner development, phase two will include the development of a commercial prototype and involve a commercialization partner to help with the commercialization process. Currently, NOx emissions from cookstoves are not subject to regulation, but they are a strategic end-user device to be considered for future building emissions reductions. 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. The team can reduce NOx emissions by 1) reducing the combustion temperature, 2) decreasing the flue gas residence time in the high-temperature zone, and 3) reducing the excess oxygen in the fuel and 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 needs to be a study evaluating fuel blends, resulting NOx emissions, and commercial cooking applications. In 2022, the research team completed a comprehensive literature review of the technology's current state and completed the initial burner design. As a result, the team fabricated a 3-D printed prototype burner for experimental evaluation focused on fuel flow and to support the assessment of an optimal catalyst substrate and structure.

Co-Funders: N/A

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

UTD CFS Burner Technology Carbon Reduction Including Hydrogen Blending - Phase 2 (1.21.H.2)

The objective of this project is to determine the decarbonization potential of typical commercial food service (CFS) appliances when utilities blend up to 30% hydrogen with natural gas. Phase 2 will focus on full appliance testing and cooking performance impacts and build on the testing of standalone burners and controls in Phase 1. GTI, through its contacts at the North American Foodservice Equipment Manufacturers, will work with CFS manufacturers to identify and supply appliances for testing. Some key performance indicators include the production of efficiency and emissions data for various stock CFS appliances. The team will observe hydrogen blends operating between 0-30%. The team will also create initial recommendations for relevant limits on hydrogen for a spectrum of stock CFS appliances. Finally, the project group will assess possible near-term modifications (e.g., controls or burner designs) to increase allowable hydrogen content. In 2021, a laboratory setup was designed and assembled to test CFS burners. The project team tested a fryer pilot burner as part of the shakedown of the test stand and data-acquisition system. During the shakedown, the team identified a need for a different capture hood and a more accurate gas flow meter. The project team addressed both issues, and testing resumed. In 2022, the team completed testing with the fryer pilot burner. The project team is currently testing a tube burner.

Co-Funders: UTD Members

Start Date: 07/01/2022
End Date: 01/31/2024
Status: Active
2022 Funds Expended: **$10,000**
Total Project Cost: **$160,000**
Total SCG Cost: **$17,778**
Total Co-Funding: **$158,222**
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. The project team tested existing commercial food service appliances with hydrogen and natural gas blends. Specific topics include decarbonization, hydrogen blending (0-30%), energy reduction technologies, and controls, including burner modulation. In 2021, a laboratory setup was designed and assembled to test commercial food service (CFS) burners. The project team tested a fryer pilot burner as part of the shakedown of the test stand and data-acquisition system. During the shakedown, the team identified a need for a different capture hood and a more accurate gas flow meter. The project team addressed both issues, and testing resumed. In 2022, the team completed testing with the fryer pilot burner. The project team is currently testing a tube burner.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$40,000**
Total Co-Funding: **$110,000**
Benefits:

UTD Commercial Foodservice Equipment Demonstrations - Phase 7 (1.14.B.7)

This project aims to provide end users, utilities, and researchers with the ability to quickly evaluate appliances, whether gas-fired or electric, and understand their performance. Researchers gathered valuable data from a restaurant and commercial cooking field demonstrations to quantify the operating and efficiency benefits of gas-fired commercial food service equipment in real-world situations. The team tested some of the industry's most recent market introductions, including a steam kettle, range, wok, conveyor oven, convection oven, boiler-less steamer, low-oil-volume fryer, and grill. The team-focused activities were in two areas. The first area focused on single-day demonstrations at test kitchens and trade shows, illustrating how well specific equipment performs. The second area focused on long-term demonstrations in restaurants.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$90,000**
Total SCG Cost: **$9,000**
Total Co-Funding: **$81,000**
Benefits:

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

UTD Gas Fired Warewasher - Phase 2 (1.19.B.2)

The project objective was to develop a gas-fired prototype of a conveyor-type warewasher (dishwasher). Door-type (low-volume) and conveyor-type (high-volume) warewashers represent a combined 43% of the market segment of warewashers. Most commercial warewashers are electric, and many 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 warewashers, modeling different heat exchanger designs to determine the best-performing configurations that fit into the footprint of an existing electric warewasher. Various prototype heat exchanger(s) were fabricated and put into a prototype unit along with a burner and blower. The team tested a functional prototype for combustion efficiency, safety, and emission standards. Researchers modeled thirteen variations of heat exchanger designs and examined the combustion system in the laboratory with the prototype tank and heat exchanger. The project team used custom controls to tune everything, and the group achieved highly favorable results (under 10ppm NOx). Technicians assembled the burner, blower, and gas valve assembly, along with a new controller for the combustion system. The project group completed the initial testing of the combustion system with the prototype heat exchanger. 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: 07/01/2020
End Date: 07/31/2023
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$8,529**
Total Co-Funding: **$171,471**
Benefits:

UTD Gas Fired Warewasher Door Machine Demonstration - Phase 3 (1.19.B.3)

The project objective is to develop and demonstrate a gas-fired prototype door-type warewasher (dishwasher). Door-type (low-volume) and conveyor-type (high-volume) warewashers represent a combined 43% of the market segment of warewashers. Most commercial warewashers are electric, and many 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 warewashers, modeling different heat exchanger designs to determine the best-performing configurations that fit into the footprint of an existing electric warewasher. In 2022, the project team tested a control system for the door-type warewasher burner system that controls ignition for the burner, firing rate, and safety controls. Upon completion of the controller testing, the final prototype system will be sent to the manufacturing partner for further testing. The manufacturer will test one prototype in its facilities and one in the research laboratory to prove the machine's performance. Initial discussions regarding the field demonstration of the gas-fired door warewashers have begun. Research on the conveyor warewasher is currently focusing on heat-exchanger modeling and design.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$145,000**
Total SCG Cost: **$19,938**
Total Co-Funding: **$125,062**
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)

The objective of this project is to develop a prototype high-efficiency smart convection oven that increases efficiency by at least 5% and also integrates smart operating controls to maximize food preparation quality and consistency. Earlier, researchers investigated a high-efficiency oven design, showing that this configuration in bench-scale tests achieved a 3% improvement in cooking efficiency and a 10% improvement to preheat energy use despite needing to be fully optimized. Based on these results and improvement areas in the initial design, the project team anticipates a 5%-10% increase in cooking efficiency should be achievable once they optimize the system. In addition, the team expects a targeted 10%-20% reduction in NOx and carbon monoxide emissions. In this project, researchers are incorporating a heat exchanger to recover heat from the flue and feed it back into the combustion air. In 2021, the project team completed basic testing on the modified heat exchanger. Researchers specified and ordered a new prototype burner with a premix system. The project team installed the new burner in the oven and completed some initial testing. The group modified the oven to mount the new burner instead of the existing burner. In 2022, additional testing and modification were underway. 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: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$23,111**
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)

This project aims to transfer prior patented technology (UTD project 2.12.M) to introduce a commercial product with one or more major baking industry manufacturers. The project team developed an innovative, cost-effective, low-NOx ribbon burner combustion system. Subsequently, they demonstrated it in a full-scale production environment at a wholesale commercial bakery in California. Results of the prototype unit in the field test showed a 50% NOx reduction and approximately 5% energy savings. A 30% market penetration in the baking industry in California would result in an estimated reduction in natural gas consumption 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. In 2021, the project team began expanding the technology commercialization outreach beyond U.S. markets into Europe and Asia. The project team completed several technical communications. The project team identified some combustion-equipment manufacturers that may be interested in licensing and commercializing the technology. In 2022, the project team continued discussions with baking industry leaders (manufacturers, suppliers, and end users) and investment entities. The technology has attracted the interest of baking-industry OEMs and end-users at 2022 BakingTech early this year. The team identified a potential commercialization partner, and they initiated licensing discussions.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$6,600**
Total Project Cost: **$125,000**
Total SCG Cost: **$33,000**
Total Co-Funding: **$92,000**
Benefits:

UTD Next Generation Commercial Foodservice Burners - Phase 6 (1.14.A.6)

This project focused on designing, developing, and testing prototypes of higher-efficiency, lower-emission, commercial food service appliances using advanced burner concepts proven for other markets and products (e.g., residential furnaces and water heaters). For this phase, the specific goal was to develop prototype commercial food service (CFS) appliances with improved efficiency and emissions using technology developed in the earlier stages of this project. This step included the development of two energy-efficient CFS fryers with NOx emissions much less than current fryers on the market as part of a project that had prime funding from SCAQMD. Compared to a standard fryer, the ones developed in this project had lower NOx emissions with improved efficiency. Based on a 100% market penetration, one fryer has a potential NOx savings of 502.9 tons/year (92% reduction), and the other has a potential NOx savings of 383.8 tons/year (70.2% reduction) within SCAQMD's territory in southern California. A more realistic expectation is a 20% market penetration that gives a potential NOx savings of 100.6 tons/year (18.4% reduction) and 76.8 tons/year (14.1% reduction) for the two fryers. In 2022, the team completed the project and issued a Final Report for the latest project phase in August 2022.

Co-Funders: UTD Members

Start Date: 06/15/2020
End Date: 12/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$140,000**
Total SCG Cost: **$18,375**
Total Co-Funding: **$121,625**
Benefits:

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

UTD Technical Support to Address Gas Foodservice Technologies - Phase 2 (1.21.G.2)

This project aims to provide technical assistance to the commercial food service (CFS) industry to address issues with energy efficiency, environmental impact, decarbonization, cooking performance, and COVID recovery. GTI Energy will continue to represent the gas industry as a part of technical advisory committees, including the NAFEM Technical Advisory committee, ASHRAE CFS Ventilation, Blue Flame Alliance Technical Advisory Committee, and input to SCAQMD CFS low NOx regulations. The project team will also work with CFS manufacturers and end users to provide data and education on the benefits of efficient gas appliances. Some topics GTI Energy will address and participate in include decarbonization through hydrogen blending, energy efficiency, emissions, and ventilation requirements.

Co-Funders: UTD Members

Start Date:	08/31/2022
End Date:	08/31/2024
Status:	Active
2022 Funds Expended:	**$5,000**
Total Project Cost:	**$100,000**
Total SCG Cost:	**$5,000**
Total Co-Funding:	**$95,000**

Benefits:

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

SUBPROGRAM: INDUSTRIAL PROCESS HEAT

GTI ENERGY Booster Ejector Enhancement of Compressor Refrigeration Demonstration

In this California Energy Commission (CEC) funded project (EPC-19-023), the team is developing a Booster Ejector Enhancement of Compressor Refrigeration (BEECR) for field demonstration. The proposed solution recovers steam from a gas-fired cooker, extracts the waste heat and water, and sends the waste steam through the ejector, which then drives the chiller reducing the consumption of electricity from the refrigeration cycle. The project team will save natural gas and water by utilizing the waste steam for facility needs and providing pre-heating and boiler-in-feed water heating. The project seeks to achieve at least a 20% reduction in energy consumption in addition to water savings and significant reductions in nitrogen oxides, particulate matter, and greenhouse gas emissions through energy savings. In October 2021, the project team submitted a draft report to the CEC about system design, baseline testing, and a field test plan. By the end of 2021, the project team had made progress toward the completion of system installation and package monitoring. In 2022, the project team was significantly delayed due to the Ukraine War, where a key project partner, Wilson Engineering Technologies, had to withdraw from the project. The project team is working on a revised technical plan with the CEC.

Co-Funders: CEC

Start Date: 12/01/2020
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$20,000**
Total Project Cost: **$1,731,556**
Total SCG Cost: **$110,000**
Total Co-Funding: **$1,621,556**
Benefits:

GTI ENERGY Burner Exchange to Support Radiative Recuperator Demonstration

The project aims to demonstrate natural gas savings and emission reductions utilizing an advanced radiative recuperator with secondary emitters (RRSE). For this CEC-funded project (PIR-15-006), GTI Energy and the host site, California Die Casting (CDC), modified a furnace to melt aluminum for die casting with an improved 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 project team will couple the RRSE with commercial hot air, ultra-low NOx burners (Bloom 1500S060C) operated with air preheated to as high as 1200ºF. This approach forms 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 leaves the RRSE to increase furnace efficiency further, lowering natural gas demand. The simple payback for this technology is 30 months. The team completed this project but cannot publish the final results until the CEC's final approval.

Co-Funders: CEC, UTD Members

Start Date: 09/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,694,999**
Total SCG Cost: **$74,999**
Total Co-Funding: **$1,620,000**
Benefits:

GTI ENERGY Ceramic Radiant Tube Inserts for Waste Heat Recovery Demonstration

The goal of this project is to demonstrate the efficacy of Ceramic Radiant Tube inserts in capturing waste heat. In this field demonstration, Radiant Tube Inserts (RTI) were inserted into the exhaust ends of tubes at California Steel in Fontana, California. Once installed, the RTIs absorbed the heat from the hot exhaust gas that would otherwise escape and radiate the captured heat back into the furnace. The resulting heat capture improved energy efficiency, temperature uniformity, tube life, emissions reductions, production quality, and furnace throughput. Thus, this demonstration has proven that low-cost, highly effective waste heat recovery devices in RTIs are available for commercial applications. This project also has shown 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 provided test report), and milestone 3 (installation of the radiant tube inserts into the furnace burners). In 2022, the project team was delayed due to scheduling conflicts, broken inserts that required replacement, and major repairs to the furnace, which required reconducting the baseline testing. Fortunately, the team completed all technical tasks by the year's end. Preliminary results showed a 44% energy savings with no significant emissions increases. The payback period is estimated to be less than one year. The next step is to complete a final report and engage project stakeholders for knowledge dissemination and commercialization activities.

Co-Funders: SoCalGas ETP

Start Date: 01/04/2021
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$52,798**
Total Project Cost: **$392,798**
Total SCG Cost: **$352,798**
Total Co-Funding: **$40,000**
Benefits:

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

GTI Energy Hydrogen Commercial and Industrial Market Characterization End-Use Research

This project will support the CEC's GFO-21-503 - Examining the Effects of Hydrogen in End-Use Appliances for Large Commercial Buildings and Industrial Applications. The objective is to conduct a technical study of the impacts of utilizing hydrogen, blended with natural gas and 100% hydrogen, in existing appliances and equipment as a decarbonization strategy for large commercial buildings and industrial processes in California. The research aims to identify and resolve key research and technology gaps through techno-economic analysis, laboratory testing and calibrated simulation of representative combustion equipment and materials, air quality modeling, and stakeholder engagement. The focus will be on understanding the cost, performance, and safety implications and the emissions benefits of adopting hydrogen in these sectors. The project team will also identify and address key benefits, challenges, and potential solutions for increasing hydrogen use in end-use equipment. GTI Energy is leading this effort with the Electric Power Research Institute (EPRI) and the University of California, Irvine (UCI) to complete this wide-reaching study. The team will establish a methodology to select equipment categories based on the magnitude of the GHG emissions associated with the type and the potential for reduction via hydrogen use. The techno-economic analysis will seek to understand the decarbonization potential of using hydrogen to fuel these equipment categories and other measures (e.g., energy efficiency) to 2035 and 2050. The team will make a comparison against business-as-usual and alternative pathways (e.g., electrification vs. diversified path).

Co-Funders: UTD Members

Start Date: 09/01/2022
End Date: 09/01/2026
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$3,557,500**
Total SCG Cost: **$752,500**
Total Co-Funding: **$2,805,000**
Benefits:

GTI Energy Solar Thermal and Particle Fluid Demonstration

The goal of this project was to successfully demonstrate a solar thermal collector and novel particle thermal storage medium in an industrial heating application. Particle heating, in combination with thermal transfer and storage technology, can recover and store energy at up to 1000°C (1832°F) for on-demand generation of heat and power. This approach would allow the recovery and storage of energy from solar or exhaust gases of natural gas-fired equipment. It could be applied to cyclic or batch processes, which are challenging for conventional heat recovery approaches. The demonstration will verify the technology's performance, energy savings, and emissions benefits. This project will first test the technology at the UC Merced campus's 60kW (12m solar collector) scale. Upon successful testing, the team will deploy the system at the USG plant in the Imperial Valley. In 2021, the team completed the on-sun testing. 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 the absorber and secondary reflector causing intercept factor reduction, 2) a higher fluid flow rate required as per the thermal model to minimize temperature gradients, and 3) superposition of bending caused by the dead weight of the receiver and bending caused by non-uniform temperature distribution. The team expects a final report in late Q4 of 2022. The project lead is working on a follow-on effort to further the particle fluid as a heat exchange medium.

Co-Funders: ARPA-E, CEC

Start Date: 10/01/2018
End Date: 12/31/2022
Status: Complete
2022 Funds Expended: **$20,000**
Total Project Cost: **$3,260,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$2,910,000**
Benefits:

GTI ENERGY Waste Heat Effective Transfer in Brewery & Distillery Demonstration

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). In this CEC-sponsored field demonstration (PIR-19-004), the project team will install a Waste Heat Effective Transfer (WHET) technology in the flue of two micro-distilleries. The WHET recovers waste heat from the brew kettle to provide preheated plant water in the facility's hot water tank, significantly reducing natural gas consumption and resultant emissions. 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, increasing gas mixing, resulting in increased average gas temperature and higher overall heat transfer rates than its competitors.

Co-Funders: CEC, Yolo Brewing, Tower Brewing, PG&E, UTD Members

Start Date: 12/01/2020
End Date: 03/29/2024
Status: Active
2022 Funds Expended: **$48,664**
Total Project Cost: **$1,948,387**
Total SCG Cost: **$177,821**
Total Co-Funding: **$1,770,566**
Benefits:

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

UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration

The objective of this project is to study, demonstrate, and optimize an integrated, zero-emission prototype for the direct reduction of iron (DRI) with hydrogen produced from a Solid Oxide Electrolysis Cell (SOEC) system. The project is a close collaboration of academia (University of California, Irvine, and Politecnico di Milano), industry (FuelCell Energy (FCE), Inc.), and a technology transfer company (LEAP). The team has proposed three system configurations representing incrementally integrated layouts between the SOEC unit and the shaft furnace. In 2021, the team determined the primary energy consumption < 8 GJ/ton Direct Reduced Iron (DRI) for the best-performing Hydrogen Direct Reduction configuration at nominal load. The team also completed a SOEC model validation on voltage-current curves with an average prediction error of <5% on the steam electrolysis experimental measurements. The model predicted electric-to-hydrogen production efficiency of < 35 kWh/kg (or >95% with 120 MJ/kg of H2 Lower Heating Value) at nominal design steady-state conditions. The project team plans to complete the validation of the SOEC co-electrolysis model for the Hybrid Hydrogen Direct Reduction (HDR) scenario with literature data, begin pressurized stack testing at FCE's manufacturing site, optimize system layouts for steam electrolysis scenarios, and initialize system configurations for co-electrolysis (hybrid HDR) in 2022.

Co-Funders: DOE, UCI, Politecnico di Milano, FuelCell Energy, Inc., LEAP

Start Date: 03/01/2021
End Date: 03/01/2024
Status: Active
2022 Funds Expended: **$137,500**
Total Project Cost: **$5,699,861**
Total SCG Cost: **$550,000**
Total Co-Funding: **$5,149,861**
Benefits:

UTD Energy Source Options for Industrial Users - Phase 2 (2.20.E.2)

The objective of this project is to provide a robust, user-friendly analytical tool that can help decision-making, which will drive decarbonization and achievement of local environmental targets. This approach will support industrial and large commercial sectors' reliable and cost-effective energy supply. The final product will be a roadmap for adopting natural gas and other energy options. This project aims to expand and simplify the use of a detailed techno-economic analysis developed in a previous project phase. The analysis considered fuel-switching and electrification scenarios for industrial and large commercial end users. The project team improved the prior study by transitioning the spreadsheet-based research to a convenient online tool that includes various applications beyond boilers. In 2021, the team analyzed a database of industrial energy consumption data for key end-use applications. The project group used it to prioritize the industrial technologies based on geographical locations that the team linked to individual funders' service territories. In 2022, the project team transitioned the spreadsheet-based tool to the online platform. The team identified several GHG reduction pathways for process-heating segments and evaluated preliminary, including net-zero carbon alternative fuels, renewable energy options, energy efficiency improvements (waste-heat recovery), electrification, hybrid energy sources, and system optimization and control.

Co-Funders: UTD Members, ESC

Start Date: 07/01/2021
End Date: 01/31/2023
Status: Active
2022 Funds Expended: **$1,281**
Total Project Cost: **$165,000**
Total SCG Cost: **$2,581**
Total Co-Funding: **$162,419**
Benefits:

UTD Gas Quality Sensor Validation Hydrogen Sensor - Phase 3 (2.14.0.3)

This project will broaden the Gas Quality Sensor (GQS) capability to measure gas composition, heating value, Wobbe number, and methane number for natural gases blended with hydrogen. Indicators that the team sees suggest that GQS accuracy will improve when they add a hydrogen detector. The team will add a hydrogen detector to the previously developed GQS and conduct calibration tests in the project's third phase. Phase three will provide data allowing the extension of the GQS capabilities beyond natural gases to hydrocarbon fuel gas mixtures containing hydrogen. The team will give the generated data to the licensee CMR Group, and combining it with their data, will help to accelerate GQS deployment with hydrogen detection capability. The team will conduct testing in the GTI Energy Industrial Combustion Laboratory's Optical lab space. The lab has the needed blending station, mixing system, computer, and data acquisition system. When CMR is ready to ship the GQS unit for testing, GTI Energy engineers will acquire needed calibration gases and set up instrumentation and data collection computers. This work will take a small amount of the team's time and needs to be conducted just before testing the GQS unit.

Co-Funders: UTD Members, CMR Group

Start Date: 07/01/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$85,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$70,000**
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 and renewable natural gas (H2/RNG) 0.5 to 1 MMBH burner in a commercial-scale furnace at GTI Energy's laboratory. The team will partner with two leading large industrial end users and two national laboratories to make certain that the final prototype burner meets the requirements of the representative end users. GTI Energy has successfully developed and bench-scale tested a 3D-printed burner design at 0.05 MMBH scale. This unit can operate efficiently and robustly with hydrogen up to 40%. The team will use the funding to demonstrate a scaled-up burner with higher hydrogen (up to 60%) to evaluate and commercialize the technology with two leading end users inOak Ridge National Laboratory (ORNL), and Argonne National Laboratory (ANL). The team will separately authorize and fund field testing of the prototype. In 2021, the project team evaluated the testing apparatus and instrumentation required to perform hydrogen testing. The project group ordered a flow meter, controls, and other equipment for high-hydrogen testing. In 2022, the project team will conduct CFD simulations for design evaluation. The project group is also analyzing a burner design for higher hydrogen firing rates with all the design conditions. The team is currently working on the design of the gas mixing station.

Co-Funders: UTD Members, ORNL, ANL

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$42,000**
Total Project Cost: **$340,000**
Total SCG Cost: **$84,000**
Total Co-Funding: **$256,000**
Benefits:

UTD High-Efficiency Crop Drying Process (2.21.D)

The objective of this project was to advance the development of a high-efficiency, low-temperature, UTD-patent-pending, low-labor crop drying process. The team can retrofit this approach into existing farm operations. The project group aims to perform preliminary design and techno-economic analyses on two crops of high market value and identify partners for commercial scale-up. Sun drying is the simplest and cheapest method of drying. The industry uses this approach 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 between the customer's drying needs and an effective high-efficiency crop drying device. In 2022, the project was able to complete and issue a final report. Two high-value crop types were identified and prioritized for further evaluation – tree nuts (almonds, walnuts, and pistachios) and field crops (alfalfa and hemp).

Co-Funders: UTD Members

Start Date: 12/31/2021
End Date: 4/31/2022
Status: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$97,000**
Total SCG Cost: **$38,000**
Total Co-Funding: **$59,000**
Benefits:

UTD Next Generation Infrared Burner - Phase 4 (2.16.A.4)

This project aims to test and optimize the performance of the new gas-fired IR burner that UTD is developing under previous project efforts (2.16.A) in partnership with Solaronics, Inc.- a leading gas-fired IR heater OEM, and a top metal foam material OEM. The goal is to operate on high hydrogen blended natural gas, perform tests on the burner with up to 100% hydrogen, and optimize the design to achieve fast start-up, uniform temperature profile, and ultra-low emissions (i.e., < 5 ppm NOx, < 30 ppm CO). Some key performance indicators include demonstrating stable operation with up to 100% hydrogen, providing comparative analysis in terms of temperature, heat flux, stability, emissions, and turndown capability, and achieving fast start-up, uniform temperature profile, and ultra-low emissions. In 2022, the team performed heat-flux measurements for different conditions and compared them with the performance of traditional IR burners. Researchers reviewed the data from the host site, and these looked promising. The team expects more discussions with the manufacturing partner and the host site, and they will gather additional data.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$21,400**
Total Project Cost: **$180,000**
Total SCG Cost: **$21,400**
Total Co-Funding: **$158,600**
Benefits:

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

UTD Ribbon Burner Performance with Hydrogen-Blended Gases (2.22.B)

This project aims to evaluate traditional ribbon burners' performance when operating with hydrogen and hydrogen-natural gas blends (i.e., 0-100%). The goal is to prove the technical feasibility and identify optimal design performance and design gaps. Some key performance indicators include heat release-temperature profile-emission data in the range of tested conditions and the correlation between hydrogen content in the fuel and test burner performance. The data and correlations obtained will serve as a basis for developing innovative decarbonization concepts that will integrate green hydrogen production, advanced waste heat, and water recovery combined with VOC mitigation and self-powered control.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$20,000**
Total Project Cost: **$175,000**
Total SCG Cost: **$20,000**
Total Co-Funding: **$155,000**
Benefits:

UTD Thermal Ejector for Water Capture from Humid Exhaust Demonstration - Phase 3 (2.17.A.3)

The objective of this project was to demonstrate novel thermal ejector technology. The aim was to recover useful process water from the humid exhaust gas and increase energy efficiency in a field demonstration. The team located the project 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). The field demonstration will recover up to 100 gallons of water per hour, representing 95% of 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. The project team has recovered more than 60,000 gallons of water 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 gallon of water recovered declines as ambient air temperature declines because less outside air is needed to remove heat from the thermal ejector pipes. In 2022, the team submitted a draft Final Report to CEC, which they will publish after their final review. Ongoing activities for this project include: conducting parametric system testing to optimize output and efficiency; and completing 12-month, long-term-durability tests. The project team is reviewing the final demonstration test data analysis to obtain energy savings estimates.

Co-Funders: CEC, UTD Members

Start Date: 07/01/2019
End Date: 03/31/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$1,480,000**
Total SCG Cost: **$16,250**
Total Co-Funding: **$1,463,750**
Benefits:

UTD Zero Emissions Processes with Carbon Recovery (2.21.C)

This project will develop a new synthetic air combustion (SAC) process to 1) improve industrial boiler or furnace efficiency when using natural gas, 2) lower carbon dioxide emissions, and 3) provide a means to capture or convert carbon dioxide into valuable products. The team will conduct laboratory tests in industrial conditions, and the results will help compare calculated and experimental results when using SAC versus typical air-fired combustion. The objective is for this process technology to help create a lower-carbon future while using natural gas in industrial boilers and furnaces. In 2021, the project team conducted synthetic air-combustion tests using artificial air containing oxygen and carbon dioxide at ambient temperature in a commercial burner. Results confirmed that burners run well on synthetic air. The team has conducted tests with preheated artificial air containing steam. In 2022, technicians modified the experimental furnace test platform to prepare for the next round of tests.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$7,500**
Total Project Cost: **$150,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$135,000**
Benefits:

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

SUBPROGRAM: RESIDENTIAL APPLICATIONS

EAC H2 Home Appliance Set Validation Test Research

Start Date: 12/01/2021
End Date: 6/01/2023
Status: Active
2022 Funds Expended: **$91,650**
Total Project Cost: **$91,650**
Total SCG Cost: **$91,650**
Total Co-Funding: **$0**
Benefits:

The SoCalGas Engineering Analysis Center (EAC) conducted validation testing on a set of appliances for deployment at the [H2] Innovation Experience, the first project of its kind in the U.S. aiming to show how carbon-free gas made from renewable electricity can be used in pure form or as a blend to power clean energy systems of the future. The focus of this work was to perform comprehensive equipment validation at the EAC lab with concentrations of hydrogen blended up to 30%. The research team analyzed safety (i.e., flashback, ignition failure, ignition delay, flame profile), emissions, and energy efficiency, which is useful for estimating energy savings. By leveraging the [H2] Innovation Experience, SoCalGas RD&D can field demonstrate a suite of appliances, including a Rinna RU130iN tankless water heater, LG UPSG3014ST Oven Range, and Valor 1700KP fireplace, at up to 20% hydrogen blend. In 2022, the EAC completed its appliance set testing. The equipment was deployed at the [H2] Innovation Experience, which is available for public tours.

Co-Funders: N/A

GTI Energy Advanced High Efficiency, Low-Capacity HVAC Systems

Start Date: 10/01/2017
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$900,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$750,000**
Benefits:

The goal of this project is the field demonstration and performance testing of advanced high-efficiency, low-capacity heating, ventilation, and air conditioning (HVAC) systems. The team coupled these systems with measures to reduce infiltration and improve building envelopes. The project group outfitted five existing single-family homes with these units and envelope improvements. The aim was to achieve more than 30 percent HVAC energy savings compared to a typical Los Angeles Basin home with standard equipment. The project team produced 24 months of data from five homes in Los Angeles and Orange County. The newly installed equipment had a lower capacity than Title 24 compliant or existing systems, 50% or lower than the equipment in the demonstration homes. The results illustrated the benefits of envelope upgrades and right-sizing the HVAC for homes with improved envelopes. The project team leveraged a combination of utility data analysis and a calibrated BEopt model to prove the potential for HVAC energy savings to be greater than 30%. The project team submitted the final report in November 2021, which they will publish as an official CEC publication. A public webinar was held on August 25, 2021, to share the project findings.

Co-Funders: CEC

GTI Energy Hydrogen Blend Burner Design Analysis and Guidelines Research

Start Date: 09/01/2021
End Date: 06/30/2023
Status: Active
2022 Funds Expended: **$210,000**
Total Project Cost: **$280,000**
Total SCG Cost: **$280,000**
Total Co-Funding: **$0**
Benefits:

In this project, GTI Energy proposes developing numerical models (i.e., computational fluid-dynamic and reduced-order models) that can quickly simulate different burner types and design variations. The project team will validate the models against experimental data and then use them 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. In 2021, GTI Energy completed the initial literature review of reduced-order models and classic burner design methods. Based on the literature review, GTI Energy 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 Energy has also begun assembling a list of appliances and burners to test. In 2022, GTI Energy prepared a market survey to understand the types and prevalence of legacy appliances still operating in the SoCalGas service territory. E&W, a consultant assisting with the market survey task, has completed the survey and compiled the results into a draft report issued in late November. GTI Energy is currently reviewing the results with E&W. The team received 27 "good" responses from a combination of homeowners, renters, and property managers. Lastly, GTI has completed testing with the first gas dryer burner identified, indicating no issues with hydrogen blends up to 30% at typical operating conditions. The team has also tested a cast iron boiler burner with up to 30% hydrogen, with no stability or emissions problems observed.

Co-Funders: N/A

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

GTI Energy Improving Efficiency of Wall Furnaces in CA Homes Demonstration

GTI Energy seeks to accelerate the availability and adoption of higher efficiency retrofit options for atmospherically vented wall furnaces prevalent in California's affordable multifamily housing. As wall furnaces are popular in affordable multifamily housing due to their low up-front costs, concentrating the benefits of developing better replacement options in low-income and disadvantaged communities. 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 access to a drain. GTI Energy anticipates that the retrofit packages will result in 10-20% annual utility bill savings with a 10-year payback. To accelerate adoption, the project team will conduct market outreach and technology transfer to property owners, installers, manufacturers, and utilities. In 2021, the project team completed baseline monitoring of all demo units. At the end of 2021, the wall furnace retrofit demonstration and monitoring of the site and equipment were underway. In 2022, the team completed the retrofit monitoring, and a technical advisory committee meeting was held on October 2022 to share the results with the CEC. The team expects the CEC to publish the final report in 2023.

Co-Funders: CEC

Start Date: 07/31/2019
End Date: 08/15/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$1,110,000**
Total SCG Cost: **$110,000**
Total Co-Funding: **$1,000,000**
Benefits:

GTI Energy Residential Gas Heat Pump Water Heater Field Demonstration

For this project, co-funded by the California Energy Commission (CEC), GTI Energy seeks 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 out-reach events. During 12 months of field and lab testing, GTI Energy identified and addressed several challenges, including minor mechanical failures and a need for installation guidelines addressing the new system's venting, electrical service, and space requirements. Upon project completion, GTI Energy demonstrated a product and a solid market. Preliminary results show that this technology provides energy consump-tion and greenhouse gas emissions reductions of roughly 54% and 49%, compared to conventional water heaters. The CEC will publish project outcomes and results in an official publication.

Co-Funders: CEC

Start Date: 04/17/2017
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$1,272,355**
Total SCG Cost: **$188,125**
Total Co-Funding: **$1,084,230**
Benefits:

GTI Energy Residential Gas Heat Pump Water Heater North America Field Demo

In partnership with GTI Energy and multiple North American utilities, the project's objective was to deploy approximately 60 residential gas heat pump water heaters (GHPWH) to collect qualitative and quantitative data in regions representing diverse climates and housing charac-teristics. The goals were to 1) demonstrate a commitment to GHPWH commercialization; 2) evaluate product readiness across various climates and housing stocks with an emphasis on reliability, efficacy, efficiency, installation experience, customer satisfaction, and manufacturer or technology developer business capabilities; 3) support utility program development with savings, cost, and installation information needed to develop and deploy programs upon product launch quickly; 4) support timely product launch by communicating real-time performance information to the manufacturer with a goal of a product launch by 2022, and 5) prime the market by providing hands-on experience to local distribution and installation companies. Despite the team's several attempts to assist OEMs in developing a suitable product for the field demonstration, they determined that additional time for product development would be required. The project team closed out the project and will monitor the GHPWH technology space for further developments.

Co-Funders: Nicor Gas, FortisBC, NEEA, Spire, Enbridge

Start Date: 03/31/2020
End Date: 03/31/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$5,053,405**
Total SCG Cost: **$53,405**
Total Co-Funding: **$5,000,000**
Benefits:

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

GTI Energy Strategic Pathways and Analytics for Tactical Decommissioning of Natural Gas Infrastructure Research

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. 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. Over time, decommissioning practices of the gas system will greatly impact customers and the gas and electric utilities. Ensuring that socioeconomic equity issues are not exacerbated through decommissioning is paramount. The project team includes an impartial California-based think-tank—the RAND Corp—along with SoCalGas, Southern California Edison, GTI Energy, and LA Regional Collaborative (LARC). The team will combine detailed gas system models with data on candidate communities' socioeconomic conditions to evaluate different decommissioning approaches. The team will work directly with Long Beach and Santa Monica stakeholders 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. In 2022, the project team developed a set of decommissioning scenarios with their engineering teams. They are performing detailed engineering analyses to understand the impacts of decommissioning different portions of the system in Santa Monica.

Co-Funders: CEC

Start Date: 10/01/2021
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$118,098**
Total Project Cost: **$1,091,358**
Total SCG Cost: **$125,000**
Total Co-Funding: **$966.358**
Benefits:

Lantec Development of Ultra Low NOx Forced Air Residential Furnace

This project aims to develop and design the performance and operational testing, certification, and commercialization of residential condensing and non-condensing forced air furnaces. The project will use a MicroNOx ultra-low NOx combustion technology which emits 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 to a point where the manufacturing partner has a viable product to introduce into a commercialized product line. The project team will test the prototype units per the certification test procedure contained in AQMD Rule 1111, including AQMD Method 100.1. The team will test the prototype furnaces against ANSI Z21.47, including 10,000 combustion cycles as prescribed within the standard. Lantec focused on finalizing the condensing and non-condensing prototype design and completing the non-condensing retrofit furnace. The project team anticipates delivery of the furnaces to GTI Energy for operational testing based on ANSIZ21.47 standards by March 2022.

Co-Funders: SCAQMD

Start Date: 05/01/2019
End Date: 12/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$432,500**
Total SCG Cost: **$92,500**
Total Co-Funding: **$340,000**
Benefits:

ORNL Hydrogen Fueled Cooking Equipment Development

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. In this project, the team will retrofit a residential cooking range and oven with flameless radiant burner technology for testing in the lab. This technology has many advantages, such as emissions reduction, wide turndown, safety, and operation with lean mixtures beyond flammability limits. In 2021, the project made progress toward designing and specifying a prototype. The team evaluated preliminary burner designs for different operating scenarios. The team worked with several manufacturers to fabricate the early-stage prototype design, and the project team issued a purchase order at the end of the year. In April 2022, a prototype burner was manufactured and tested with hydrogen and natural gas blends. In June 2022, the team fabricated the finalized design of burners for full system integration on a Samsung residential cooktop. In September 2022, the team installed hydrogen-compatible burners in the cooktop. Comprehensive performance testing on the cooktop using hydrogen and natural gas blends began in September, and the team completed it before the year-end. ORNL will issue a final project report and press release in the second Quarter of 2023.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 09/13/2023
Status: Active
2022 Funds Expended: **$400,000**
Total Project Cost: **$900,000**
Total SCG Cost: **$400,000**
Total Co-Funding: **$500,000**
Benefits:

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

ORNL Residential Hydrogen Blended Space Heater Development

The objectives of the project are to 1) design, fabricate, evaluate, and optimize a burner capable of operating on natural gas containing up to 40% hydrogen, 2) conduct a techno-economic-environmental analysis to support the business case, 3) study the compatibility of the developed burner with different commercial systems with regards to form and fit to design a universal retrofit kit, and 4) identify and engage with an OEM towards a commercialization pathway. In this project, a residential space heater will be retrofitted with a flameless heterogeneous burner technology to develop a clean and safe space heating appliance. The idea is to guarantee it can operate on hydrogen and natural gas fuels. The team will address emissions, safety, turn-down, reliability, and efficiency in designing the space heater. The team will give special attention to flame velocity and temperature when introducing hydrogen to the fuel mixture. Conventional burners lead to high NOx emissions due to the extreme flame temperature and high flame velocity, which makes them susceptible to flashback, thus creating safety hazards. Both factors can inhibit the usage of hydrogen-blended fuel in building heating equipment. Therefore, a low-temperature, flameless, heterogeneous catalytic oxidation burner is ideal for safely converting the fuel energy into the desired heat quality. The primary focus of the proposed effort is to enable higher hydrogen blended fuels in a 40k Btu/h space heating system which would accommodate the typical 2,000 sq ft home.

Start Date: 11/01/2021
End Date: 11/01/2023
Status: Active
2022 Funds Expended: **$225,000**
Total Project Cost: **$600,000**
Total SCG Cost: **$600,000**
Total Co-Funding: **$0**
Benefits:

Rinnai Residential GHPWH Product Development and Testing

The objective of this project was to support Rinnai America Corporation (RAC) in evaluating a European gas heat pump (GHP) combination space and water heating system (combi). The idea was to explore how the technology components can be scaled down to function in the stand-alone GHP 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 stand-alone gas heat pump water heater. This conclusion 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 completed the evaluation and delivered the final report in December 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 compared to the European version. Evaluation results show the feasibility of converting the European unit and achieving similar performance and efficiency characteristics. A plan to fully develop and transform the European version, 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: Completed
2022 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$150,000**
Benefits:

UCI Catalytic Burner Retrofitted Water Heater Lab Demonstration

This project is a follow-up to a previous project that identified several viable flameless radiant burners that the industry could retrofit to achieve near-zero NOx emissions from commercially available water heaters. While these burners have existed for some time in different applications, they have yet to be installed into water heaters. Thus, for comparison, several burner configurations will be procured and deployed in water heaters. The team will assess the performance of the retrofitted water heaters (I.e., ignition performance, efficiency, emissions, and tolerance to hydrogen content). The study will compare the results to the legacy burner technology commonly found in water heaters. The relative tolerance to hydrogen content will also be evaluated, providing insight into how these burners can help reduce carbon emissions from natural gas with hydrogen blends. In 2021, the University of California, Irvine (UCI) procured and designed one of three burner technologies they plan to develop as a retrofit kit for commercially available water heaters. They completed the first batch of preliminary tests on the first burner design. In 2022, the research team completed their initial performance, emission, and safety evaluation while beginning the design process of integrating the catalytic burner into a full-scale system.

Co-Funders: N/A

Start Date: 09/01/2020
End Date: 09/01/2023
Status: Active
2022 Funds Expended: **$55,000**
Total Project Cost: **$295,000**
Total SCG Cost: **$295,000**
Total Co-Funding: **$0**
Benefits:

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

UCI Low NOx Water Heater Retrofit for Hydrogen Blends Development

The project's objective is to take existing low NOx water heaters and improve the operational limits of hydrogen tolerance. The project's goals are to evaluate the modifications that would allow adding additional hydrogen, to carry out the improvements, and demonstrate the amount of additional hydrogen that could be blended and allow reliable operation. The team will do laboratory testing to evaluate general observations, ignition, flashback, and efficiency. In addition, the team will quantify emissions to understand how the NOx, carbon monoxide and unburned hydrocarbon (UHC) levels change with increased hydrogen addition. In 2021, the team evaluated, baselined, and proposed several modifications to the water heaters they received. Some methods they used to assess 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. In 2022, the team completed the initial testing of their appliance set. The research team focused on design modifications to improve the hydrogen tolerance of the burners and is evaluating those modifications under comprehensive safety, performance, and emissions testing.

Co-Funders: N/A

Start Date: 10/01/2020
End Date: 02/28/2023
Status: Active
2022 Funds Expended: **$85,000**
Total Project Cost: **$241,468**
Total SCG Cost: **$241,468**
Total Co-Funding: **$0**
Benefits:

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) a 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 savings and emissions reductions versus best-in-class conventional sorption and vapor compression-type THPs. The project team completed laboratory preparations for testing the BH.20 using a Virtual Test Home (VTH) protocol. The test infrastructure is complete, and the remainder of the activity focuses on data acquisition and control setup. The test apparatus is undergoing shakedown to test a different heat pump before the arrival of BOOSTHEAT's unit. BOOSTHEAT experienced a production delay in 2020-2021 for various reasons. The company addressed key technical challenges and consolidated staff under a single roof. In early 2022, the company indicated that their new units' reliability and performance had improved. BOOSTHEAT is also re-developing the packaging and controls of the thermal compressor so that the BH.20 can provide both space heating and domestic hot water. BOOSTHEAT expects to make a unit available for testing and additional technical refinement (including using a VTH protocol) in the first quarter of 2023.

Co-Funders: UTD Members, OEMs

Start Date: 07/01/2020
End Date: 03/31/2023
Status: Active
2022 Funds Expended: **$0**
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 investigated the performance of a hybrid system that is commercially available in the U.S. for space and water heating. The team evaluated this hybrid system in the virtual test home (VTH) to develop performance curves for space and water heating in multiple part-load and ambient temperatures. The industry can implement these performance curves in building energy models to quantify the 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 explored the integration of VTH with the hybrid space and water-heating equipment, leveraging the heating season of 2021-2022. For Phase 2, researchers developed infrastructure to install the selected hybrid system in the laboratory. The system operated in the 2022 heating season. The team exposed the outdoor unit to ambient temperatures from 5°F to 60°F. The team also simulated space and water heating loads using the VTH protocols considering a simulated single-family low-load home. This research is complete—the group issued a Phase 2 Final Report for project 1.19.I in June 2022.

Co-Funders: UTD Members, PERC

Start Date: 05/19/2020
End Date: 03/31/2022
Status: Completed
2022 Funds Expended: **$0**
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 Field Evaluation of Indoor Air Quality in Residential Kitchens (1.20.K)

Through field evaluations, this project aims to determine the effect of cooking emissions on residential indoor air quality (IAQ) in a scientific manner in real-world situations. This project presents the opportunity to collect field data to differentiate emissions from cooking processes versus those from appliances by comparing direct-vent range hoods versus recirculating hoods. The team prepared a residential kitchen ventilation test setup in a laboratory facility to provide additional comparative data. Activities included 1) interactions with the property manager to schedule the 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 team will compare the kitchen IAQ data among apartments; 4) analyzing IAQ data from multi-unit residences; and 5) planning for switchover of select gas to electric ranges. In 2022, the IAQ sensor packages and range cooking-location sensors gathered gas and particulate measurements from six kitchens in ENERGY STAR units and six Phius-occupied units. (Phius is a non-profit organization committed to decarbonization.) The gas and particulate data were analyzed during cook events and non-cooking periods. Researchers compared ventilation strategies based on gas and particulate measurements between the direct-vent range hood in the ENERGY STAR units and the recirculating hood and heat-recovery ventilator in the other units.

Co-Funders: UTD Members, Black Hills Energy

Start Date: 07/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$335,000**
Total SCG Cost: **$92,235**
Total Co-Funding: **$242,765**
Benefits:

UTD Gas Engine Heat Pump Modeling, Testing, and Implementation - Phase 2 (1.21.E.2)

This project aims to demonstrate the recently-introduced Yanmar Air Handling Unit (AHU) Integration Kit at a cooling-demonstration site to validate performance and savings in life cycle costs. The AHU kit pairs a high-efficiency gas engine-driven heat pump (GEHP) to a packaged rooftop air handling unit to apply GEHPs to a broader range of commercial buildings and minimize installation costs. A successful demonstration of the AHU kit will support a high-efficiency and cost-effective role for natural gas in commercial buildings for cooling-dominated climates. Some key performance indicators are to obtain at least 12 months of field data, achieve a seasonal coefficient of performance (COP) > 1 for both cooling and heating performance, and publish results in the technical paper and conference presentation. The project team compared hourly measured field data on the heating and cooling performance with the limited laboratory test data on the same unit. In 2022, the group held regular meetings with the National Research Council Canada staff and Yanmar Co., Ltd. to collaborate on GEHP model development and share performance data.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$5,900**
Total Project Cost: **$180,000**
Total SCG Cost: **$5,900**
Total Co-Funding: **$174,100**
Benefits:

UTD HeatAmp Absorption 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. The team will optimize a cost-effective alpha prototype "burner/boiler" assembly and design a system for future evaluation in GTI Energy's laboratory. The unit draws in and upgrades ambient heat via an outdoor fan coil. The sorption module drives the heat pump effect, which houses ammoniated salts. The system aims to achieve a projected energy and emission reduction of >33% vs. standard fuel-fired equipment. The primary target is domestic hot water applications, with options for combined space and water heating ("combi") or pool heating functions. In 2022, the team readied the alpha burner and boiler assembly for testing. Upon completion of testing, HeatAmp will ship proprietary hardware to the research team. In parallel, researchers will complete the burner and boiler test plan with HeatAmp's input and, upon finalization, make necessary preparations to facilitate experimental testing of the burner and boiler. The team will prepare a system design analysis memo based on the whole-system modeling currently underway. Under a subsequent phase, the project team will fabricate, evaluate, and improve full-packaged prototype heat-pump water heaters.

Co-Funders: UTD Members

Start Date: 12/31/2021
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$2,286**
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)

This project aimed to develop and demonstrate a hybrid residential combined HVAC and water heating (combi) system in the laboratory. The project used off-the-shelf appliances and novel controls to integrate gas and electric systems with micro-CHP, energy storage, and renewable energy systems. This approach reduced operating costs and GHG emissions by up to 50% and achieved COPs of up to 1.5. This approach will improve energy resilience and help retain a high-efficiency role for NG and LPG in the residential forced-air market. It also prepares the industry for nascent gas heat pump technology that will require solutions for system integration. In 2022, a residential nanogrid testbed was built and achieved key performance markers. The prototype performance matches best-in-class advanced combi performance. The virtual test home performance-based modeling determined significant energy, cost, and emissions-related savings are possible with the hybrid self-powered system compared to a traditional 90%-efficient furnace, 0.62 uniform energy factor water heater, and 15 seasonal energy efficiency ratio heating seasonal performance factor air conditioner. Results from this project were presented at the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2022 Winter Conference and the World Gas Conference 2022 in Daegu, Korea, in May 2022. In July, the team presented a paper at the Purdue 2022 Compressor Engineering, Refrigeration & Air Conditioning conference. The team will present additional papers resulting from this research at the ASHRAE 2023 Winter Conference.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 03/31/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$580,000**
Total SCG Cost: **$68,073**
Total Co-Funding: **$511,927**
Benefits:

UTD Hydrogen Blending End-Use Performance and Safety Field Demonstration (1.22.A)

This project intends to demonstrate blended hydrogen gas's safety, technical, and performance implications from an end-user perspective in a simulated neighborhood. The project aims to 1) measure the end-user performance and safety impacts of a wide array of fuel-fired equipment (e.g., HVAC, water heating, cooking), 2) quantify the efficacy of in-field retrofits and mitigation strategies for individual appliances, and 3) estimate the decarbonization potential of hydrogen blending through population modeling. In coordination with Southwest Gas, the project team seeks to leverage their utility training facility in Henderson, NV, as a hydrogen-blended equipment demonstration and outreach platform. The project will leverage the site's existing plans to install and operate an on-site electrolyzer to blend hydrogen at a variable rate into an islanded distribution network serving the training facility. The 15 homes within the simulated neighborhood will house the experimental equipment.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$16,000**
Total Project Cost: **$450,000**
Total SCG Cost: **$16,000**
Total Co-Funding: **$434,000**
Benefits:

UTD Hydrogen-Blended Gas in ResCom Combustion Equipment - Phase 3 (1.20.H.3)

This project intends to support the potential deployment of up to 30% hydrogen blended gas in North American buildings. The team will assess the performance, emission, safety, and quality impacts of hydrogen mixing on widely used but low-load peripheral gas appliances such as gas lights, space heaters, outdoor fire pits, and indoor fireplaces. Specifically, the project team aims to determine the impacts and limits of hydrogen blending on these gas systems, assess qualitative results on aesthetic combustion equipment, and recommend changes for improved compatibility and performance. In 2022, test stands were built and modified for standardized testing of furnaces and water heaters. The team completed a preliminary literature review on relevant test and certification methods. The research team developed a comprehensive test plan, with testing expected to occur in the third or fourth quarter of 2022. As part of the R&D road mapping and outreach efforts under this project, the team prepared a summary paper for the World Gas Conference held in May 2022. Researchers demonstrated that methane emissions decrease with added hydrogen. The response to results was very positive, particularly with high interest from organizations in Latin America. There are several emerging options for distributed gas quality and hydrogen sensors. The project team is meeting with representatives from several sensor manufacturers.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$10,000**
Total Project Cost: **$150,000**
Total SCG Cost: **$10,000**
Total Co-Funding: **$140,000**
Benefits:

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

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 yet to be tested in past phases of the project. The goal is to 1) develop and publish representative methane emission factors, 2) determine the conditions under which these appliances release unburned methane, and 3) 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. In 2021 under Phase 2, researchers prepared the testing area and instrumentation for testing furnaces. The team conducted several shakedown tests to address issues with the methane analyzers, instrumentation, control programs, and data acquisition. The team completed testing of the first furnace (two-stage 80% AFUE), and they tested the remaining furnaces in early 2022 under Phase 3. The other furnaces included a single stage and two modulating condensing units. The team collected total hydrocarbon emissions data for both steady-state and part-load tests to generate a full picture of the emission profile for typical furnace operation. The team has started data analysis for the Final Report since the experimental phase is completed for Phase 2. The team will quantify the methane emissions profiles for the four furnaces at various part-load conditions to generate emission factors. Differences in emissions will be correlated to operational differences to understand how the team can mitigate emissions in equipment design and operation.

Co-Funders: UTD Members

Start Date: 08/01/2021
End Date: 08/31/2023
Status: Active
2022 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)

The goal is to find a technology to achieve a 5-15% edge over standard efficiency gas dryers. In this project, researchers are investigating next-generation gas dryer technologies to exceed EnergyStar efficiency levels. In 2021 under Phase 2, the project team developed a slightly modified test procedure to reduce the variability and provide repeatable results that will allow researchers to benchmark technology improvements. After this modified procedure was adapted, the team completed baseline testing of the DOE test clothes and a real-world towel load baseline test. In Phase 2, researchers investigated additional heat-recovery options, modulation techniques, indirect-fired methods, direct venting, and alternative burners. Testing at four firing rates consistently showed around a 2% improvement with lower firing rates. The dryer was insulated and sealed to test potential boost from fewer leaks and allow heat recovery implementation. After several variations, technicians achieved a 5%-6% increase in insulation and sealing efficiency and 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: 02/28/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$24,706**
Total Co-Funding: **$125,294**
Benefits:

UTD Next Generation Residential Gas Dryer Development - Phase 3 (1.15.C.3)

The goal is to find a technology to achieve a 5-15% edge over standard efficiency gas dryers. In this project, researchers are investigating next-generation gas dryer technologies to exceed EnergyStar efficiency levels. They developed an early-stage prototype with promising technology. Phase 1 of this project focused on assembling a test station in an environmental chamber to maintain temperature and humidity to make certain 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 consistently showed around a 2% improvement with lower firing rates. The dryer was insulated and sealed to test potential boost from fewer leaks and allow heat recovery implementation. After several variations, technicians achieved a 5%-6% increase in insulation and sealing efficiency and a 6% reduction in drying time. The insulation and sealing also allowed researchers to implement an innovative heat-recovery design. Any proprietary technologies discovered during the project will result in a UTD invention disclosure. In 2022 under Phase 3, the team built an environmental chamber to perform a subsequent product development and testing round. Researchers are awaiting the completion and availability of a new test chamber to complete testing.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 07/31/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$160,000**
Total SCG Cost: **$28,000**
Total Co-Funding: **$132,000**
Benefits:

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

UTD Residential Cooking Pollutants and Indoor Air Quality - Phase 2 (1.17.H.2)

The objective of this project was 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 along with data from the previous phase of this project. In Phase 1, the team studied capture hoods. They found that the effectiveness of residential hoods was less than 50% for cooking on the front burners and would be ineffective at capturing cooking and combustion emissions. This project segment determined the types and volumes of emissions in residential cooking, including NOx, particulates, heat, and moisture. The team conducted Phase 2 testing to measure and compare the cooking emissions of natural gas, propane, and electric residential ranges. 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 oven-burner technology could improve IAQ. In 2022, the team completed cooking emissions tests for natural gas, electric, and propane gas ranges. The team will include the results in the Final Report for Phase 2, expected in 2023, along with an updated list of resources and information about IAQ and indoor cooking.

Co-Funders: UTD Members

Start Date: 06/01/2020
End Date: 10/31/2022
Status: Complete
2022 Funds Expended: **$2,667**
Total Project Cost: **$85,000**
Total SCG Cost: **$11,333**
Total Co-Funding: **$73,667**
Benefits:

UTD Residential Gas Absorption Heat Pump Water Heater - Phase 6 (1.11.H.6)

This project was based upon a gas-fired heat pump water heater (GHP-WH) developed and supported in conjunction with UTD Project 1.11.H. This project aims to scale up the same absorption heat pump technology by a factor of eight. The objective is to support the development of the next-generation GHP-WH by eliminating a major cost hurdle for some installations, along with enhancing reliability and efficient diagnostics. One effort is to reduce the installation barrier and cost of a condensate drain by developing a proprietary method of neutralizing, collecting, and disposing of combustion condensate. This aspect benefits users where access to a sanitary sewer drain is otherwise cost-prohibitive. Also, the team can leverage Enhanced Solution Level Control (ESLC) to improve the onboard diagnostics, which can enhance system reliability and long-term performance. Using the experience of 12 pre-commercial GHPWH prototypes tested in demonstrations conducted in Phases 1 to 4, GTI Energy and Stone Mountain Technologies, Inc. (SMTI) identified typical conditions, root causes of poor efficiency, and product failures. SMTI is the developer of the technology advanced in this and other UTD projects. Technical tasks under Phases 5 and 6 improved the final design and fabrication of test setups to evaluate the proof of concept of the liquid level sensor (LLS) platform and the de-condensation idea. For Phase 6, the team completed an agreement with SMTI to produce a next-generation alpha prototype GHPWH. SMTI delivered the updated unit in the fourth quarter of 2022. Researchers concluded the Phase 6 test plans and fabricated prototypes of additional features.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$185,000**
Benefits:

UTD Robur and SMTI Low-Capacity Gas Absorption Heat Pump Laboratory Evaluation (1.20.A)

This project aims to evaluate and optimize the performance of low-capacity gas absorption heat pumps (GAHPs). The units of interest in this project were the Robur K18 (60 MBH) and SMTI 40K (40 MBH). The team will apply them to residential combination space and 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. This experimental effort assessed how the GAHP performs and how system parameters are optimally controlled (system modulation, space vs. water heating modes, air handler operation, etc.). The team will commission the K18 in the third quarter of 2022. The team will develop performance curves from the performance rating test plan results. The team will develop a simulated-use evaluation test plan to create integrated solutions for the K18 unit in the North American market using off-the-shelf components. The team expects the simulated-use evaluations to optimize controls, equipment sizing, and design guidelines.

Co-Funders: UTD Members, OEMs

Start Date: 07/01/2020
End Date: 03/01/2023
Status: Active
2022 Funds Expended: **$0**
Total Project Cost: **$175,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$151,000**
Benefits:

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

UTD Safe Use of Hydrogen in Buildings (1.22.G)

The purpose of this project is to enable the broad deployment of hydrogen-blended gas by proactively addressing consumer and regulatory concerns about its safe use in buildings. This project will characterize the propensity of hydrogen in blends with natural gas to preferentially leak from existing building gas distribution systems and appliance gas handling subsystems. This project also aims to address barriers to the safe use of higher hydrogen blends greater than 30% in residential and commercial appliances. Some key performance indicators are 1) quantifying leakage of hydrogen blended gas compared to natural gas from standard fittings, 2) identifying design requirements for high hydrogen blend operation (i.e., 40-100%), and 3) publicly disseminating findings and recommendations through peer-reviewed publications and webinars. In 2022, GTI Energy kicked off the project with a literature review into prior research on preferential hydrogen leakage from low-pressure gas distribution systems and fundamentals of detonation wave formation for mixtures of methane and hydrogen. GTI Energy is also working on installing and configuring Converge computational fluid dynamics (CFD) software which will be used to analyze detonation wave formation.

Co-Funders: UTD Members

Start Date: 08/31/2022
End Date: 08/31/2024
Status: Active
2022 Funds Expended: **$10,000**
Total Project Cost: **$150,000**
Total SCG Cost: **$20,000**
Total Co-Funding: **$130,000**
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) can produce enough electric energy to power a tankless natural gas water heater. In Phase 3, efforts incorporated a novel heat-pump configuration with a TEG-HX design. The goal was 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 or a primary COP of >1.0. In 2022, the team disassembled the tankless water heater unit with the combustion chamber, and they reviewed different sections to understand integration approaches better. The area around the combustion zone has space, and the team identified additional room for integrating the TEGs. The team generated a solid model for integrating the TEG assembly. The team also developed three different schemes for optimized integration of the TEG, and the team will choose one based on the approach's feasibility.

Co-Funders: UTD

Start Date: 07/01/2019
End Date: 01/31/2022
Status: Complete
2022 Funds Expended: **$0**
Total Project Cost: **$1,340,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$1,260,000**
Benefits:

SoCalGas™