Momentum is Building


"Around the world, commitments to decarbonization
and renewable energy are growing.

Private industry and governments are investing

in technologies to accelerate the energy transition.

This support for innovation is essential for empowering new ways of generating energy, moving goods and people, and improving the environment. And as always, California is leading."

— MARYAM BROWN
PRESIDENT, SOCALGAS

Contents

Introduction

Momentum is building in the fight against climate change. Around the world, more than 90 countries have committed to major greenhouse gas (GHG) emissions reductions and climate action. The United States (US) has pledged to reduce its emissions by 50 to 52 percent below 2005 levels by 2030 and to achieve net zero emissions from national government operations by no later than 2050.[1,2] California is even more ambitious, seeking to reach a net zero carbon economy by 2045, in large part through an 85-percent cut in GHG emissions.[3]

Thousands of companies are participating in this process, not only by cutting emissions and improving energy efficiency, but also by investing in the projects and companies that are actively developing, demonstrating, and deploying the technologies and processes that can make this transition possible.

Examples abound. In California, Brimstone has developed the first carbon-negative process for making portland cement.[4] Companies in Sweden and the US are exploring the production of "green" steel using clean hydrogen. And in Washington, Twelve is breaking ground on the world's first facility that will produce E-Jet®, a fossil-free, power-to-liquids sustainable aviation fuel (SAF) made from carbon dioxide (CO_2) captured from the air, water, and renewable energy.[5]

Continued public and private support for these types of projects is critical if the world is to achieve its ambitious decarbonization goals and transition to new, more equitable ways of generating energy, moving goods, and traveling—whether across town on errands, commuting to work, or flying around the world.

But change does not happen overnight. During the energy transition, natural gas remains an important lower-emission alternative to more polluting fossil fuels such as oil and coal. As more and more renewable energy comes online, natural gas can help maintain grid reliability, safety, and stability, as well as energy affordability. Any plan to decarbonize the world's economy should, therefore, also include a transitional role for domestically abundant and affordable natural gas

"Innovation has brought us to an inflection point; the coming decade will be decisive."

—INTERNATIONAL MONETARY FUND

as well as a long-term plan to include gaseous fuels such as clean hydrogen and renewable natural gas (RNG).

SoCalGas RD&D Shepherds Technology from Laboratory to Market

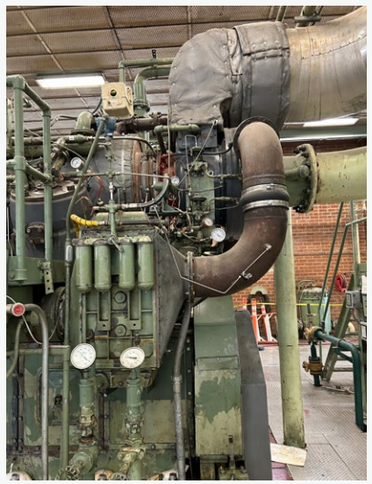
With more than 21 million customers and one of the nation's largest networks of gas transmission, storage, and distribution infrastructure, SoCalGas plays a central role in the ongoing decarbonization of the energy industry in California. Importantly, SoCalGas is an active investor in projects and technologies on the forefront of the energy transition.

The SoCalGas Research, Development, and Demonstration (RD&D) group is tasked with identifying and supporting projects and technologies with the potential to save energy, reduce GHG emissions, improve air quality, and increase the safety, reliability, and affordability of energy for SoCalGas customers, including those in environmental and social justice (ESJ) communities.

"It's really difficult to bring new technologies into the commercial market. The only way to do that is to go out and build things and see how they work. Without public funding and SoCalGas RD&D's financial support, we would not have been able to do that."

—JASON HANLIN

DIRECTOR OF TECHNOLOGY DEVELOPMENT,
CENTER FOR TRANSPORTATION AND THE ENVIRONMENT



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

SoCalGas RD&D has invested tens of millions of dollars in thousands of projects and technologies. In 2023, RD&D staff invested $7,597,782 in numerous energy delivery and utilization, clean fuels, and carbon management technologies—from water-positive direct air capture (DAC) systems and hydrogen fuel cell electric delivery vans to water electrolysis, ultra-low-emission furnaces, portable electrochemical emissions analyzers, and in-line pipeline inspection tools.

Investments over time have continued to yield results, with many technologies in the SoCalGas RD&D portfolio moving from the laboratory to pilot-scale demonstrations to commercial deployments. Other projects supported by SoCalGas RD&D have influenced policy and regulation, laying the groundwork for new methods of emissions detection approved by the US Environmental Protection Agency (EPA) or the passage of California's Senate Bill (SB) 1380, the Short-Lived Climate Pollutant Reduction law, which took effect on January 1, 2022.[6,7]

"Research funding from SoCalGas provides us with a reliable foundation for our work, enabling us to delve into crucial areas that directly affect the lives of all Californians. Moreover, it grants us the freedom to explore innovative research topics that are being recognized as necessary for a sustainable, carbon-free future. Thanks to this funding, we are making a meaningful impact on our state's future."

—ROBERT FLORES, PH.D

SENIOR SCIENTIST,
APEP | ADVANCED POWER AND ENERGY PROGRAM,
UNIVERSITY OF CALIFORNIA, IRVINE

Vision, Mission, & Values

The vision, mission, and values of SoCalGas RD&D align with SoCalGas' mission to build the safest, cleanest, 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

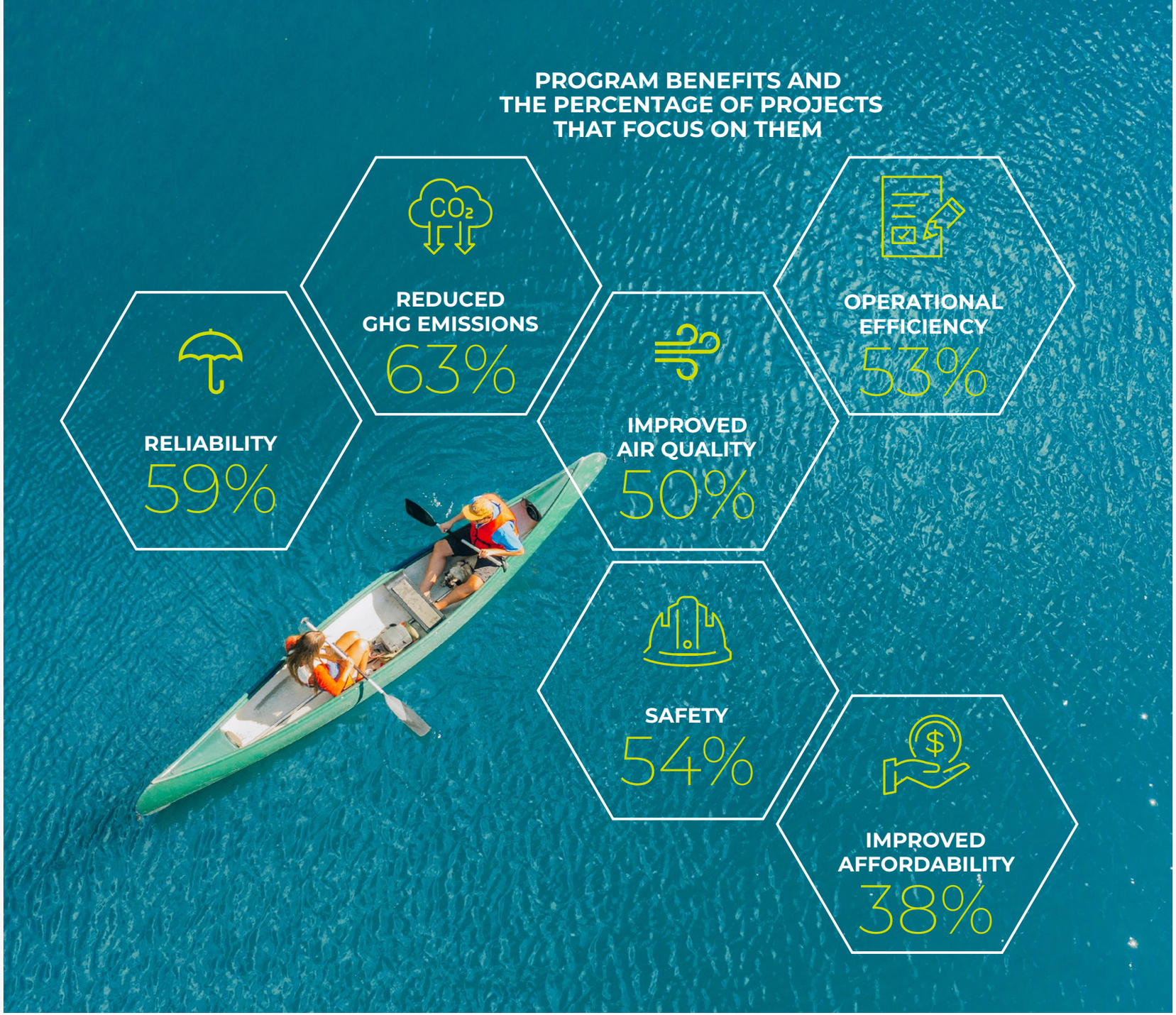
Our experts in science, engineering, energy systems, and environmental policy seek answers to some of today's most pressing energy questions.

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.



Ratepayer Benefits

RELIABILITY The quality of providing an adequate, secure, and resilient supply of energy to meet ratepayer needs.

SAFETY The assurance that gas pipelines and the ratepayers who live, work, and recreate around them are protected from intentional and unintentional damage and harm.

OPERATIONAL EFFICIENCY The ability to operate a system or technology at high performance levels while using the least amount of energy and as few resources as possible, resulting in cost savings to ratepayers.

IMPROVED AFFORDABILITY The quality of reducing the cost of energy to ratepayers and making it more accessible to a broader, more diverse population.

REDUCED GHG EMISSIONS The decrease in greenhouse gases associated with climate change that are released into the atmosphere.

IMPROVED AIR QUALITY The enhancement of the air ratepayers breathe through reductions in the concentration of harmful criteria pollutants, such as carbon monoxide, particulate matter, and nitrogen oxides.

2023 IN REVIEW

"SoCalGas RD&D gave us the freedom to perform basic and applied research and to follow that research where it naturally led us. That was a tremendous opportunity that enabled us to greatly expand our project's original scope."

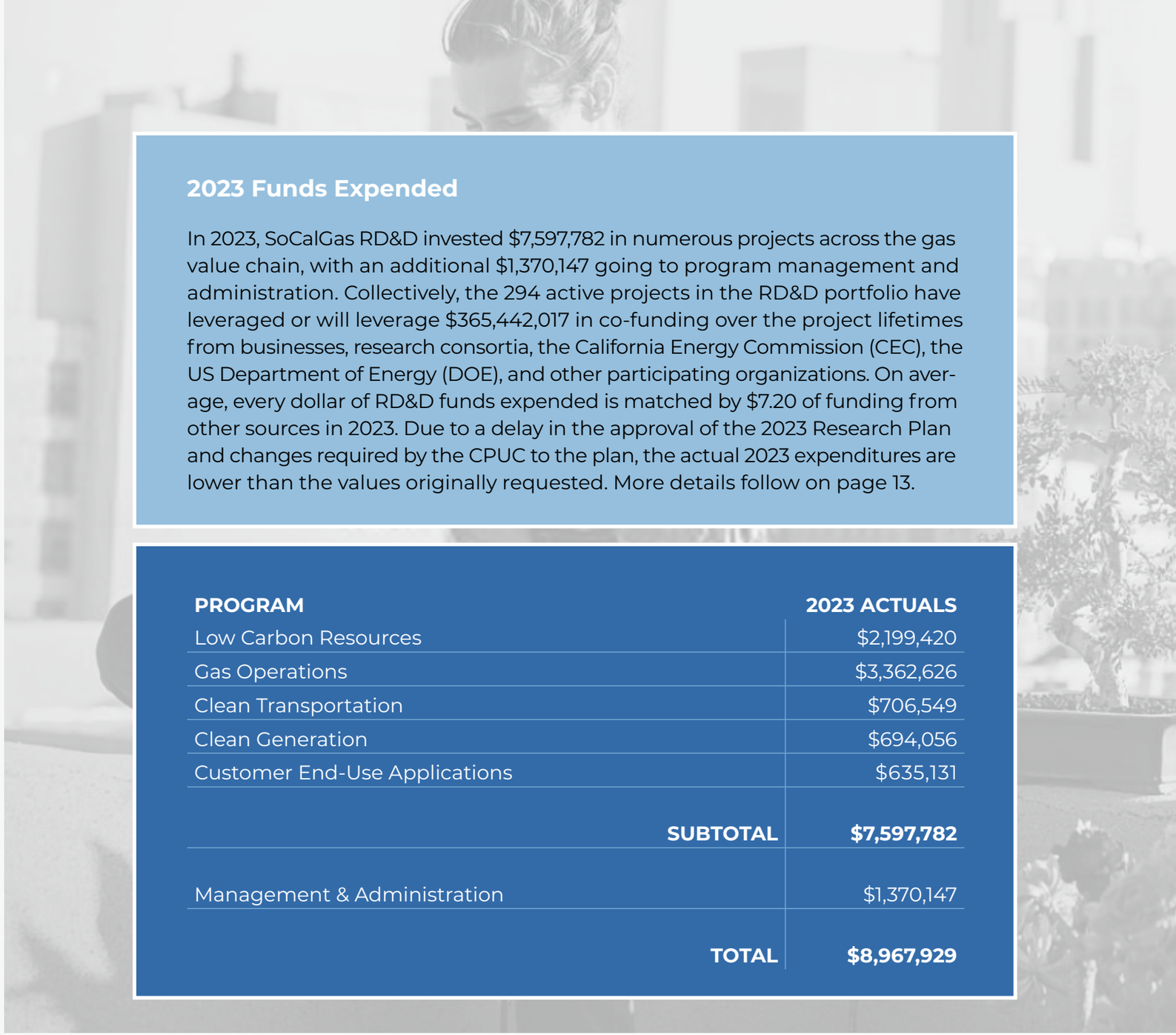
—KATHERINE J. CHOU, PH.D.

DIRECTOR | BIOH2 CONSORTIUM, GROUP MANAGER & SCIENTIST | BIOENERGETICS GROUP | BIOSCIENCES CENTER, NATIONAL RENEWABLE ENERGY LABORATORY

Financial Highlights

In 2023, SoCalGas RD&D supported 294 RD&D projects that represent the entire gas value chain in California. In executing these projects, SoCalGas collaborated with many of the most forward-thinking research consortia, universities, national laboratories, public agencies, and entrepreneurs across 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.

Split across five programs—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 substantial progress toward commercializing new safe, reliable, and affordable clean energy products and technologies.

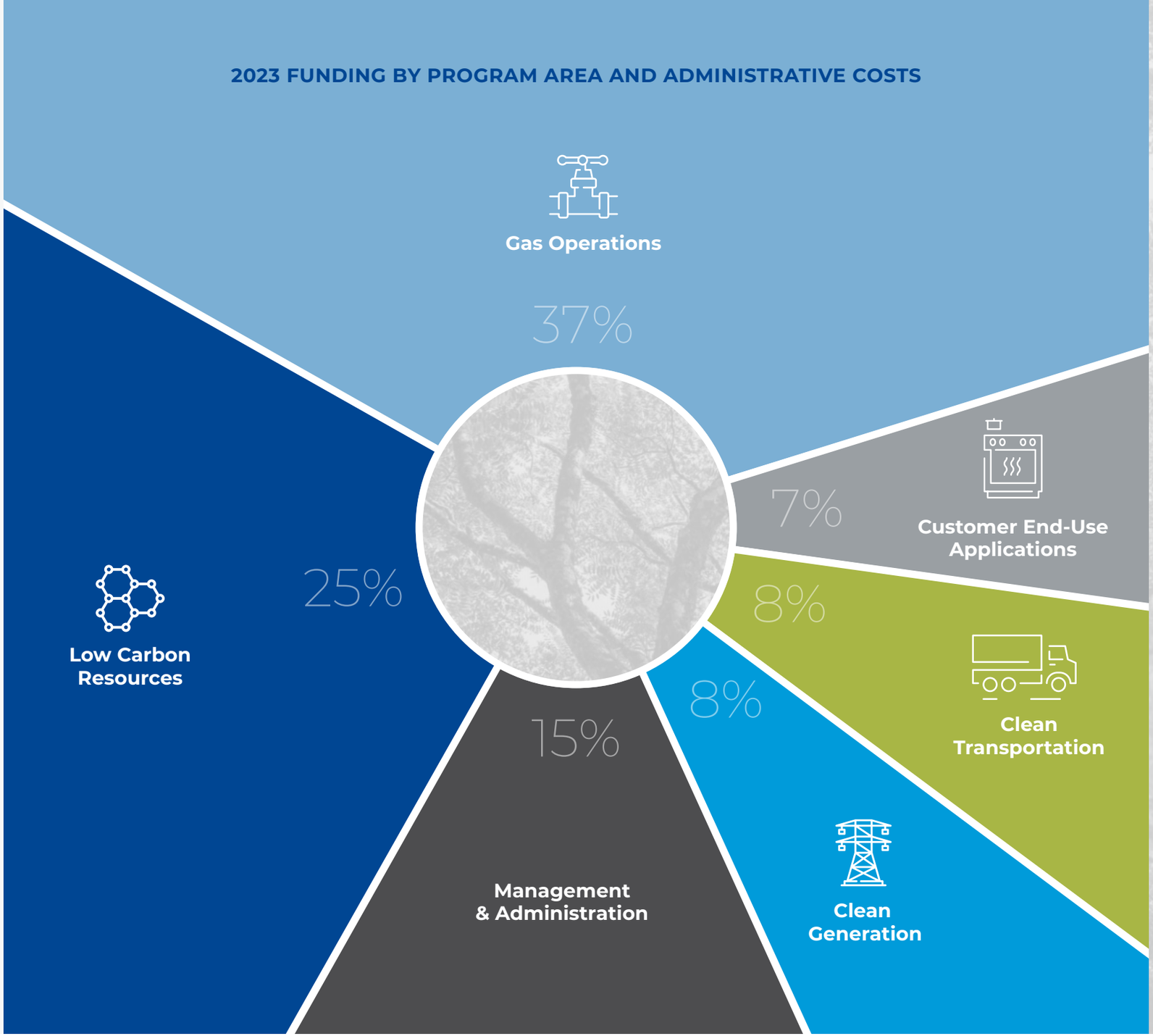


2023 Funds Expended

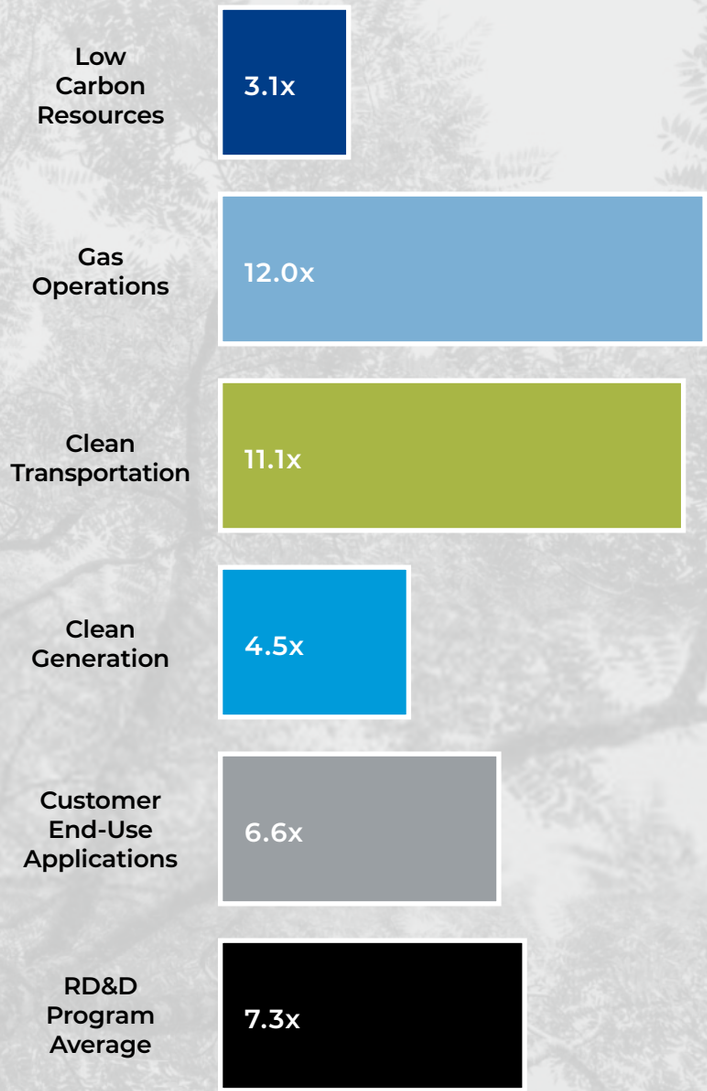
In 2023, SoCalGas RD&D invested $7,597,782 in numerous projects across the gas value chain, with an additional $1,370,147 going to program management and administration. Collectively, the 294 active projects in the RD&D portfolio have leveraged or will leverage $365,442,017 in co-funding over the project lifetimes from businesses, research consortia, the California Energy Commission (CEC), the US Department of Energy (DOE), and other participating organizations. On average, every dollar of RD&D funds expended is matched by $7.20 of funding from other sources in 2023. Due to a delay in the approval of the 2023 Research Plan and changes required by the CPUC to the plan, the actual 2023 expenditures are lower than the values originally requested. More details follow on page 13.

PROGRAM	2023 ACTUALS
Low Carbon Resources	$2,199,420
Gas Operations	$3,362,626
Clean Transportation	$706,549
Clean Generation	$694,056
Customer End-Use Applications	$635,131
SUBTOTAL	**$7,597,782**
Management & Administration	$1,370,147
TOTAL	**$8,967,929**

2023 FUNDING BY PROGRAM AREA AND ADMINISTRATIVE COSTS



RATIO OF OUTSIDE FUNDING TO SOCALGAS FUNDING FOR ALL PROJECTS ACTIVE IN 2023



Revisions to the 2023 Research Plan

On June 15, 2022, SoCalGas submitted its 2023 RD&D Research Plan through Advice Letter (AL) 5991-G, seeking approval for a spending level of $16,874,000.

On January 1, 2023, SoCalGas ceased entering into new agreements for RD&D projects pending a Commission Resolution on AL 5991-G for the 2023 RD&D Research Plan. During 2023, SoCalGas maintained its ongoing RD&D activities for multi-year programs previously approved by the CPUC, including agreements entered during 2022 and prior.

On November 30, 2023, the Commission issued Resolution G-3601, which partially approved and modified SoCalGas's AL 5991-G, setting the funding level for the 2023 RD&D Plan at $16,874,000, with program administration capped at 10 percent of the total budget, or $1,687,400.[8] SoCalGas was further authorized to spend its approved 2023 RD&D funding in calendar year 2024.

SoCalGas was also ordered to reallocate $7,301,717 of its 2023 Gas RD&D funding from the following subprograms within the Low Carbon Resources (LCR), Clean Transportation (CT), Clean Generation (CG), and Customer End Use Applications (CEUA) programs:

- Carbon Capture, Utilization, and Sequestration (LCR)
- Off-Road (CT)
- Onboard Storage (CT)
- On-Road (CT)
- Refueling Stations (CT)
- Distributed Generation (CG)*
- Industrial Process Heat (CEUA)*
- Residential Appliances (CEUA)

In determining how to reallocate the funds, SoCalGas primarily considered three factors:

Specific Reallocations Required by the CPUC

SoCalGas was ordered to reallocate a) $129,938 toward its proportional share of a comprehensive Gas RD&D database and b) $675,000 toward a comprehensive program evaluation. Additionally, SoCalGas was authorized to continue ongoing projects in its Distributed Generation and Industrial Process subprograms. Total funding associated with this category equals $1,719,500.

Recovery of Costs

Pursuant to the directives of Res. G-3601 and considering previously approved directives from the Commission in Res. G-3586 for continuation of multi-year projects in between annual research plan cycles, SoCalGas proposed the retirement of the programs disallowed by G-3601 and presented incurred costs for ongoing projects up to November 30, 2023, as the respective retirement costs for the disallowed subprograms. SoCalGas reallocated approximately $2,399,904 towards retirement costs for these disallowed subprograms.

Revisions to the 2023 Research Plan

Discretionary Reallocations

SoCalGas reallocated the remaining $3,182,313 (see table on right) toward subprograms and projects that comply with the RD&D criteria outlined in G-3601, including reallocating a portion of these funds toward gas pipeline and system integrity, gas system decommissioning, and cybersecurity.

Revised 2023 Research Plan and Tier 2 AL Resolution for 2023

In compliance with Resolution G-3601, SoCalGas submitted a revised 2023 Research Plan (AL 6273-G) proposing the reallocations presented above.[9] On April 10, 2024, the CPUC's Energy Division approved the revised 2023 Research Plan as submitted.

Reallocated Subprograms	Reallocated Funds
Renewable Gas Production	$1,122,084
Environmental & Safety[(i)]	$250,000
Operations Technology[(ii)]	$250,000
System Design & Materials[(iii)]	$250,000
Integration & Controls[(iv)]	$905,144
Advanced Innovation	$100,059
Commercial Applications	$250,146
Commercial Food Service	$54,880
Total Reallocated Funds to Authorized Subprograms	**$3,182,313**

i. Indicates funds that have been reallocated to potential gas system decommissioning research efforts.

ii. Indicates funds that have been reallocated to potential cybersecurity research efforts.

iii. Indicates funds that have been reallocated to potential gas system integrity research efforts.

iv. Indicates a portion of funds has been reallocated to potential cybersecurity research efforts ($250k).

Stakeholder Engagement

2023 ANNUAL STAKEHOLDER WORKSHOP

On April 20, 2023, SoCalGas RD&D hosted an online workshop attended by 238 individuals from a variety of organizations, including the California Public Utilities Commission (CPUC), GTI Energy, Bakersfield College, CEC, DOE, Pipeline Research Council International (PRCI), the California Air Resources Board (CARB), Argonne National Laboratory, and Communities for a Better Environment.

RESEARCH WEBINARS

In 2023, SoCalGas presented four quarterly research webinars open to the public, discussing projects supported by SoCalGas RD&D. These webinars benefit ratepayers, businesses, and other researchers in the field by educating them about innovative new technologies soon coming to market and enhancing transparency.

- **Hybrid Direct Air Capture of CO_2 Water-Positive Carbon Dioxide Removal**
  March 1, 2023: This webinar focused on Avnos' innovative hybrid direct air capture of CO_2 technology, which produces water as it removes CO_2 from the ambient air. The result is a highly resource- and cost-efficient approach to direct air capture that can be deployed virtually anywhere in the world as both a decarbonization and water stress solution.
- **Hydrogen Fuel Cell Yard Trucks at the Port of Los Angeles**
  May 25, 2023: SoCalGas and GTI Energy discussed a hydrogen fuel cell yard truck demonstration at the Port of Los Angeles that investigated truck performance in a demanding, real-world cargo-handling application. SoCalGas, GTI Energy, CARB, Capacity Trucks, TraPac, and others developed and tested two new zero-emissions fuel cell electric terminal tractors and assessed their operation at TraPac's terminal.

Stakeholder Engagement

238

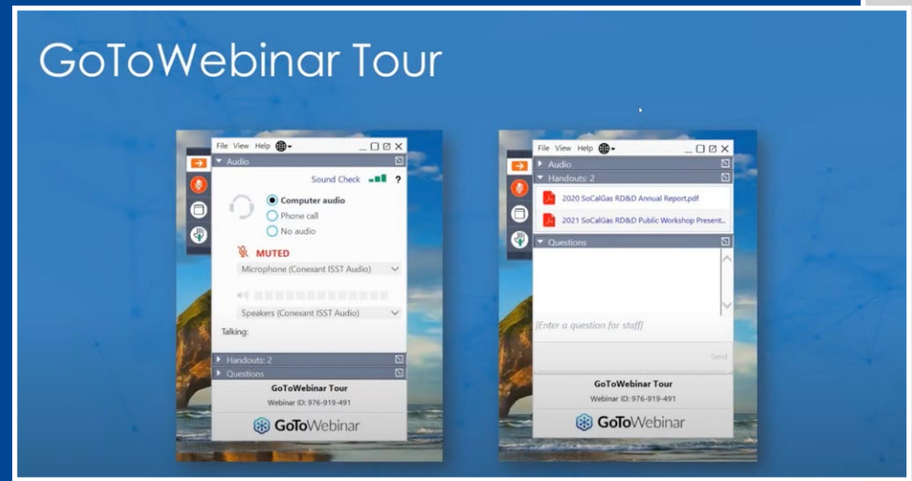
TOTAL ATTENDEES
OF 2023 PUBLIC WORKSHOP

RESEARCH WEBINARS

(Continued)

» **Explorer Robot – Seam Weld Crack Sensor**
August 17, 2023: Daphne D'Zurko and Suzy Chaillou discussed the Intero/Pipetel Explorer Robot with seam weld crack detection technology. This technology detects cracks along the seam welds of pipe without multiple passes. This webinar was attended by more than 100 attendees from 47 unique companies including utilities, pipeline companies, research consortia, and agencies both federal and state.

» **Industrial Decarbonization – Priority Technical Spaces**
November 9, 2023: Darcy Partners spoke about its strategic analysis of technologies impacting industrial decarbonization and leveraged a variety of data sources to understand the impact of emergent industrial energy transition technologies. They identified three areas of priority: thermal energy storage, distributed hydrogen production, and point-source carbon capture. For each, Darcy explored and compared early-stage companies working on these solutions.



Stakeholder Engagement

SOCALGAS RD&D 2023 KNOWLEDGE TRANSFER

In person and virtually, program staff represented SoCalGas RD&D at more than 50 events throughout the state and nation in 2023, including:

2023 ARPA-E Energy Innovation Summit

2023 Bren Alumni Corporate Sustainability Network Summit

2023 Cleantech Forum North America

2023 Deloitte Renewable Energy Seminar

2023 Hydrogen Online Workshop at Bakersfield College

2023 Hydrogen and Fuel Cell Seminar

2023 US DOE Hydrogen Program 2023 Annual Merit Review and Peer Evaluation Meeting

ACT Expo

Advanced Energy and National Security Conference

Alliance for Renewable Clean Hydrogen Energy (ARCHES) Working Group Meeting

AIChE Annual Meeting

American Chemical Society Meeting

Argonne National Lab Research Overview

California Hydrogen Business Council Fuel Cell Electric Bus Workshop

California Hydrogen Leadership Summit

Cal State LA Senior Capstone Project Presentation

CARB Transit Infrastructure Workshop

Carbon Capture Technology Expo

Career Panel at Granada Hills Charter School

Catalyst H2

CEC Clean Transportation Program Advisory Committee

CEC Commissioner Workshop on California's Economic Outlook

CEC Food Production Investment Program Workshop

CEC Gas R&D Workshop

Climate Forward Conference 2023

DOE Combined Heat and Power Workshop

DOE Office of Clean Energy Demonstrations Reviewer's Meeting

Draytech 2023

[H2] Innovation Experience Drone Showcase

H2 SilverSTARS PSA Commissioning

Hydrogen Blending Pilot Project Stakeholder Workshop

Hydrogen Grand Prix Judging

Hydrogen Markets Americas Conference

Hydrogenext Conference

Stakeholder Engagement

SOCALGAS RD&D 2023 KNOWLEDGE TRANSFER

(continued)

Hydrogen North America 2023

IEEE Power & Energy Society General Meeting

ICM 2023 Climate Action Conference Program

Low-Carbon Resources Initiative Tech Week

Mission Hydrogen Webinar: Hydrogen Storage for Trucks

National Renewable Energy Laboratory (NREL) Natural Gas Vehicle Technology Forum

North America Hydrogen Technology Expo

NREL Growth Forum

NREL Partner Forum

Octane Technology Innovation Forum

Pacific Gas and Electric Company Innovation Summit 2023

Pipeline and Hazardous Materials Safety Administration CO_2 Transport Workshop

Pipeline and Hazardous Materials Safety Administration RD&D Forum

Pipeline Research Council International Emerging Fuels Symposium

SoCalGas RD&D 2023 Annual Workshop

South Coast Air Quality Management District's Clean Fuels Advisory Meeting

STARS Technology Dedication Ceremony at SunLine Transit Agency

STEPS+ Research Symposium at the University of California, Davis

Sustain SoCal Driving Mobility 10

University of Southern California CO_2 SMART Research Center Meeting

Utilization Technology Demonstration (UTD) 2023 Board Meeting

US Hydrogen & Fuel Cells Energy Summit

VerdeXchange

VERGE 23 | Sustainability Conference 2023

World Ag Expo

Zero-Emission Appliance Standards Workshop

Zero Emission Bus Conference

Significant 2023 Milestones

TOTAL FOLLOW-ON FUNDING

$145M+

IN 2023

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 build momentum toward commercialization by securing demonstration partners, project sites, and additional public and private investment. In 2023, 10 companies received follow-on funding:

» **Avnos**
Building on work performed with support from SoCalGas RD&D, Avnos received financial commitments from ConocoPhillips, Shell Ventures, and JetBlue Ventures worth at least $80 million. Avnos plans to use these funds to scale up its proprietary hybrid direct air capture technology, which extracts CO_2 directly from the atmosphere and produces distilled water as a byproduct.

» **BioVind**
The CEC awarded $999,970 to BioVind for the development of a test kit and field-testing guide for detecting microbial species associated with microbiologically influenced corrosion (MIC) in gas pipelines and storage facilities, and the adoption of staff's determination that this action be exempt from CEQA. The innovative test kit will help lower the risk of MIC-related leakages and reduce costs associated with MIC detection, mitigation, and control.

» **Bridger Photonics**
In 2023, the DOE awarded Bridger Photonics $5 million from its Advanced Research Projects Agency-Energy Seeding Critical Advances for Leading Energy technologies with Untapped Potential program. The funds will be used to further commercialize Gas Mapping LiDAR™, a next-generation methane detection and quantification technology.

» **Captura Corporation**
On January 12, 2023, Captura announced the closing of a $12 million Series A financing round. Equinor Ventures led the round and was joined by Aramco Ventures, the Caltech Seed Fund, Hitachi Ventures, Future Planet Capital, and mTerra Ventures. Captura will use the funds to help accelerate its piloting program and, simultaneously, continue to improve the technology.

» **Doosan Mobility Innovation**
On April 25, 2023, Doosan Mobility Innovation Co., Ltd. (DMI) announced that it expects to receive $1.54 million in funding from Shinyoung Securities Co., Ltd. DMI is a world leader in designing and developing hydrogen fuel power systems for small Uncrewed Aerial Systems.

Significant 2023 Milestones

294

TOTAL **ACTIVE PROJECTS** IN 2023

TOTAL **PROJECTS INITIATED** IN 2023

42

TOTAL **PROJECTS COMPLETED** IN 2023

78

FOLLOW-ON FUNDING

(continued)

» **Immaterial**
SoCalGas RD&D alumnus Immaterial raised a $20 million Series A round led by SLB and joined by AP Ventures, Cepsa, Chevron, Energy Revolution Ventures, JERA, TRIREC, and Ultratech CP.

» **STARS Technology Corporation**
STARS raised $175,000 from two angel investors to advance development of its compact steam-methane reformer designed to extract hydrogen from water and methane.

» **Susteon**
In May 2023, the Aviation Climate Taskforce awarded Susteon with a $400,000 grant to pioneer an innovative direct air capture (DAC)-to-jet-fuel approach—transforming conventional DAC to aviation-aligned reactive DAC by combining CO_2 capture with CO_2 conversion. Susteon will use the grant to create a new material that can capture and convert CO_2 into methanol and ethanol, which can then be upgraded to sustainable aviation fuel.

» **Upstart Power**
Upstart Power, a leading developer and manufacturer of solid oxide fuel cell (SOFC) power systems for on-demand backup power and distributed generation, announced the closing of a $17 million Series C financing round. Upstart Power will use the funds to accelerate the global commercialization of its innovative, on-demand backup and grid-augmenting SOFC generators.

» **Zero Emission Industries**
In 2023, Zero Emission Industries (ZEI) announced the completion of an $8.75 million Series A financing round. Chevron New Energies led the Series A round and was joined by Trafigura and Crowley. ZEI intends to use the funds to advance its mission to make hydrogen technology—such as its world-leading commercial hydrogen fuel cell vessel launched in the San Francisco Bay in 2021—commercially viable.

PUBLICATIONS, PATENTS, AND CITATIONS

In 2023, 44 projects co-funded or otherwise supported by SoCalGas RD&D were featured in articles, reports, and technology briefs.

See Appendix for more information.

Significant 2023 Milestones

18

PROJECTS WON A TOTAL OF **$44,325,838** FROM PUBLIC AGENCIES

PUBLIC FUNDING AWARDS

In 2023, RD&D staff supported 17 winning proposals applying for public funding. These projects were awarded $43,318,747 in research funding from the California Energy Commission, US Department of Energy, National Energy Technology Laboratory, the Pipeline and Hazardous Materials Safety Administration, and the US Department of Transportation.

Lead Investigator	Research Program*	SoCalGas RD&D Cash Funding Committed	Project Funding Awarded	Awarding Agency
Arizona State University	GO	$0†	$1,000,000	PHMSA/DOT
Enchanted Rock	CG	$200,000	$2,142,968	CEC
GTI Energy	CEUA	$460,000	$864,506	CEC
Noble Thermodynamic Systems	CG	$500,000	$4,242,259	CEC
Zero Emissions Industries	CT	$300,000	$5,250,000	CEC
ClearSign	CG	$500,000	$1,600,000	DOE
GTI Energy	GO	$0†	$999,319	CEC
GTI Energy	CEUA	$150,000	$3,000,000	DOE
GTI Energy	CEUA	$200,000	$3,701,786	DOE

**LCR (Low Carbon Resources) GO (Gas Oporations) CT (Clean Transportation) CG (Clean Generation) CEUA (Customer End-Use)*

†SoCalGas committed in-kind support to this project.

Significant 2023 Milestones

PUBLIC FUNDING AWARDS

(Continued)

Lead Investigator	Research Program*	SoCalGas RD&D Cash Funding Committed	Project Funding Awarded	Awarding Agency
GTI Energy	CT	$300,000	$6,000,000	DOE
GTI Energy	CEUA	$500,000	$7,000,000	DOE
Oak Ridge National Lab	LCR	$700,000	$925,000	DOE
PARC	LCR	$200,000	$200,000	DOE
Susteon	LCR	$375,000	$1,500,000	DOE
Susteon	LCR	$100,000	$400,000	DOE
Susteon	LCR	$300,000	$1,500,000	DOE/NETL
UC Berkeley	GO	$0†	$1,007,091	CEC
UCLA	GO	$0†	$2,992,909	CEC
	TOTAL	**$4,785,000**	**$44,325,838**	

**LCR (Low Carbon Resources) GO (Gas Oporations) CT (Clean Transportation) CG (Clean Generation) CEUA (Customer End-Use)*

†SoCalGas committed in-kind support to this project.

Significant 2023 Milestones

DEPLOYED TECHNOLOGIES

A major goal of SoCalGas RD&D is to bring technology from the laboratory to market. In 2023, 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 2023 include:

- Alternate Crack Sensor (M2016-004 Ph IV)
- CEPM for Turbochargers (CPS-14B-08): Greenhouse Gases Emissions Reduction, Low Cost Instruments to Detect/Quantify Leaking Seals, Packing, or Dump Valve (SRP-GHG-01:MEAS-9-02)
- Develop guideline for API 1163 for Inspections Qualification for Level 1, 2, and 3 (IM-1-06)
- Enhancements to ASTM F2897 Encoding Standard for Gas Distribution Components (5.22.v)
- Greenhouse Gases Emissions Reduction, High Flow Sampler Replacement (SRP-GHG-01: MEAS-9-03)
- ILI-Based Generic External Corrosion Growth Rate Distribution for Buried Pipelines (EC-01-13)
- Improve ILI Sizing Accuracy (PHMSA) (NDE-4-19)
- INGAA - Geohazard Management JIP
- Internal Corrosion Management
- Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration
- NREL GKN Metal Hydride Storage Integration with Renewable Energy and Fuel Cells Demonstration
- Odor Detection Threshold Study - Phase II, Tasks 1 & 2 (M2016-002)
- Subsidence Study
- Technology Testing Assessment Facilities (AMI Smart Metering)
- Validate In-Line Inspection (ILI) Capabilities to Detect/Characterize Mechanical Damage (PHMSA) (NDE-4-18)

"SoCalGas RD&D's ability to fund and participate in research, development, and demonstration projects with small businesses like ours is very valuable. They were instrumental in helping us move forward from the lab to a first-of-a-kind commercial demonstration."

—ROBERT S. WEGENG,
PRESIDENT AND CHIEF TECHNOLOGY OFFICER,
STARS TECHNOLOGY CORPORATION

2023 Equity Activities

In 2023, SoCalGas RD&D undertook several activities to serve under-resourced communities through educational opportunities related to clean energy. Early in the year, RD&D staff published its Equity Engagement Roadmap, a multi-year vision for improving equity engagement within SoCalGas RD&D. Other activities included:

Hydrogen Grand Prix:
SoCalGas RD&D collaborated with Horizon Educational to sponsor 10 high school teams at five Title I high schools throughout Southern California in the Hydrogen Grand Prix (H2GP). One of the teams—Los STEMateros from Los Angeles—placed 14th globally.

Cal State LA Capstone Senior Design Program:
SoCalGas RD&D supported students from the Engineering, Computer Science, and Technology (ECST) program at California State University, Los Angeles, in their work on the ECST Capstone Senior Design Project. The engineering students conducted a feasibility study on the potential of taking the university's existing, grid-connected Hydrogen Research and Fueling Facility off the grid. This project provided valuable training in a variety of useful skills and technologies, including engineering design, electrolyzers, batteries, and interaction with engineering, operations, and design professionals.

[H2] Innovation Experience:
RD&D staff conducted a tour for Cal State LA engineering students of its [H2] Innovation Experience, the first-in-the-nation home to be powered with a hydrogen-fueled microgrid that uses solar panels to renewably generate carbon-free hydrogen from water.

Energy of STEM Summer Camp 2023:
Two representatives from SoCalGas RD&D mentored K-12 students from a variety of populations—including ESJ communities—at this summer camp hosted by the Viterbi School of Engineering at the University of Southern California (USC). The students took part in demonstrations, lessons, hands-on projects, and group work in a fun, engaging environment. They explored a variety of concepts, including aerodynamics, physics, coding, energy, and electronics. SoCalGas covered the cost of printing all camp materials.

2023 Equity Activities

SOCALGAS RD&D SUPPORTED

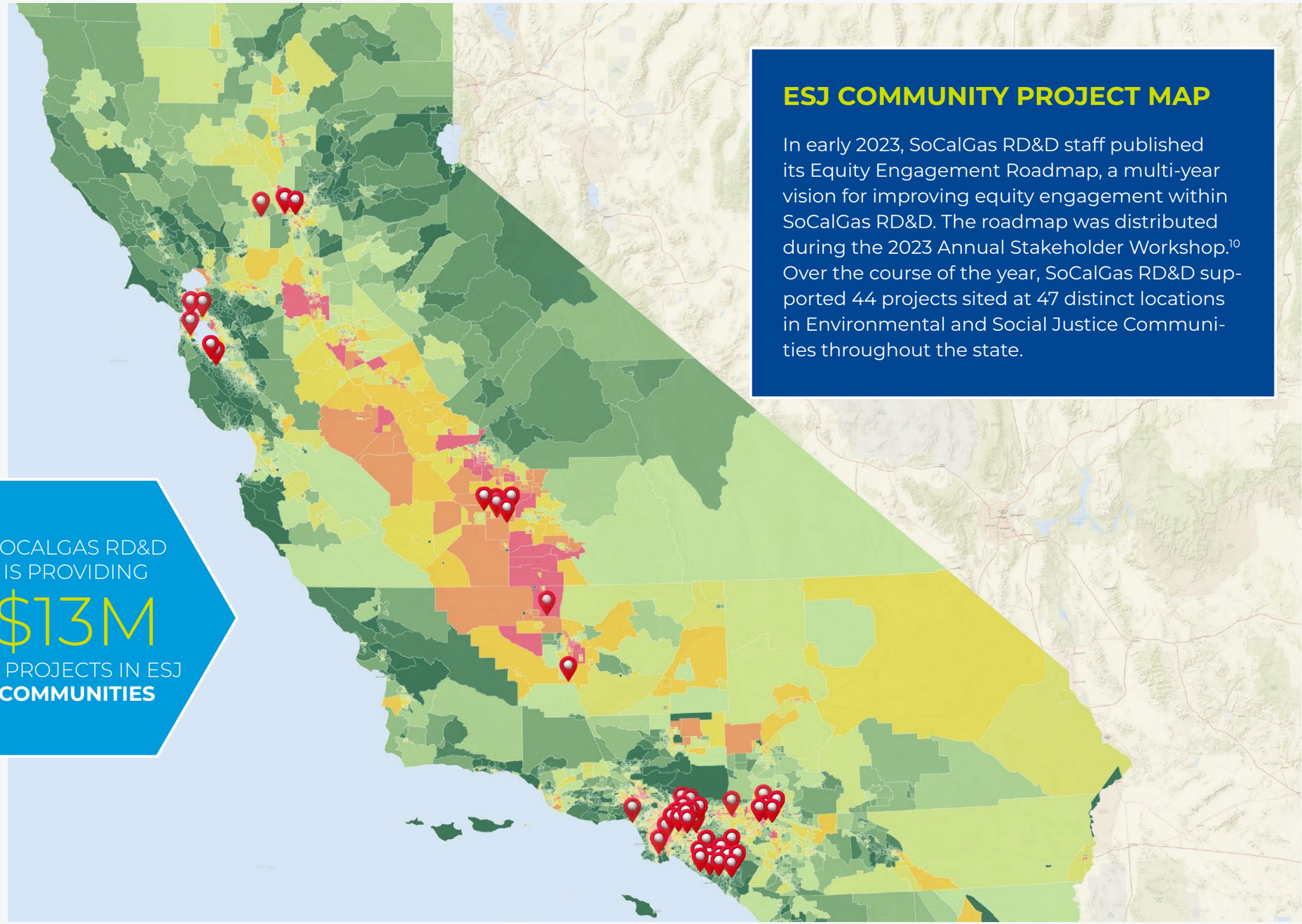
44

PROJECTS LOCATED IN ESJ **COMMUNITIES** IN 2023

SOCALGAS RD&D IS PROVIDING

$13M

TO PROJECTS IN ESJ **COMMUNITIES**



ESJ COMMUNITY PROJECT MAP

In early 2023, SoCalGas RD&D staff published its Equity Engagement Roadmap, a multi-year vision for improving equity engagement within SoCalGas RD&D. The roadmap was distributed during the 2023 Annual Stakeholder Workshop.[10] Over the course of the year, SoCalGas RD&D supported 44 projects sited at 47 distinct locations in Environmental and Social Justice Communities throughout the state.

H2 Grand Prix expands opportunities and changes lives

Students from Los Angeles build and race hydrogen fuel cell vehicles at the 2023 H2GP World Finals in Las Vegas.

SPOT LIGHT

2023 EQUITY ACTIVITIES

"Every dollar that companies such as SoCalGas invest in programs like this changes kids' lives."

—ISRAEL HERNANDEZ
TEACHER, ENGINEERING DESIGN,
BOYLE HEIGHTS STEM MAGNET
HIGH SCHOOL

Left to right: Rene Flores, Yatziri Rodriguez, Juan Aguilar-Lepe, Joel Salcedo, Israel Hernandez, Jorge Sorto

In 2022, SoCalGas RD&D collaborated with Horizon Educational to sponsor 10 high school teams at five high schools throughout Southern California in the Horizon Hydrogen Grand Prix (H2GP). Each of the schools receives Title I funding supporting low-income students. In addition to furthering equitable education, the partnership helps students gain vital skills needed to tackle global climate challenges.

"The H2GP is a series of programs focused on hydrogen and fuel cell education," said Max Accordino, Head of Business Development at Horizon Educational. For high schoolers, the H2GP culminates in a fuel cell electric vehicle (FCEV) racing series where students design, build, and race 1/10th-scale, remote-controlled FCEVs. In the 2022-23 school year, hundreds of schools across 13 countries took part, helping students develop critical thinking and creativity, as well as traditional science, technology, engineering, and math (STEM) skills.

One of the teams sponsored by SoCalGas RD&D—Los STEMateros—was from the Boyle Heights STEM Magnet

High School in Los Angeles. "In their school's first year participating in H2GP, this group of 9th and 10th graders made it all the way to the world finals in Las Vegas," said Accordino.

The team was led by Israel Hernandez, an engineering design teacher. "I love introducing students to a wide variety of topics, including drones, robotics, computer aided design, and 3D printing," said Hernandez. When he presented the opportunity to take part in the H2GP, his students jumped on it. "The idea of applying what they had learned in class to build an FCEV really sparked their interest."

Hernandez began by teaching the five team members about fuel cell technology and then provided them with a kit from Horizon Educational that included everything they needed to build a basic FCEV. That was enough to get the students started, but they knew that to really compete, they would need to improve upon the base model—a process that proved challenging on many levels.

"They were competing with more experienced teams that had been a part of H2GP for four or five years," said Accordino. "Many teams were also from schools in more affluent areas with access to greater financial resources."

Fortunately, what the Boyle Heights team lacked in funding, it made up in creativity. "The students modified their FCEV more than any other first-year team I have seen," said Accordino. "They actually hacked into the fuel cell, tested individual cells, and made their own controller to improve the vehicle's efficiency." The students also replaced the standard nickel metal hydride battery with a much more powerful, lighter lithium-ion battery and modified the chassis to reduce weight.

After the students built the FCEV, they entered it into three practice races in Orange County, California, further modified the vehicle, and then participated in the regional state qualifier races. "They were the only brand-new team to qualify for state finals, where they placed fifth out of 100 teams," said Accordino. "That is very impressive for a first-year team."

In September 2023, the students traveled to Las Vegas for the World Finals, a six-hour endurance race with teams attempting to complete the greatest number of laps around a track. Before racing, the students presented their vehicle to a panel of judges. Then, once the race began, the students were in charge of everything. "The teachers were not allowed to touch the car at all," said Accordino. "So, if the car broke down, it was completely up to the students to get it back on track." Ultimately, the students exceeded all expectations and placed 14th in the world.

"They were very excited," said Hernandez. "They realized they could compete with the best teams. Next year's season has not even officially begun, and they are already meeting after school and working on their next design."

"SoCalGas RD&D supported these students throughout their journey because they believe that the best way to educate the workforce of the future is to start young," said Accordino. "It has been fantastic working with them."

"As a teacher, I have a lot on my plate," added Hernandez. "SoCalGas took much of the stress off my shoulders, helping us to interact with the media and supporting the program financially. I didn't have to worry about any fundraising."

Graduates of H2GP develop real-world renewable energy, engineering, and collaboration skills that set them apart when applying for college or internships. "Companies like SoCalGas regularly reach out to us asking how they can gain access to these students," said Accordino. "They really are our future."

"Every dollar that companies such as SoCalGas invest in programs like this changes kids' lives," concluded Hernandez. "They are no longer asking themselves if they belong in STEM. And, when they go to college, they're not going to second-guess themselves and question whether they can handle a STEM major. They will know that they belong."

Program

Goals and Structure

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

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

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

In 2023, SoCalGas RD&D planned to allocate funding across five research program areas: Low Carbon Resources, Gas Operations, Clean Transportation, Clean Generation, and Customer End-Use Applications.

2023 RESEARCH PROGRAM AREAS*

Low Carbon Resources

Carbon Capture, Utilization, and Sequestration

Renewable Gas Production

Gas Operations

Environmental & Safety

Operations Technology

System Design & Materials

System Inspection & Monitoring

Clean Generation

Distributed Generation

Integration & Controls

Clean Transportation

Off-Road

Onboard Storage

On-Road

Refueling Stations

Customer End-Use Applications

Advanced Innovation

Commercial Applications

Commercial Food Service

Industrial Process Heat

Residential Appliances

*See page 13 for information about recent changes to the structure of SoCalGas RD&D.

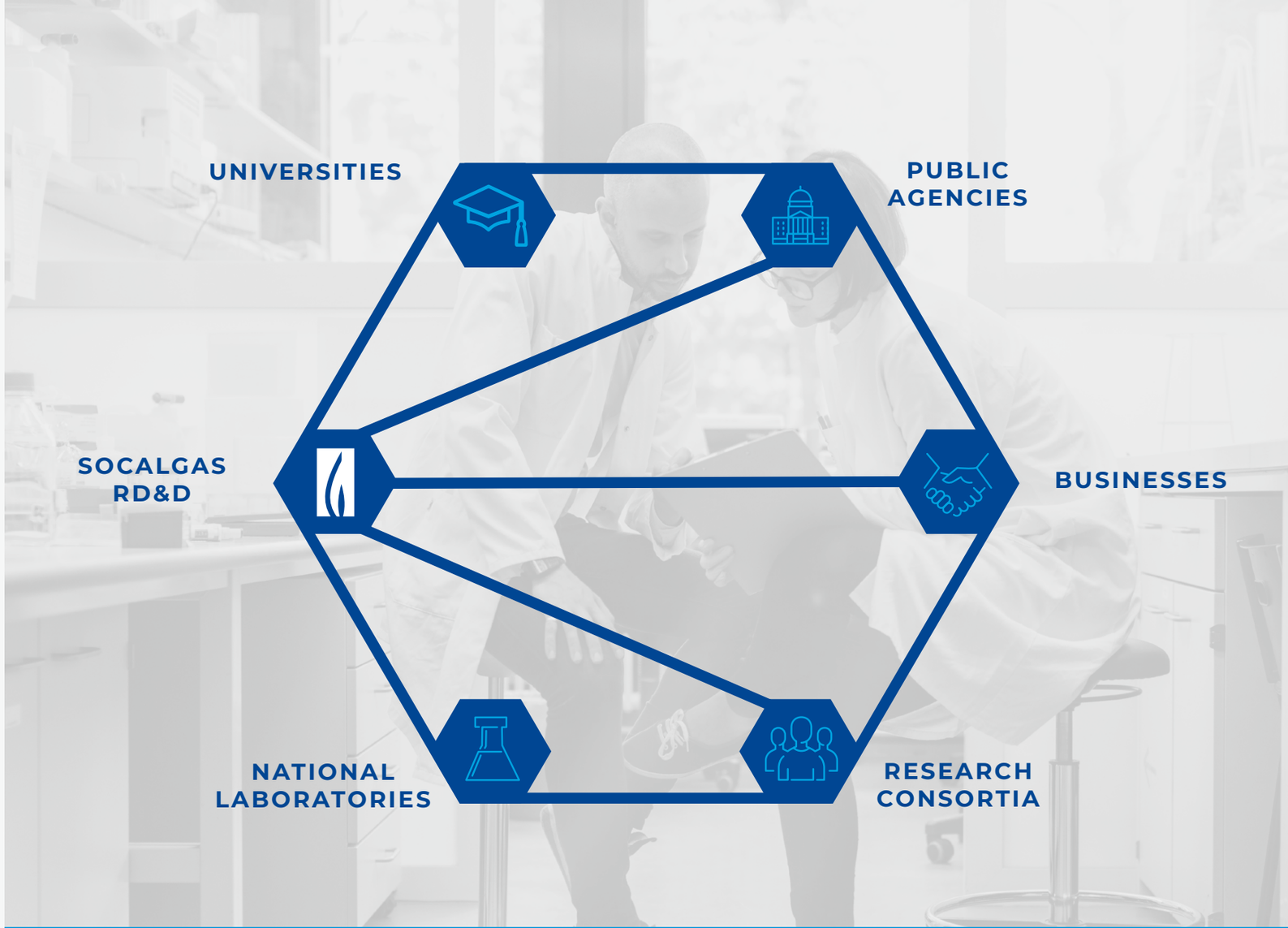
Research Collaborators

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 laboratories, startups, and established businesses, to maximize the impact of their investments in promising technologies and products with high potential for commercialization.

These relationships, which program staff have developed and fostered over many years, enable SoCalGas to engage science and technology experts, other utilities, pipeline operators, 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 allows program staff to help develop products and technologies that benefit ratepayers by lowering customer costs, saving energy, increasing safety and reliability, improving air quality, and reducing GHG emissions.

Together, RD&D staff and research collaborators exchange information and research concepts, collaborate on project development, establish 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 successfully execute projects.

See Appendix for more information.



"Energy research, development, and deployment programs are an essential part of the effort to achieve California's climate and energy policy goals."

—CALIFORNIA PUBLIC UTILITIES COMMISSION

PROGRAM:

LOW CARBON RESOURCES

The Low Carbon Resources program seeks to decarbonize the gas supply while improving its affordability and reliability. To achieve this goal, program staff members develop, promote, and advance new technologies aimed at increasing and expanding the production and use of clean hydrogen and RNG. They also support projects to displace conventionally sourced pipeline gas and to capture and permanently remove atmospheric GHG emissions. In addition, the Low Carbon Resources program aims to promote and advance new technologies for carbon capture, as well as the reuse of captured carbon in the manufacturing of RNG and other useful products or its permanent sequestration in subsurface geologic formations.

This program includes two subprograms.

Carbon Capture, Utilization, and Sequestration

This subprogram focuses on carbon management—a vital component 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. Carbon management technologies seek to remove the remainder of the excess CO_2 from the atmosphere and the ocean; capture carbon emissions from point sources; convert carbon into useful products such as plastics, cement, or biofuels; and sequester CO_2 in subsurface geologic formations.

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

In compliance with CPUC Resolution G-3601, this subprogram has been retired. See page 13 for more information.

Renewable Gas Production

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

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

California firm develops first water-positive hybrid direct air capture technology

SoCalGas RD&D helps bring innovative carbon removal system from laboratory to demonstration and prepare for regional deployment in carbon capture hub.

SPOT LIGHT

Program: **Low Carbon Resources**

Collaborator: **Avnos**

Total Project Cost: **$3,150,000**

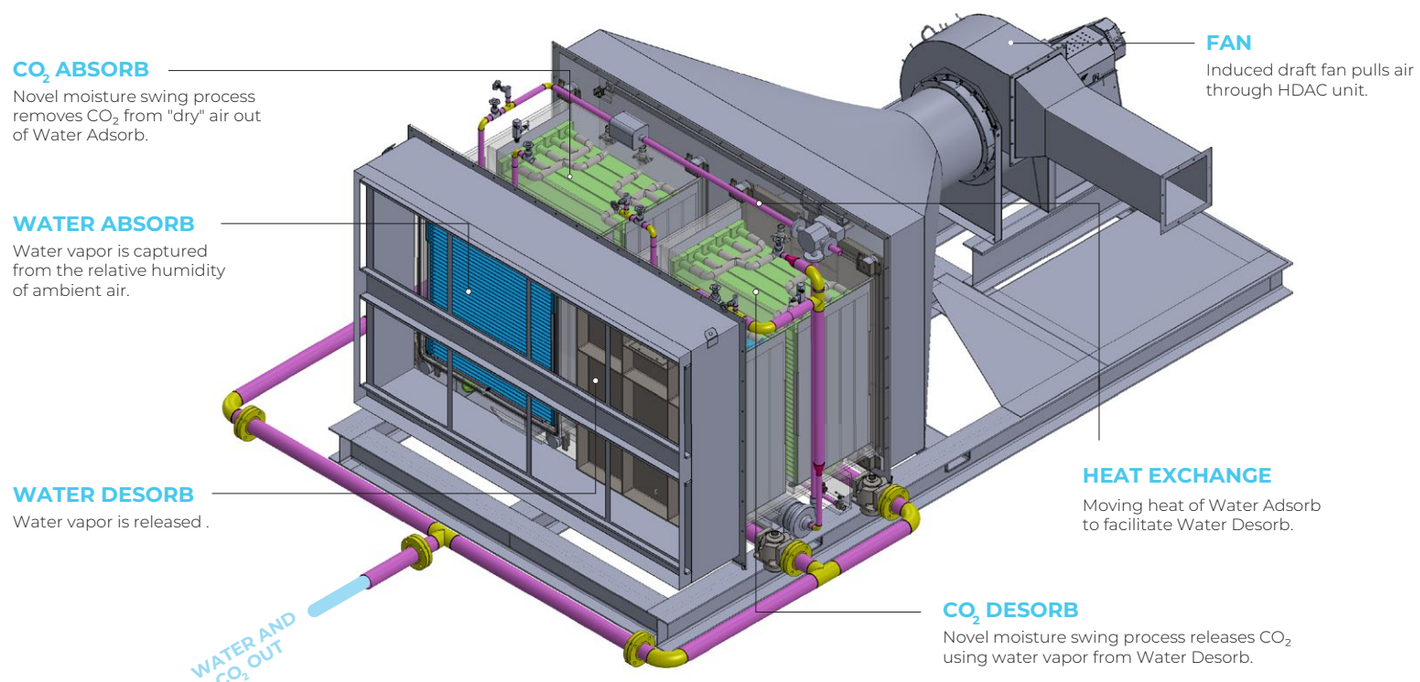
SoCalGas: **$650,000**

Cofunding: **$2,500,000**

Primary Benefits:

REDUCED GHG EMISSIONS

IMPROVED AIR QUALITY



HDAC Pilot Unit Design: *30 tons per year CO_2 / 150 tons per year water HDAC pilot unit*

Atmospheric carbon dioxide (CO_2) levels are rising. Reducing or eliminating CO_2 emissions is a critical step in bringing these levels down but it is not enough. It is also necessary to research, develop, and deploy additional methods of capturing CO_2, both from point sources such as smokestacks as well as legacy emissions from the atmosphere itself. In California, the California Air Resources Board explicitly calls for the "capture and storage of carbon" as part of its plan to achieve carbon neutrality.[11]

One way to remove legacy CO_2 is direct air capture (DAC). "DAC is a negative-emissions technology," said Will Kain, founder and CEO of Avnos. "It enables us to pull down emissions that have been in the atmosphere for a long time."

For several years, Avnos has been developing an innovative hybrid direct air capture (HDAC) technology capable of capturing both CO_2 and water from the same air stream. "Our HDAC system is the first DAC technology that is water-positive," said Kain. "For every ton of CO_2 it

removes from the atmosphere, our system produces up to five tons of water."

In early 2021, Avnos collaborated with SoCalGas RD&D and Pacific Northwest National Laboratory (PNNL) on a project supported by a grant from the US Department of Energy (DOE) to deploy a pilot-scale HDAC system in Kern County, California. SoCalGas provided $650,000 in match funding and helped secure the project location at an industrial plot north of Bakersfield in an area categorized as an environmental and social justice community. "This project would not have happened without SoCalGas RD&D," said Kain. "The capital they provided catalyzed activity on the project."

PNNL, which initially developed the HDAC technology, helped Avnos translate its laboratory-scale design to the 30 ton-CO_2 per year pilot unit. Joining these three organizations were the University of North Texas, BASF, and Barr Engineering, the project's engineering, procurement, and construction partner.

"The goal of this project was to prove that HDAC works in the field," said Kain. "The most significant challenge we faced was integration of the CO_2 and water removal subsystems." The unit, which uses an induced-draft fan to pull air through it, is divided into two chambers, each of which includes a water-capture and a CO_2-capture bed. At any time, one side of the system is active, capturing CO_2 and water from the air.

During this process, water is removed from the air by a desiccant developed by BASF until a target humidity level is reached. The dehumidified air then travels to the CO_2 removal subsystem, where the CO_2 is adsorbed onto a specialized material developed at the University of North Texas. Once the active, adsorbing chamber is saturated with CO_2, it switches to desorption—outputting CO_2-rich air for downstream use or sequestration—while the other half switches back to adsorption. The HDAC system also outputs distilled water. This cycle repeats, providing a nearly continuous stream of captured CO_2.

"In most DAC systems, water and CO_2 compete for the adsorbent material," said Kain. "By removing water from the air before it reaches the CO_2 removal subsystem, our technology virtually eliminates that competition, enabling a much more effective CO_2 uptake. The system also requires no thermal input and, unlike competing DAC systems, can run entirely on renewable electrons." By the end of 2023, the team had proven that HDAC works in the field and moved into optimizing system operations.

The team has identified a variety of uses for the system outputs. "We have looked at adding to municipal water supplies, providing cooling water in data centers, and providing irrigation for growing plants, which would have the benefit of capturing additional CO_2," said Kain. At larger scales, Avnos envisions working with fuel synthesis partners to convert water and CO_2 into synthetic, carbon-neutral fuels such as sustainable aviation fuel.

"Ultimately, the bigger market will be permanent sequestration of CO_2 in subsurface geologic formations, including depleted oil and gas wells," said Kain. Project developers could build HDAC systems onsite and attempt to monetize the CO_2 via US Internal Revenue Code, Section 45Q, which provides up to a $180 tax credit for every ton of CO_2 permanently sequestered.[12] Another option is the small but growing voluntary carbon market, where large emitters can purchase credits to achieve net-zero operations.[13]

To get there, Avnos, PNNL, and SoCalGas RD&D have begun working on a scaled-up demonstration system, also in Bakersfield, that is designed to be capable of removing 300 tons-CO_2/year from the atmosphere, with deployment anticipated by late 2024 as part of a regional carbon capture hub. "That system will serve as one module of a commercial-scale system," said Kain. "So, if you wanted to capture 3,000 tons per year, you would install 10 of those modules, and so on."

"Procurement is underway on the demonstration project," said Kain. "We have applied a lot of the learnings from the pilot project to the design of the 300-ton model. After completing that, our plan is to build and demonstrate a 3,000-ton-per-day system by late 2025." He anticipates that the HDAC technology will be ready for commercial deployment by early 2026.

PROGRAM:

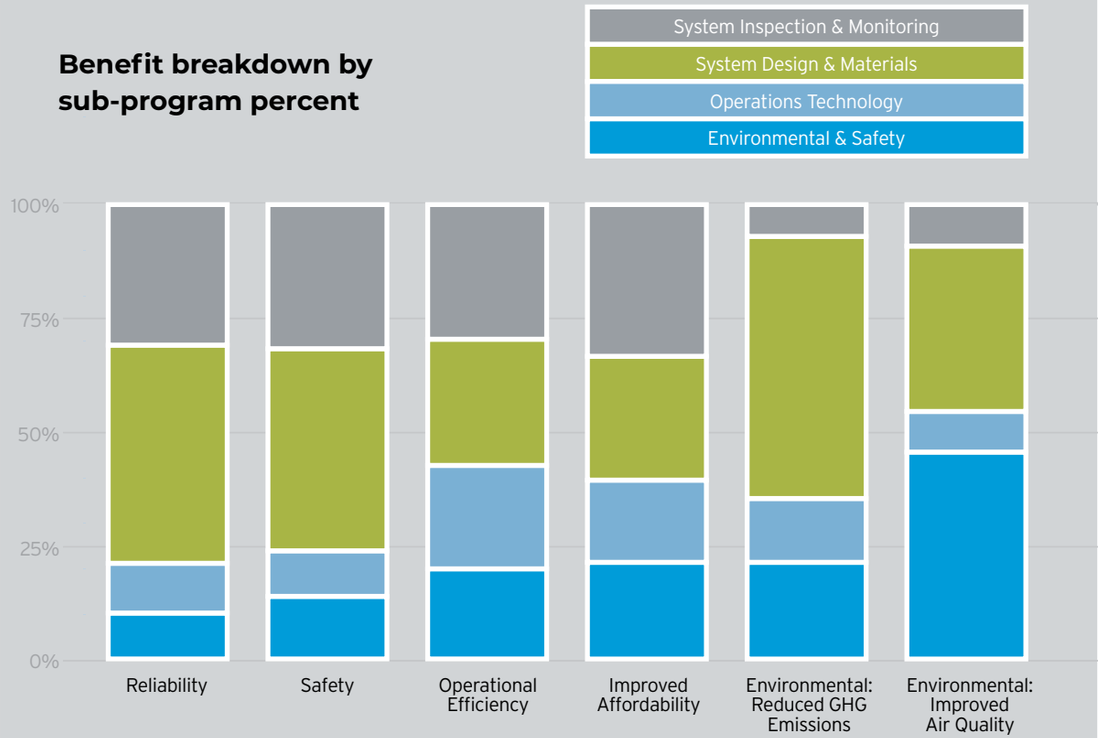
GAS OPERATIONS

The Gas Operations RD&D program supports pipeline transmission, distribution, 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 facilitates technology development driven by emerging regulatory requirements. Its primary goals are to develop, test, and introduce new gas operations technologies that are beneficial to ratepayers, public safety, and the environment.

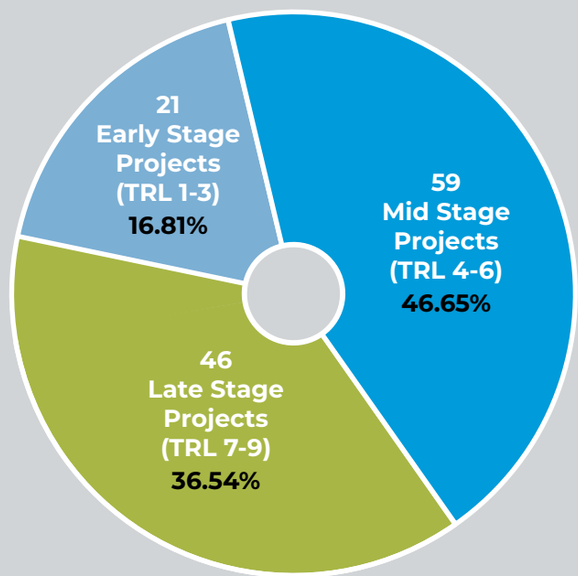
Each project within this program was evaluated for its potential to provide ratepayer benefits appropriate to its technology readiness level (TRL).[14] The TRL is a systematic framework used to assess the maturity and readiness of technologies for practical application.

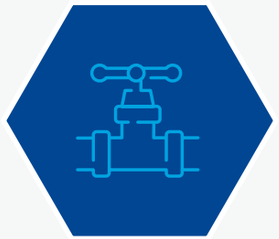
TRLs 1-3 span projects conducting basic technology research to those performing analytical and laboratory

Benefit breakdown by sub-program percent



Percent of projects by technology readiness level





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

The program invests in technology development projects that are divided into the subprograms below. Gas Operations staff have prepared detailed summaries of each project supported by this program and identified associated ratepayer benefits.

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 and company employees or contractors working on or around the pipeline. Areas of key project focus include damage prevention, efficiency improvements, criteria pollutant reduction, and exploring how blending hydrogen into the pipeline impacts the operation and maintenance of the pipeline system, including modifications to the regulations and standards related to reliability, safety integrity, and environmental impacts. In 2023, this subprogram represented 18.4% of the Gas Operations project portfolio.

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

Operations Technology

This subprogram advances and develops techniques for the construction, operation, maintenance, rehabilitation, and testing of gas pipelines and systems that facilitate continued safe and reliable service. It also supports technologies that improve employee training and explores how to prevent gas leaks that result from blending hydrogen into the pipeline. Projects in this area refine and advance techniques that optimize current processes and equipment, leading to reliability, safety, operational efficiency, and improved affordability. In 2023, this subprogram represented 11% of the Gas Operations project portfolio.

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, affordability, and maintainability throughout the life cycle of pipeline assets. Other considerations include improving air quality and reducing GHG emissions. Projects include research to advance engineering design standards and models, developing risk analytical tools to comply with pipeline integrity regulations, modeling operational efficiencies of gas storage and compressor station assets, and assessing the effects of incorporating gas from nontraditional sources (biogas and hydrogen-blend) on overall natural gas quality and system integrity. Ultimately, lessons learned on these projects help SoCalGas better design, engineer, and develop its pipeline system. In 2023, this subprogram represented 42.2% of the Gas Operations project portfolio.

System Inspection & Monitoring

The objectives of this subprogram include developing technologies and methods for the inspection, monitoring, and testing of pipelines and pipeline components to assess the condition and performance of pipeline facilities. Projects in this subprogram leverage AI, machine learning, and preventive and predictive maintenance technologies, including data analytic models and data lakes. Projects can also focus on improving pipeline reliability, safety, and operational efficiency through data management that enables the identification of precursors to failures or incidents. Projects may also seek to improve performance of the natural gas system through development of new and existing internal inspection, external inspection, and monitoring technologies. In 2023, this subprogram represented 28.4% of the Gas Operations project portfolio.

New testing methodologies push the boundaries of electrochemical portable analyzer technology

SoCalGas develops new emissions testing methodology for internal use and sets the stage for wider deployment by its customers.

SPOT LIGHT

Program: **Gas Operations**

Collaborator: **Innovative Environmental Solutions**

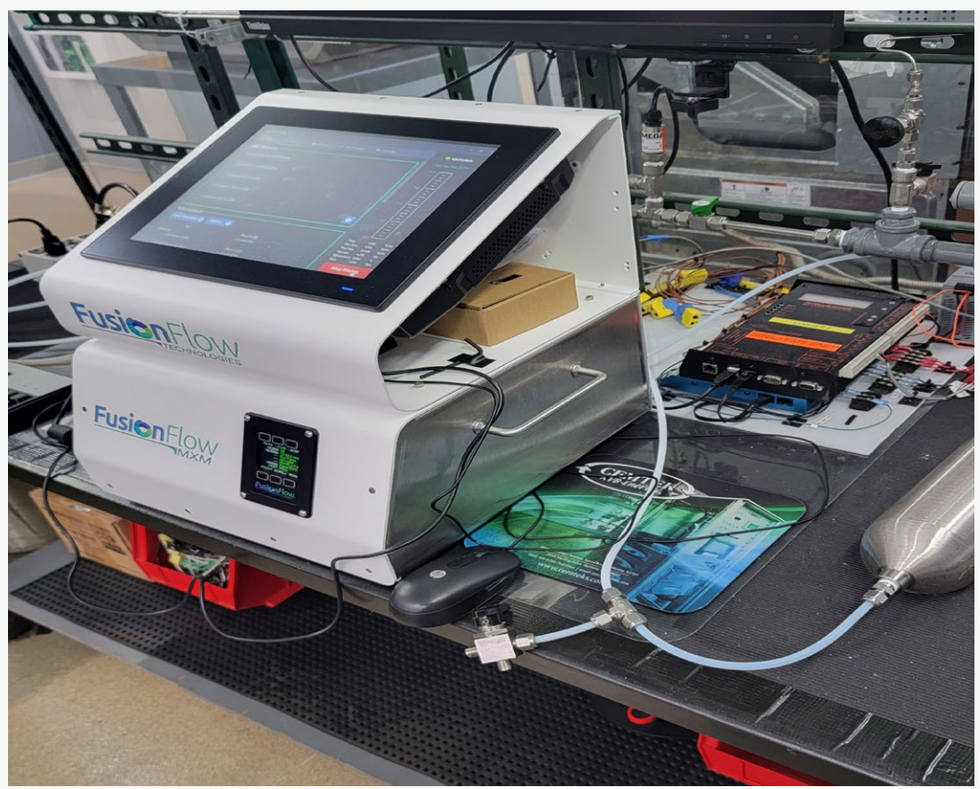
Total Project Cost: **$76,360**

SoCalGas: **$76,360**

Cofunding: **$0**

Primary Benefits:

IMPROVED AIR QUALITY



A variety of equipment types—including natural gas boilers and compressors—emit criteria pollutants such as nitric oxide (NO), nitrogen dioxide (NO_2), and carbon monoxide (CO). US National Ambient Air Quality Standards require that the US Environmental Protection Agency (EPA) and state and local agencies regulate criteria pollutants.

Facilities that emit such pollutants traditionally had a single option when verifying compliance with emissions targets. "They had to conduct expensive and complicated tests requiring multiple personnel and analyzers in large trailers," said Andy Sanchez, an engineer in the Compressor Services team at SoCalGas.

Test methods for handheld, portable electrochemical analyzers were originally created to detect normal to high emissions ranges—hundreds of parts per million (ppm)—instead of the lower emissions targets that have been introduced through new regulation.

PROJECT METHODOLOGY

To address this challenge, SoCalGas worked with Innovative Environmental Solutions (IES) on an earlier project initiated by Pipeline Research Council International in 2018 to develop new, more efficient testing methods that could reduce costs, maintain quality, and enable accurate measurement of NO, CO, and NO_2 concentrations as low as 25 ppm. This earlier project resulted in two new methods—Other Test Method (OTM)-038 and OTM-039—both approved by the EPA in 2020.[15]

As new low-emission technologies—such as fuel cells and certain generators—have entered the market, emissions targets have continued to decrease, prompting SoCalGas and IES to explore innovative, economical ways to measure emissions at even lower levels. "At 5 ppm for NO or NO_2 or 20 ppm for CO, there was no real guidance from the manufacturer or anyone else on how to use electrochemical portable, handheld analyzers," said Wendy Coulson, PhD, of IES.

On the new project, SoCalGas and IES sought to determine whether they could use the Testo® 350 electrochemical portable analyzer to repeatedly and reliably measure such ultra-low pollutant concentrations, as well as to investigate the limits of detection for these species. Success in this endeavor would enable facilities to conduct rapid and accurate measurements at ultra-low concentrations using electrochemical portable analyzers.

To get started, the research team developed an experiment plan and repurposed a gas blending system that SoCalGas had used on earlier hydrogen-related projects. "That system enabled us to create our own gas mixtures in the laboratory in real time and greatly expanded our testing capabilities," said Sanchez. "We set up NO, NO_2, and CO cylinders, as well as a dilution cylinder containing pure nitrogen."

"Using that system, we could connect the Testo 350 to the system's output and step our gas concentration up or down, comparing our measurements to what we knew the concentrations to actually be," said Sanchez. During test runs with concentrations less than 5 ppm, the analyzer sometimes measured anomalous readings. "If we were feeding the analyzer CO but it was reading NO, we would consider that noise."

The team sought to determine the cause of the noise and eliminate the anomalous readings. They also explored improving the accuracy of the measurements, looking at a variety of variables, including sensor age and periodicity of use. They learned that if they calibrated the CO, NO, and NO_2 sensors at 5 ppm before starting testing and used sensors that were less than 12 months old and in regular use, the noise did not manifest. "We discovered that the vintage and history of the sensors were critical factors," said Sanchez. "We found that we could achieve accurate detection levels of 0.5 ppm for NO_2 and 1.5 ppm for CO when using a cell that was used periodically and is less than 12 months old."

"Through systematic and careful research, we demonstrated in the laboratory that if you follow the calibration protocol we developed, you can trust those numbers, even at really low concentrations," said Coulson. "We anticipate that field trials will prove out the methods we developed in the laboratory and enable very economical measurement of ultra-low emission levels."

When deployed, the technology could have a significant impact. "Many of our customers use portable analyzers to determine if their equipment is compliant," said Gregg Arney, Compressor Services Team Lead at SoCalGas. As maximum allowable emissions limits drop, SoCalGas technicians could still perform onsite testing and provide accurate measurements using this technology, helping customers verify compliance, identify non-compliant equipment faster, and take corrective action sooner. "That could save time and reduce both the emissions and the costs associated with environmental compliance in any industry that has combustion limits."

"Solving complex problems requires nuance, rigor, and deep work," said Coulson. The process of producing defendable scientific work can pay off in many ways. "We not only achieved our specific goals, but also received a request from Testo to share our final report with the gas engine market as an example of how to measure low NOx levels. With greater public and industry dissemination, who knows what else is possible?"

PROGRAM:

CLEAN TRANSPORTATION

The Clean Transportation program supports activities that minimize environmental impacts related to the transportation sector. Focusing on utilization of hydrogen, this program facilitates the development of zero-emission technologies for on-road and off-road applications, as well as fueling infrastructure and on-board storage technologies. In compliance with CPUC Resolution G-3601, this program has been disallowed (page 13). During 2023, this subprogram supported previously approved projects in 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, cargo handling equipment, and aircraft.

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

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. The subprogram seeks to identify and manage concerns and issues arising from refueling of gaseous fuels—from storage to safety and standardization.

SunLine Transit Agency deploys hydrogen fuel cell paratransit bus

SPOTLIGHT

Program: **Clean Transportation**

Collaborator: **A-1 Alternative Fuel Systems**

Total Project Cost: **$2,086,608**

SoCalGas: **$531,166**

Cofunding: **$1,555,442**

Primary Benefits:

- REDUCED GHG EMISSIONS
- IMPROVED AIR QUALITY
- IMPROVED AFFORDABILITY

SunLine Transit Agency deploys hydrogen fuel cell paratransit bus

Transit agencies and other public and private fleet operators have begun to explore the transition to zero-emission vehicles such as battery-electric buses or hydrogen fuel cell shuttles. "Unfortunately, the high cost of such vehicles, as well as their limited availability, has kept many agencies and fleets from purchasing them," said Kevin Gilio, vice president at A-1 Alternative Fuel Systems. "And, although battery-electric vehicles (BEVs) are the right option in many applications, many of our transit customers have reported that BEVs do not have enough range, leading many of them to order multiple BEVs to meet their route schedules."

To address these challenges, A-1 collaborated with SoCalGas RD&D, TESCO, Davey Coach Bus Sales, SunLine Transit Agency, US Hybrid, Luxfer Gas Cylinders, and Turtle Top, which specializes in manufacturing small to mid-sized buses built on Chevrolet, Ford, and Freightliner chassis. "There is a tremendous need for an affordable, zero-emission option that can match the range of

The project team upfitted an existing IC paratransit bus manufactured by Turtle Top on a Ford cutaway E-450 platform.

comparable gas- and diesel-powered trucks and buses," said Gilio. "For this project, our goal was to convert a standard gas-powered paratransit bus to a hydrogen fuel cell-powered vehicle that refuels in 15 to 20 minutes and can travel 200+ miles per fill."

The team selected a 12-seat paratransit bus manufactured by Turtle Top on a Ford cutaway E-450 platform. "SunLine is committed to providing public transportation to the Coachella Valley and advancing zero-emission technologies," said Ray Allen, chief maintenance officer at SunLine Transit. "We are excited to evaluate the performance of this new hydrogen fuel cell paratransit bus to determine if it has a place in our fleet moving forward." SunLine operates a fleet of paratransit buses to serve people who are functionally unable to use its fixed-route service.

Understanding how to convert the baseline vehicle required a combination of modeling and experimentation. "Basically, we removed the internal combustion (IC) engine and all the associated IC components," said Gilio. "Then, we added our hydrogen fuel storage solution equipped with Luxfer type-III storage tanks." US Hybrid served as the system integrator, integrating the electric propulsion system and the fuel cell with A-1's storage solution, as well as all other electronic components such as heating and air conditioning.

One of the team's most pressing challenges was ensuring that the upfitted bus did not exceed the maximum weight specifications for a 14,500 GVWR vehicle. "Hydrogen tanks—which operate at 5,000 pounds per square inch—are heavier than natural gas tanks and significantly heavier than the baseline bus's ambient-pressure gasoline tanks," said Gilio.

Positioning the new components was also quite a challenge. "The bus was not built to house hydrogen storage tanks, batteries, and a fuel cell," said Gilio. "For certain parts, we had to use trial and error to find their right place on the vehicle and to determine where lower-weight or smaller substitutions were possible."

By December 2023, the project team had completed the bus conversion and quality assurance processes and transferred the new zero-emission vehicle to SunLine Transit, where it entered operations. Concurrent with the 12-month demonstration period, the project team plans to send a second converted paratransit bus to the Larson Transportation Institute's Bus Research and Testing Center in Altoona, Pennsylvania. There, the bus will undergo rigorous testing for maintainability, reliability, safety, performance, structural integrity and durability, fuel economy, noise, and emissions. A-1 will also confirm the bus's compliance with the Federal Transit Administration's Buy America requirements.

"Once we have completed all that, we will have a product that authorized Turtle Top dealers TESCO and Davey Coach can sell to their customers at transit agencies, hotels, airports, retirement homes, and more," said Gilio. He also believes that the team will be able to scale its solution to other platforms such as the Ford F-550. "We designed the technology with adaptability in mind."

By project's end in late 2024, the team hopes to develop a kit that A-1 can use to convert a variety of gas-powered paratransit or shuttle buses to hydrogen fuel cell buses. The kit would include the propulsion system, batteries, electric motor, and fuel cell. Such a solution addresses some key challenges to the widespread adoption of zero-emission buses. "Our approach provides a near-term and affordable way for fleets to transition to hydrogen fuel cell technology without the high capital costs associated with purchasing a new vehicle," said Gilio. "We will continue to work closely with project partners on ways we can improve the hydrogen bus as we receive more real-world feedback from SunLine."

The adaptability of this technology is key when considering its potential to decarbonize other fleet vehicles, such as those used by SoCalGas for day-to-day operations. SoCalGas has been tasked with decarbonizing its fleet in the most cost-effective way possible. Its fleet contains a wide range of vehicle types with range and duty cycle requirements that are not well suited to current BEV options. Advancing fuel cell technology for medium-duty vehicles and developing modular kits that could potentially be implemented across multiple OEM platforms has the potential to simplify the transition and reduce costs for SoCalGas, as well as other fleets.

"This project would not have been possible without SoCalGas RD&D," said Gilio. "They provided 25% of the project cost and really helped build momentum." SoCalGas also provided access to its network of potential end users, who provided useful input about their experiences with other hydrogen fuel cell buses—input that the project team was able to incorporate into its solution. Working with SoCalGas RD&D had one other critical benefit: "As a leader in the industry, their name has clout. When someone hears that SoCalGas is backing a project, they take it more seriously."

SunLine Transit Agency is evaluating the performance of the new hydrogen fuel cell paratransit bus to determine if it has a place in its fleet moving forward.

PROGRAM:

CLEAN GENERATION

The Clean Generation program targets the development and demonstration of high-efficiency products and technologies associated with the generation of power for the residential, commercial, and industrial market segments. Its goals are to reduce emissions, lower customer costs, integrate renewable fuels, and improve energy reliability and resiliency.

Clean Generation comprises two subprograms.

Distributed Generation

This subprogram develops and enhances distributed generation technologies. Microgrids and the increasing availability of RNG and clean hydrogen offer new opportunities for the deployment of low-emission and renewably fueled distributed generation technologies. In compliance with CPUC Resolution G-3601, this subprogram has been disallowed. See page 13 for more information.

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.

Bloom Energy powers Caltech buildings with hydrogen generated onsite

Technology manufacturer leverages its fuel cell platform to accelerate electrolyzer production.

SPOT LIGHT

Program: **Clean Generation**

Collaborator: **Bloom Energy**

Total Project Cost: **$1,500,000**

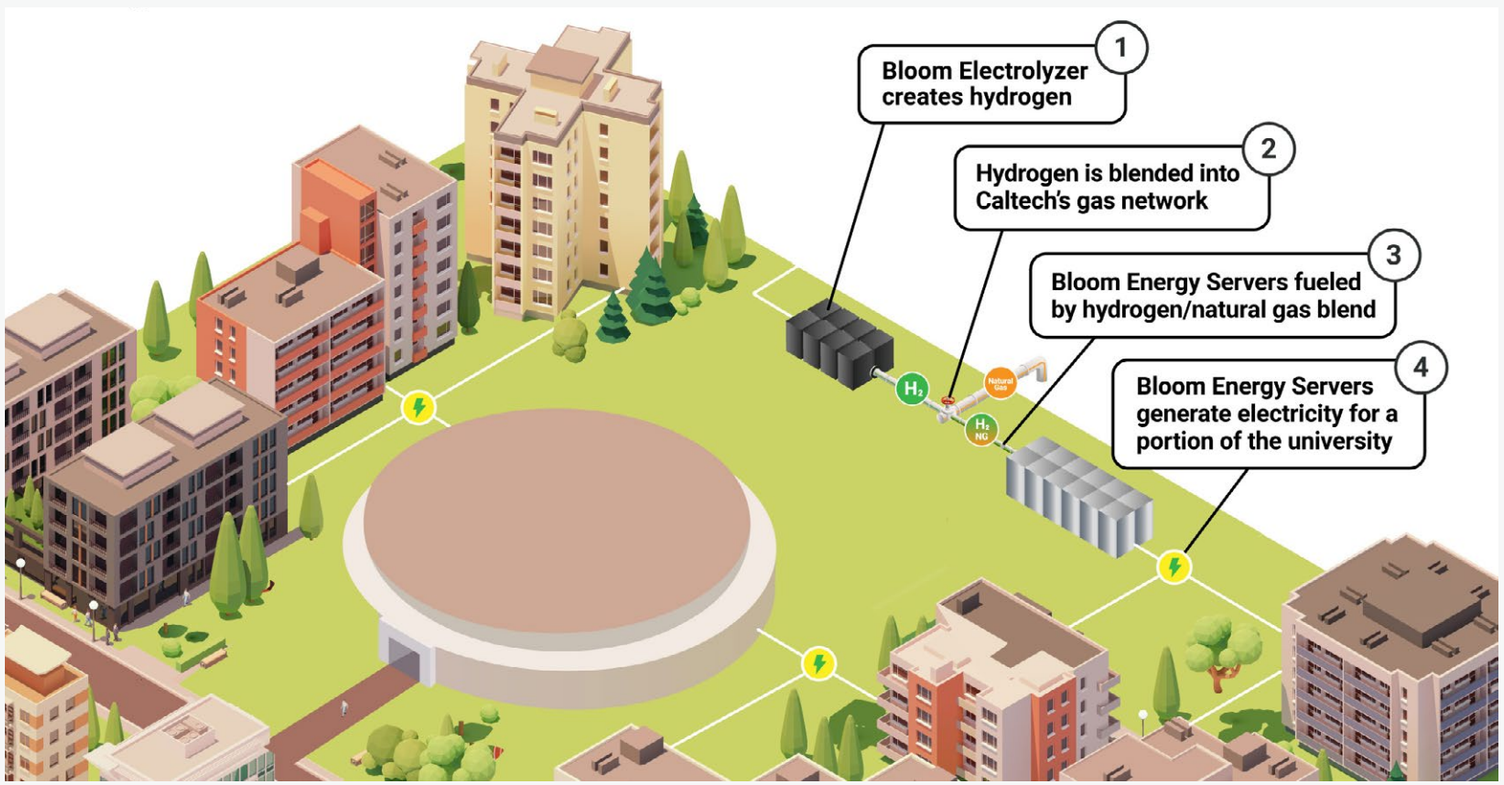
SoCalGas: **$500,000**

Cofunding: **$1,000,000**

Primary Benefits:

REDUCED GHG EMISSIONS

IMPROVED AIR QUALITY



California leads the nation in decarbonizing its energy supply, with the goal of achieving net carbon neutrality by 2045.[16] Achieving that goal is a multi-decade process, involving dramatic changes in how people travel, move goods, design buildings, grow food, and produce and consume energy.

"It's called the energy transition for a reason," said Rick Beuttel, vice president of Hydrogen Business at Bloom Energy. "It took us more than 100 years to get into this mess. We are not going to get out of it overnight." Over the past decade, California has made great progress toward decarbonization, increasing annual generation of renewable electricity via solar by 20-fold since 2012 and via wind power by 63%.[17]

"But we have hit a cap," continued Beuttel. "If we are really going to drive big change and clean up our energy supply, we need to focus on developing clean, reliable power sources, including hydrogen." There is widespread

consensus that clean hydrogen is the most practical way to decarbonize hard-to-electrify, heavy industries including steelmaking, cement manufacturing, shipping, and aviation. In pursuit of this goal, Bloom Energy has developed a solid oxide technology platform that enables both hydrogen production and distributed generation of electricity.

Bloom Energy has successfully deployed more than 1 gigawatt (GW) of its solid oxide fuel cell technology, including 4 megawatts (MW) at Caltech in Pasadena, California. "What we had not yet done was integrate our fuel cell Energy Server® with our solid oxide, high-temperature electrolyzer in a real-world environment," said Beuttel.

To address this challenge, Bloom Energy collaborated with SoCalGas RD&D in 2021. Together, the two organizations sought to produce clean hydrogen via electrolysis, compress and dehydrate it, blend it into Caltech's existing natural gas infrastructure, and convert the resulting hydrogen blend into electricity via the existing solid oxide fuel cells to power buildings on campus. "These are all proven technologies and processes, but we needed to ensure that the integrated system worked safely," said Beuttel. "That was the key technical challenge."

Before deploying the integrated system at Caltech, Bloom Energy built and tested the entire Bloom Electrolyzer and gas processing unit at its R&D facilities in California's Bay Area. "Once everything tested out, we disassembled it and reassembled it on the Caltech campus in early 2023," said Mark Parrish, director, Structured Finance and Corporate Development, at Bloom Energy. "After commissioning, we began operations in late 2023, with the goal of collecting data for 15-18 months."

"Caltech was very supportive throughout the project," said Parrish. "Bloom Energy fuel cells power multiple buildings on campus. The Institute really values the sustainability and reliability benefits of fuel cells, especially to support the microgrid on campus." This demonstration gave the project team the opportunity to explore the decarbonization of natural gas infrastructure. "We believe that advancing hydrogen delivery models, including within existing gas infrastructure, is a critical step on the road to decarbonization."

"This type of project advances the ball for the demonstration of hydrogen blending into the natural gas system," said Beuttel. "This was more than a demonstration in a laboratory. It is operating in real-world conditions on a university campus. We advanced the industry's body of knowledge."

The project team also explored the potential role of hydrogen in storing energy. The economics of building enough battery energy storage for the electrical grid are cost-prohibitive. "When you have a lot of renewables on the grid, you can run the electrolyzer, store the hydrogen as required, and convert it into electricity when demand rises," said Parrish. "In effect, it is a perpetual optimization machine that allows you to balance renewable energy supply and demand."

"SoCalGas RD&D was an ideal partner," said Parrish. "When we approached Caltech about their involvement, having SoCalGas on the project team made our proposal much more credible. I do not think this type of a project happens without the involvement of the gas utility." SoCalGas RD&D provided $500,000 in match funding, as well as valuable technical services and consulting. "And, importantly, they moved fast and were responsive."

SoCalGas is evaluating the results of the project to help determine the feasibility of installing Bloom Electrolyzers tied to renewable electricity at two of its Los Angeles facilities that are currently powered by electricity generated using Bloom's solid oxide fuel cell technology and natural gas. Such a solution would enable SoCalGas to reduce natural gas consumption and associated greenhouse gas and air pollutant emissions.

"Decarbonization will benefit everyone in California, really everyone on Earth," said Beuttel. "In this project, we demonstrated the safe generation of hydrogen—not at an industrial location but right in the middle of a university campus—and showed that we could blend it with natural gas and pipe it without any leaks to fuel cells and then convert it into power."

PROGRAM:

CUSTOMER END-USE APPLICATIONS

The Customer End-Use Applications program focuses on developing, demonstrating, and commercializing technologies that cost-effectively improve the efficiency and reduce the environmental impacts of gas equipment used in residential, commercial, and industrial settings.

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, 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 Heat

This subprogram develops advanced heating technologies and systems for use in the industrial sector. The industrial process heat end-use sector represents some of the largest users of gaseous fuels and the most difficult applications to decarbonize. In compliance with CPUC Resolution G-3601, this subprogram has been disallowed. See page 13 for more information.

Residential Appliances

This subprogram develops, demonstrates, and enhances technologies and advancements related to gas-consuming appliances in residences. In compliance with CPUC Resolution G-3601, this subprogram has been retired. See page 13 for more information.

Clean combustion technology paves way toward next generation of natural gas applications

Lantec Products adapts clean combustion technology to residential forced air furnaces and virtually eliminates nitrogen oxide emissions.

SPOT LIGHT

Program: **Customer End-Use Applications**

Collaborator: **Lantec Products**

Total Project Cost: **$432,500**

SoCalGas: **$92,500**

Cofunding: **$340,000**

Primary Benefits:

- OPERATIONAL EFFICIENCY
- REDUCED GHG EMISSIONS
- IMPROVED AIR QUALITY

"Our challenge was trying to incorporate our new burners into the footprint of an existing, commercially available forced air furnace while making sure that the end product was safe, cost-effective, and easy to service with existing parts."

—STEVEN LANG,
BUSINESS DEVELOPMENT MANAGER,
LANTEC PRODUCTS

Los Angeles suffers from the highest ground-level ozone levels in the nation. To meet federal ozone standards, the region must dramatically reduce emissions of nitrogen oxides (NOx), the key pollutant that creates ozone. The most effective way to achieve the necessary reductions is through extensive use of technologies that minimize or eliminate emissions.

One company seeking to pave the way for widespread NOx emissions reductions is Lantec Products. Its products are used in wastewater treatment facilities, chemical treatment systems, and other industrial processes that require cleanup of liquid and air emissions before their release into the environment.

Lantec developed a clean combustion technology for use in applications ranging from small domestic appliances to large industrial burners. Lantec collaborated with SoCalGas, GTI Energy, Johnson Controls, and the South Coast Air Quality Management District (SCAQMD) to adapt this technology to

The project team adapted Lantec's clean combustion technology to residential forced air furnaces.

residential forced air furnaces. Such furnaces typically emit particulate matter, volatile organic compounds, and NOx, making them an ideal subject for research.

In 2018, Lantec partnered with SCAQMD to retrofit a condensing and a non-condensing forced air home furnace from Johnson Controls with its combustion technology. SoCalGas RD&D matched funding from SCAQMD to move the project forward. The goal was to develop a next-generation furnace that could meet an emissions target of 7 nanograms (ng) of NOx per joule (J)—half of the current requirement of 14 ng-NOx/J set by SCAQMD's Rule 1111.[18]

"We have spent considerable time developing this adaptation," said Steven Lang, business development manager at Lantec Products. "Our challenge was trying to incorporate our new burners into the footprint of an existing, commercially available forced air furnace while making sure that the end product was safe, cost-effective, and easy to service with existing parts," said Lang. "That is not easy."

Critically, Lantec sought to develop a burner that required as little modification as possible to the original furnaces. "In an ideal world, we would unscrew the existing burners, put in the new ones, and suddenly have an ultra-low-NOx furnace," said Lang.

Lantec conducted baseline testing on the unmodified burners in early 2019, looking at a variety of metrics, including combustion capacity rating, combustion gas composition, and emissions of carbon dioxide, carbon monoxide, and NOx. Lantec then finished out the year developing a benchtop burner unit that met both the performance requirements and the cost target.

In January 2020, Lantec began phase two. "Our goal was to design and build two at-scale combustion systems

and install them in the condensing and non-condensing furnaces," said Lang. "Fundamentally, we knew that our combustion system should work exactly the same in both furnaces."

During this phase, Lantec went through six design iterations before achieving success. "We ran into several challenges," said Lang. "Achieving the emissions target on its own was rarely a problem." Instead, one of the biggest challenges Lantec faced was eliminating a persistent resonance that resulted from hot air blowing past heat exchanger tubes inside the furnaces. "It was loud enough to be unacceptable from a consumer standpoint."

In overcoming this problem, Lantec experimented with different ways to configure the burners and the combustion chambers. "Typically, low-NOx burners pre-mix fuel and air before combustion," said Lang. "When that process doesn't work well, you can get different concentrations of fuel and air in the gas stream, which can lead to hotspots within the combustion gas. Those spots are where the majority of NOx is formed."

"It was a bit like playing whack-a-mole," said Lang. "One iteration would minimize resonance but not ignite consistently. Another would run too hot for consumer safety or use parts that were not serviceable in the field. It was quite a bit of work but in the end, we came up with a design that met all the different requirements." Phase two concluded with operations, data collection, and internal testing of the new units.

In phase three, GTI Energy conducted third-party testing, completing these activities in mid-2023. "They ran a series of tests to assess the operational, safety, and emissions characteristics of the furnaces," said Lang. "They were very impressed. Our units exceeded all the performance requirements, including emissions, by a tremendous amount. With the condensing furnace we achieved emissions of 0.96 ng-NOx/J—far below the Rule 1111 regulatory target and significantly better than our original goal." The non-condensing furnace achieved slightly higher levels, at approximately 1.82 ng-NOx/J.

GTI and Lantec are enthusiastic about what comes next. "The completed design is nearly ready for commercialization," said Lang. "A manufacturer such as Johnson Controls would still need to perform quality assurance and quality control testing and, perhaps, optimize the form factor for commercial use. But we are close."

"We are also excited to study this design and learn to adapt it to larger applications," said Lang. "We suspect that redesigning this technology for other commercial and industrial applications—such as cooking—will not be as challenging as what we have already overcome. This project showed us that there is a potential path forward for natural gas applications that almost completely eliminate NOx emissions."

"Funding from SoCalGas RD&D was absolutely critical in helping us demonstrate the completed units and advance this technology toward commercialization," said Lang. "We were very appreciative of their participation on this project and look forward to their continued involvement on the team as we seek to deploy this solution more widely in the field."

Appendix

2023 Funding Recipients

Airgas USA, LLC

Air Technology Laboratories Inc

Alliance for Sustainable Energy, LLC

Alliance Source Testing

American Institute of Chemical Engineering

Baker Hughes Oilfield Operations

Barr Engineering Co.

BioVind LLC

Boys & Girls Club

Bridger Photonics Inc

Burns & McDonnell Engineering Co.

C-FER Technologies Inc

California Institute of Technology

Cameron West Coast Inc

Captura Corp.

Center for Transportation and the Environment

CNC Builders Inc

Colorado State University

County of Riverside

Darcy Partners LLC

Doby Hagar Trucking Inc

Driltek Inc

East Los Angeles College Foundation

Electricore, Inc.

Electrochaea Inc

EN Engineering, Inc.

EvolOH, Inc.

FedEx Corporation

Gas Machinery Research Council

Gas Technology Institute

Geo Drilling Fluids Inc

Getty Images, Inc.

Golden State Graphics

GTI Energy

Haliburton Energy Services

Immaterial Ltd.

Innovative Environmental

Int Translations

Interact PMTI Inc

IWVC, LLC

Jacobs Engineering Group Inc

KORE infrastructure LLC

Lantec Products

Linde Engineering North America LLC

Los Angeles Valley College

McMaster-Carr Supply Co.

Metalogic Inspection Services (Pacific) LLC

Metron

Momentum

Netcentric Technologies, Inc.

Northeast Gas Association

Onyx Oil Service Inc

Parsons Environment & Infrastructure

Pinnacle Petroleum Inc

Pipeline Research Council International, Inc.

Quality Tubular Services Inc

Rancho Santiago Community College

Regents of the University of California

Rincon Consultants Inc

Rival Well Services

R. R. Donnelley

RSI Pipeline Solutions Inc

Schlumberger Technology Corp

South Coast Air Quality Management District

South Bay Center for Counseling

Spec Services Inc

Stafford Multimedia, LLC

STARS Technology Corporation

Sustain SoCal

Susteon, Inc.

SWCA Environmental Consultants

Taft College Foundation

The Select Group

Trinity Safety Company LLC

ULINE

University of Tulsa

University of California – Berkeley

University of California – Los Angeles

Weatherford US, LP

World Wide Technology LLC

Zones LLC

RD&D Alumni Companies

ANESI GAS HEAT PUMPS

CAPTURA

kevala

SIERRA ENERGY

AVNOS

CLEAN ENERGY SYSTEMS

LANTEC PRODUCTS INCORPORATED

STARS Technology Corporation

BLUE FRONTIER

Electrochaea

Mainspring

Susteon

BRIDGER PHOTONICS

EVOLOH

METRON

twelve

BRIMSTONE

H2U TECHNOLOGIES

noble thermodynamics

Upstart Power A Smarter Generator for a Cleaner Tomorrow™

C1ZERO Decarbonizing Natural Gas

immaterial

SCALED POWER

ZERO EMISSION INDUSTRIES

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2023 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, Caltech, and the University of California. 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 five 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

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 25 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 2023 Projects

18

Initiated

0

Completed

10

Annual Dues

$72,250

2023 Dues Paid

$0

Total RD&D Funding

$753,397

Total Consortium Funding

$9,872,862

Operations Technology Development

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

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

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

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

Total 2023 Projects

46

Initiated

9

Completed

13

Annual Dues

$750,000

2023 Dues Paid

$0

Total RD&D Funding

$2,587,968

Total Consortium Funding

$24,689,727

Pipeline Research Council International

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

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

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

Total 2023 Projects

34

Initiated

5

Completed

11

Annual Dues

$150,000

2023 Dues Paid

$0

Total RD&D Funding

$1,781,309

Total Consortium Funding

$32,351,524

Utilization Technology Development

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

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

Total 2023 Projects

34

Initiated

20

Completed

21

Annual Dues

$350,000

2023 Dues Paid

$0

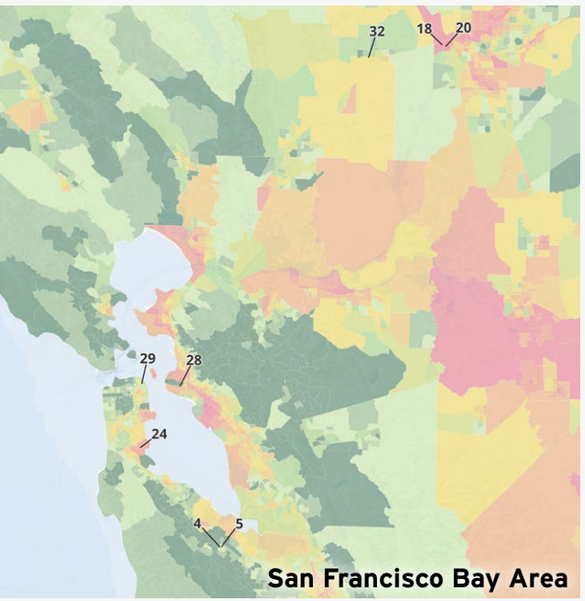
Total RD&D Funding

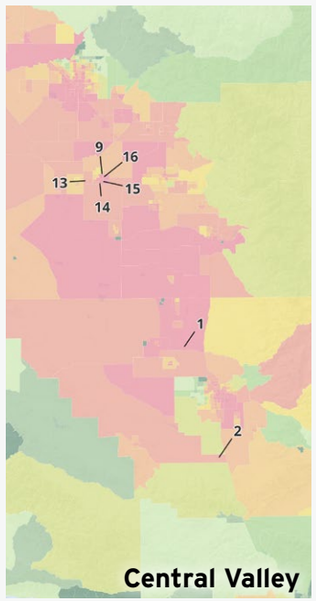
$915,022

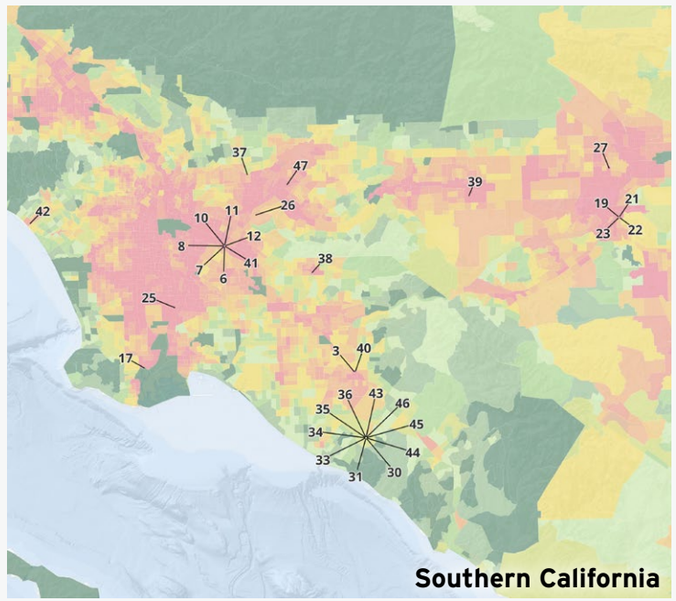
Total Consortium Funding

$12,781,327

2023 Projects in ESJ Communities







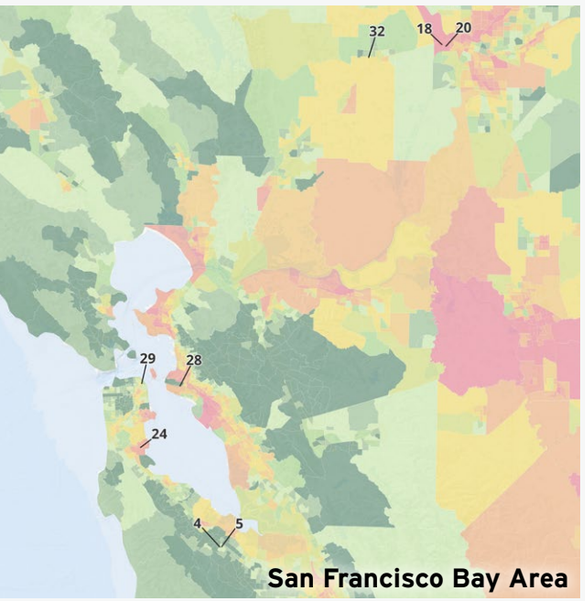
Low Carbon Resources

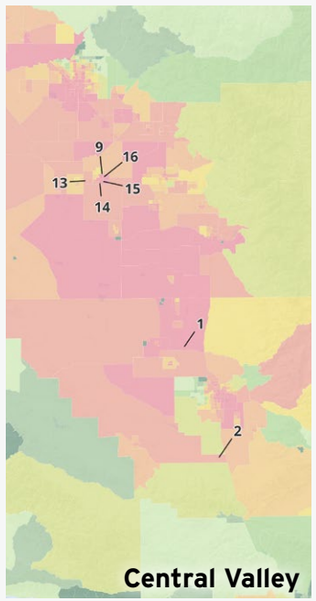
1. AVNOS Combined Water and CO2 Direct Air Capture System Demonstration; Bakersfield
2. AVNOS Hybrid Direct Air Capture to Fuels Demonstration; Bakersfield
3. Kore Biosolids Pyrolyzer Field Test; Santa Ana
4. Stanford Energy Efficient Strategies for Capture of Atmospheric CO2; Stanford
5. Susteon Stanford Iron-Oxide Based Catalytic Methane Pyrolysis Development; Stanford

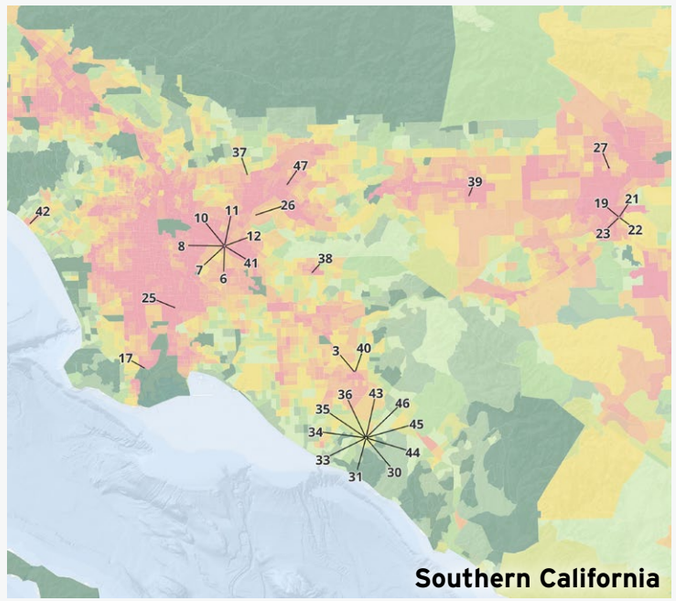
Gas Operations

6. Enhanced Locating Technologies for Underground Pipelines with Better Accuracy (8.20.I) (CEC GFO-19-502, group 3); Pico Rivera
7. Smart Shutoff Technology for Commercial and Residential Buildings; Pico Rivera
8. 3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management; Pico Rivera
9. Airborne Automated Threat Detection System-Monitoring and Surveillance of Imminent Threats Through Remote Sensing; Hanford (San Joaquin Valley)
10. Data Logger Evaluation Project - Phase II; Pico Rivera
11. Low NOx Portable Analyzer; Pico Rivera
12. Technology Testing Assessment Facilities (AMI Smart Metering); Pico Rivera
13. Subsidence Study; Armona
14. Subsidence Study; Hanford
15. Subsidence Study; Hanford
16. Subsidence Study; Hanford

2023 Projects in ESJ Communities







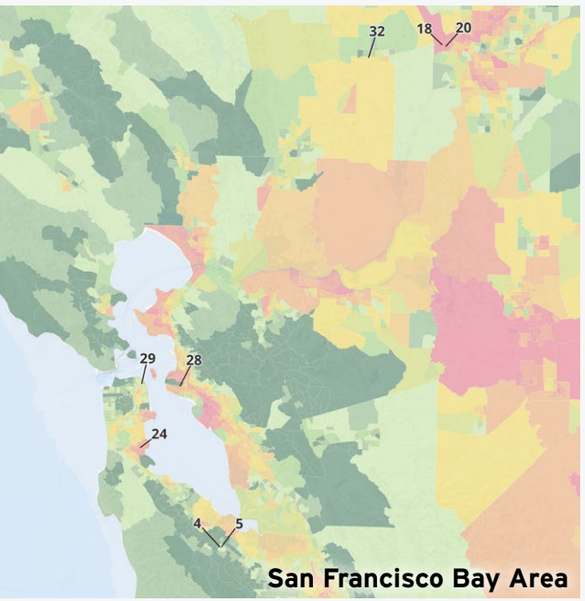
Clean Transportation

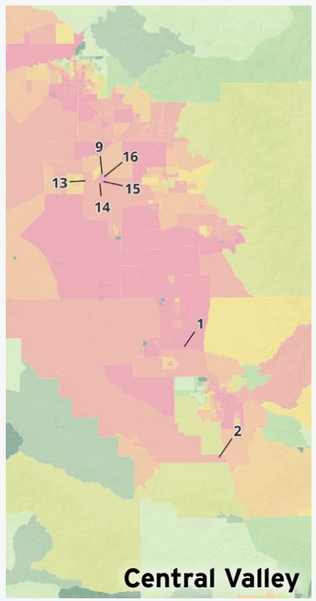
17. GTI Hydrogen Fuel Cell Yard Truck Port of Los Angeles Demonstration; Wilmington
18. Cummins Integrated Fuel Cell Electric Powertrain Demonstration; West Sacramento
19. GTI CNG Plug-In Class 8 Hybrid Truck Development and Demonstration; Riverside
20. GTI Energy Hydrogen Fuel Cell Switcher Locomotive Demonstration; West Sacramento
21. SCAQMD Heavy Duty Truck Engine In-Use Emission Study; Riverside
22. SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study; Riverside
23. UC RIverside Hydrogen Blended Natural Gas Engine Durability Test; Riverside
24. ZEI Harbor Craft Demonstration; South San Francisco

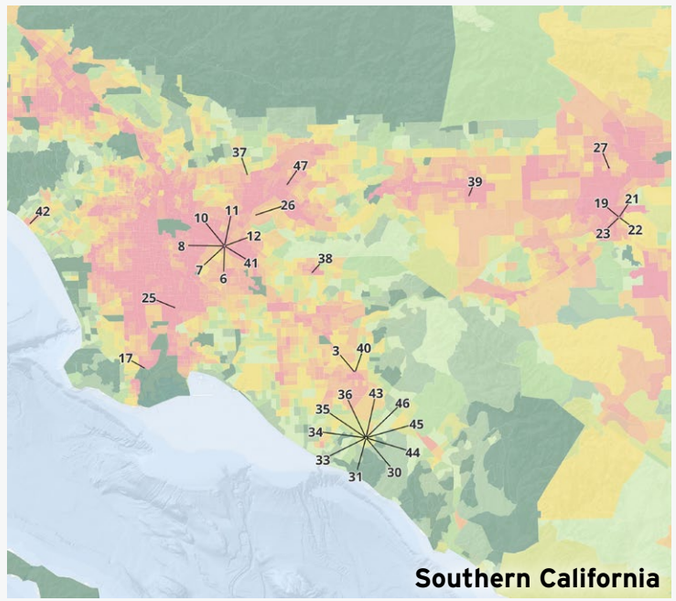
Clean Generation

25. EPRI ORC Waste Heat Recovery Demonstration; Compton
26. GTI Energy Marathon/EC Power mCHP Testing and Demonstration; City of Industry
27. Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration; Colton
28. Noble Thermodynamic Systems Ultra-Efficient CHP using a Novel Argon Power Cycle Development; Alameda
29. QSI Nano-Power Generation System Proof-of-Concept; San Francisco
30. UCI Capstone H2 Blending Research; Irvine
31. UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing; Irvine
32. Blue Frontier Fuel Cell Integrated Air Conditioning System Dynamic Lab Testing; Davis
33. UCI Fuel Cell Supported Nanogrid Controls Evaluation; Irvine
34. UCI Fuel Cells in Data Centers Research; Irvine
35. UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research; Irvine
36. UCI Integrated SOFC, Solar, and Storage System in ZNE Residential Nanogrid Design; Irvine

2023 Projects in ESJ Communities







Customer End-Use Applications

37. METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration; El Monte

38. GTI SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration; La Habra

39. GTI Energy Burner Exchange to Support Radiative Recuperator Demonstration; Ontario

40. GTI Energy Waste Heat Effective Transfer in Brewery & Distillery Demonstration; Santa Ana

41. EAC H2 Home Appliance Set Validation Test Research; Pico Rivera

42. GTI Strategic Pathways and Analytics for Tactical Decommissioning of Natural Gas Infrastructure

43. UCI Hydrogen Blend Commercial Stove Low NOx Catalytic Burner Development; Irvine

44. UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration; Irvine

45. UCI Catalytic Burner Retrofitted Water Heater Lab Demonstration; Irvine

46. UCI Low NOx Water Heater Retrofit for Hydrogen Blends Development; Irvine

47. GTI Model-Based Control Hospital Decarbonization Demonstration; Baldwin Park

Acronyms and Initialisms

Acronym	Definition
AB	Assembly Bill
ARCHES	Alliance for Renewable Clean Hydrogen Energy
BEV	Battery-electric vehicles
Caltech	California Institute of Technology
CARB	California Air Resources Board
CEUA	Customer End-Use Applications
CEC	California Energy Commission
CFR	Code of Federal Regulations
CG	Clean Generation
CHP	combined heat and power
CO	carbon monoxide
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
CT	Clean Transportation
DAC	Direct air capture
DOE	Department of Energy
DOT	Department of Transportation
DMI	Doosan Mobility Innovation
ECST	Engineering, Computer Science, and Technology
EPA	Environmental Protection Agency
ESJ	Environmental and social justice
EVA	Energy Virtual Assistant
FCEV	Fuel cell electric vehicle
GHG	greenhouse gas
GW	gigawatt
H2GP	Hydrogen Grant Prix
HDAC	Hybrid direct air capture
IC	Internal combustion
IES	Innovative Environmental Solutions
ILI	In-Line Inspection
IP	Intellectual Property
J	joule
kW	kilowatt
LBNL	Lawrence Berkeley National Laboratory
LCFS	Low Carbon Fuel Standard
LCR	Low Carbon Resources
LDC	Local Distribution Companies
M	million
MEA	membrane electrode assembly
MIC	Microbiologically influenced corrosion
MS-SOFC	metal-supported solid oxide fuel cell
MW	megawatt
ng	nanogram
NGA	Northeast Gas Association
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	nitrogen oxides
NREL	National Renewable Energy Laboratory
OIR	Order Institute Rulemaking
OTD	Operations Technology Development
OTM	Other Test Method

Acronyms and Initialisms

PHMSA	Pipeline and Hazardous Materials Safety Administration
PM	particulate matter
ppm	Parts per million
PNNL	Pacific Northwest National Laboratory
PRCI	Pipeline Research Council International
R&D	research and development
RD&D	research, development, and demonstration
RNG	renewable natural gas
SAF	Sustainable aviation fuel
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SCG	SoCalGas
SME	Subject matter expert
SoCalGas	The Southern California Gas Company
SOFC	Solid oxide fuel cell
STEM	Science, Technology, Engineering, and Math
TRL	technology readiness level
US	United States of America
USC	University of Southern California
UTD	Utilization Technology Development
ZEI	Zero Emission Industries

ATTRIBUTIONS

Page 5 https://www.imf.org/en/Publications/fandd/issues/2021/09/bezos-earth-fund-climate-change-innovation-levin

Page 6 SoCalGas RD&D interview with Jason Hanlin, September 22, 2023.

Page 7 Private communication with Robert Flores.

Page 10 SoCalGas RD&D interview with Katherine Chou, November 3, 2023.

Page 23 SoCalGas RD&D interview with Robert S. Wegeng, November 22, 2023.

Page 30 https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energy-research-development-and-deployment

ENDNOTES

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2. https://www.whitehouse.gov/ceq/news-updates/2022/11/17/ceq-launches-global-net-zero-government-initiative-announces-18-countries-joining-u-s-to-slash-emissions-from-government-operations/
3. https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/
4. https://www.brimstone.com/
5. https://www.businesswire.com/news/home/20230711105932/en/Twelve-Commences-Construction-of-First-Commercial-Scale-Plant-in-US-for-Producing-Sustainable-Aviation-Fuel-from-CO2
6. See Gas Operations spotlight, New testing methodologies push the boundaries of electrochemical portable analyzer technology, on page 36 of this document.
7. Reference available upon request.
8. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M521/K196/521196139.PDF
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12. https://www.irs.gov/instructions/i8933
13. https://carboncredits.com/what-is-the-voluntary-carbon-market/
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17. https://cleantechnica.com/2023/08/23/solar-generation-in-california-increased-almost-20-fold-in-the-last-11-years/
18. https://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1111.pdf

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

2023 SUMMARY OF ONGOING AND COMPLETED PROJECTS

LOW CARBON RESOURCES

SUBPROGRAM: CARBON CAPTURE, UTILIZATION, & SEQUESTRATION

AVNOS Combined Water and CO2 Direct Air Capture System Demonstration
This project aims to design, build, and operate a hybrid direct air capture (HDAC) system that captures 30 tons of carbon dioxide and 300 tons of water annually. Avnos is developing HDAC technology capable of capturing water and carbon dioxide from ambient air in one system. The team tested a new carbon capture technology called "Isothermal Water Vapor and Carbon Dioxide (CO2) 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 CO2 captured. The system also eliminates external heat and water consumption, improving the value proposition for Avnos' direct air capture technology. This project, which kicked off in 2020, will further demonstrate the outstanding technical and economic performance of the transformational HDAC technology. The project team completed the design of an HDAC system in 2021. In 2022, the group selected a host site in Bakersfield, California, and advanced on their site design and material procurement efforts. In 2023, the project team completed equipment fabrication, site development, equipment installation, and the system's commissioning. The system started operating, testing, and collecting data in Q1 2024.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$125,000**
Total Project Cost: **$650,000**
Total SCG Cost: **$3,135447**
Total Co-Funding: **$2,485,447**
Benefits:

AVNOS Hybrid Direct Air Capture to Fuels Demonstration
SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: Office of Naval Research, Total Energies

Start Date: 11/01/2022
End Date: 10/31/2024
Status: Disallowed
2023 Funds Expended: **$125,000**
Total Project Cost: **$4,685,545**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,185,545**
Benefits:

C4-MPC Microwave Catalysis for Process Intensified Modular Production of Carbon Nanomaterials from Natural Gas Development
SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

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

Start Date: 05/05/2020
End Date: 09/30/2024
Status: Disallowed
2023 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 CO2 Capture from Oceanwater Using Highly Efficient Electrodialyzer Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: Captura

Start Date: 11/01/2021
End Date: 03/31/2024
Status: Disallowed
2023 Funds Expended: **$350,000**
Total Project Cost: **$1,702,267**
Total SCG Cost: **$1,055,000**
Total Co-Funding: **$647,267**
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 operating cost data. This project is part of the overall effort to advance DAC technology to help reach U.S. Department of Energy (DOE) cost-per-kg carbon dioxide targets (DOE Earthshot target for carbon removal is $100/ton carbon dioxide). 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 was completed in 2023 and helped inform techno-economics and the technology's life-cycle analysis. Additionally, system performance and data the team gathered during the project will be used to guide future technology development activities.

Co-Funders: Svante, Climeworks, DOE

Start Date: 10/01/2020
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$50,000**
Total Project Cost: **$4,980,280**
Total SCG Cost: **$450,000**
Total Co-Funding: **$4,530,280**
Benefits:

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

PNNL has developed the IC3M platform to capture and convert carbon dioxide (CO_2) into valuable materials. Supported by a Technology Commercialization Fund partnership with DOE-FECM and SoCalGas, IC3M initially demonstrated methanol production at low temperatures (below 190°C) using hydrogen and CO_2 captured in a liquid solvent. The project will further explore the IC3M system's flexibility in producing chemicals and fuel precursors, such as formic acid, methyl formate, ethylene glycol, methane, and ethanol. The team seeks to improve methanol conversion rates to meet economic targets. Unlike conventional CO_2 capture technologies, which require CO_2 desorption, compression, and transportation, the IC3M system integrates captured CO_2 directly into the final product, reducing energy consumption. The project involves adapting other catalysts and reagent co-feeds to the capture solvent system, enabling the targeting of several large-market C1 and C2 products. This approach reduces energy inputs and makes IC3M viable for modular, distributed processing platforms. Potential applications include separating and converting CO_2 from landfill, wastewater, and manure off-gas. In 2023, the project team successfully captured and converted CO_2 from simulated flue gas into methanol, achieving a single-pass conversion rate of over 60 mol% and methanol selectivity of over 80 mol% through an integrated 2-step process. The water content influenced catalyst activity and selectivity in the solvent. The team demonstrated anhydrous operation to maintain high catalyst activity and productivity, highlighting the importance of water management in real-world applications. They also identified a more active and selective catalyst system for methanol synthesis compared to earlier formulations.

Co-Funders: DOE

Start Date: 08/30/2022
End Date: 08/30/2025
Status: Active
2023 Funds Expended: **$0**
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 Production of CO2-Negative Building Composites Development - CRADA 553

This project aims to sequester millions of tons of carbon dioxide annually by using water-lean solvents as an organic base catalyst to produce building materials from waste lignin, lignite, and CO2. Pacific Northwest National Laboratory (PNNL) is leveraging its "Integrated Capture and Conversion of CO2 to Methanol" (IC3M) process to develop a platform for creating carbon-dioxide-negative composite building materials. These materials will offer better durability and lifetime use than current market equivalents, contributing to the composite industry. The project started in Q4 2021, focusing on solvent-based carboxylation to convert aromatic hydrocarbon bonds in lignin and lignite to aromatic carboxyl bonds using water-lean solvents. By 2024, the team demonstrated chemical fixation of CO2 on various lignin and lignite sources and scaled up to 100-gram batches for composite manufacturing. They refined procedures for extruding baseline composites of un-functionalized lignin at 80% by weight filler content without expensive lubricants or additives. In 2023, the PNNL team identified conditions for manufacturing lignite (80%)-plastic composites using shear-assisted procession and extrusion (ShAPE). The ShAPE-produced lignite composite bars, with 80 wt.% lignite fillers, achieved a flexural modulus of 3.2 GPa, meeting international building codes for decking applications. A detailed Life Cycle Assessment (LCA) of lignite-composite panels indicated a reduction in global warming potential (GWP) by 21% to 57% compared to conventional wood-plastic composites, with GWP results ranging from 0.74 to 1.36 kgCO2e over a 100-year time horizon.

Co-Funders: DOE

Start Date: 10/01/2021
End Date: 10/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$3,246,000**
Total SCG Cost: **$540,000**
Total Co-Funding: **$2,706,000**
Benefits:

Stanford Energy Efficient Strategies for Capture of Atmospheric CO2

This project aimed to continue developing sorbent technology pioneered by Stanford University, which reacts with carbon dioxide in the presence of water and requires 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 aimed 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 developed energy-efficient non-equilibrium plasma and plasma-activated reductants to release carbon dioxide bound in carbonates and produce carbon dioxide-derived products to regenerate the sorbent. This project's novelty was exploring non-equilibrium plasmas that exist at low temperatures, can be powered by renewable energy, and can provide a sustainable way to capture and convert carbon dioxide. 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. The project team will utilize results from this initial project to inform potential future research activities.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 12/31/2023
Status: Completed
2023 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

This project aimed to develop a structured material assembly (SMA) for capturing carbon dioxide (CO2) from the air. The purpose of this project was to optimize the composition of the SMA to maximize the carbon dioxide adsorption rate, sorbent renewability, and CO2 capture capacity. With this project, Susteon advanced the SMA technology from a 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 were 1) 50% improvement of structured direct air capture (DAC) sorbent carbon dioxide working capacity over the current lab performance - <1% capacity fade achieved and >300 cycles completed; 2) 50% improvement of structured DAC sorbent carbon dioxide capture rate – achieved with renewable electricity integration; 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. The project kicked off in Q4 of 2021. In 2022, Susteon designed and built a 1 kg/day CO2 bench-scale DAC test unit to evaluate the performance of the structured sorbent system. The project was completed in 2023 and has demonstrated CO2 adsorption at ambient conditions and subsequent desorption using electrical heating. In addition, no degradation of the sorbent bed was observed when the system performed more than 250 cycles, and the pressure drop across the SMA was consistent and below the target value. Final TEA indicated the feasibility of achieving DAC cost reduction to < $250/ton CO2. Technology scale-up will proceed with additional support from the Department of Energy and other entities.

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

Start Date: 09/01/2021
End Date: 08/31/2023
Status: Completed
2023 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 Plasma Assisted Catalytic Conversion of CO2 and Propane to Propylene and CO Development

This project aimed 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 carbon dioxide (CO_2) as a soft oxidant to produce ethylene and propylene from ethane and propane, respectively. The team pursued the following objectives under this project: 1) design and modify an existing bench scale plasma reaction system for testing the proposed process, 2) perform catalyst preparation, characterization, and evaluation under relevant operating conditions, 3) experimentally investigate CO_2 oxidative dehydrogenation in the plasma reactor with and without catalyst, and 4) develop process modeling activities based on experimental results. This technology is promising because it can offer 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. Test results have shown that the catalysts developed under this project can obtain propane conversion as high as 60% and propylene yield as high as 80%. The team concluded that plasma-assisted catalytic conversion of CO_2 and propane into propylene and carbon monoxide could be commercially viable at scale, which may create a viable carbon utilization platform.

Co-Funders: DOE

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

Susteon Stanford Iron-Oxide Based Catalytic Methane Pyrolysis Development

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: DOE ARPA-E

Start Date: 11/01/2021
End Date: 12/31/2023
Status: Disallowed
2023 Funds Expended: **$0**
Total Project Cost: **$2,415,139**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,915,139**
Benefits:

SUBPROGRAM: RENEWABLE GAS PRODUCTION

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

Caltech Hybrid Electrochemical and Catalytic Hydrogen Compression System Development

Start Date: 12/01/2022
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$2,500,000**
Total SCG Cost: **$300,000**
Total Co-Funding: **$2,200,000**
Benefits:

Researchers at Caltech propose to develop a hybrid electrochemical, catalytic approach for generating compressed hydrogen. This technology differs from water electrolysis because it involves a two-step process. 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). It allows it to be stored without 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 off-peak operations 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. In 2023, the team completed an initial techno-economic analysis demonstrating that this technology's levelized cost of hydrogen demonstrates a high sensitivity to current density. Other activities completed this year include the development of a prototype 3-cell stack, integrating the technology with a low-pressure electrolyzer, and designing and testing the catalytic reactor system. Researchers at PNNL are currently developing a continuous operating system, which they will test later in the project.

Co-Funders: DOE ARPA-E

EvolOH High-speed AEM Electrolyzer Manufacturing Development

Start Date: 12/01/2022
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$125,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$150,000**
Benefits:

This project aims to develop high-speed coating methods for anion exchange membrane (AEM) electrolyzer technology to increase 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 low-cost, 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 represent a meaningful strategy to lower the levelized hydrogen costs and improve the domestic supply of hydrogen production equipment. Thus far, the project team has achieved intermediate-speed coating in this process, previously identified as a major manufacturing bottleneck. The team also validated the performance and stability of electrolyzer cells and stacks developed using this production technique. In particular, the project team developed new and improved catalyst ink formulations, demonstrating improved performance and processability. As part of this project, EvolOH also participated in a third-party techno-economic analysis to validate their anticipated stack material and manufacturing costs and understand the cost savings that may be realized as they increase the manufacturing scale. The project team plans to complete this project in 2024 by finalizing the ink formulation and demonstrating high-speed coating processes.

Co-Funders: EvolOH

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

Kore Biosolids Pyrolyzer Field Test

This project aimed 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 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 be transformed into 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 demonstrated 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. Kore gathered operation data on system performance to guide future development and deployment activities. After multiple successful system runs and data-gathering activities, the team decommissioned the system in Q1 2023.

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

Start Date: 02/13/2017
End Date: 03/31/2023
Status: Completed
2023 Funds Expended: **$300,000**
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 reactor and other SMR technologies. The integrated system will utilize the balance of plant components—water-gas shift reactor, pressure swing adsorption, heat exchangers, gas processing, instrumentation and controls, and electrical—of the HydroPrime MIN HC300 to handle and process both the feed stream and syngas output stream of the STARS reactor and other successive SMR technologies. Successful integration would demonstrate and validate the production of a pure hydrogen output stream using different distributed SMR technologies. The project team agreed with FirstElement Fuel (FEF) to host the unit in Q4 2021, on-site in Livermore, California, to support its hydrogen refueling operations for fuel-cell electric vehicles. Construction of the Linde HydroPrime unit was completed and shipped to the FEF site in 2022. In Q4 2023, FEF unilaterally terminated this research collaboration agreement before it was finished. Other potential deployment opportunities are being reassessed for future uses of this unit.

Co-Funders: FirstElement Fuel (in-kind)

Start Date: 11/15/2019
End Date: 12/31/2023
Status: Canceled
2023 Funds Expended: **$0**
Total Project Cost: **$4,064,200**
Total SCG Cost: **$3,064,200**
Total Co-Funding: **$1,000,000**
Benefits:

LLNL Modular Hybrid Electrobioreactor Demonstration

This project aims to advance the integrated electrobioreactor technology developed at Lawrence Livermore National Laboratory (LLNL). The 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). After an initial project kick-off in 2022, work was delayed until Q3 2023 to accommodate contractual delays. In 2023, the team at LLNL, with support from Electrochaea, successfully designed and manufactured many 3D-printed electrodes with various porosity, flow-field patterns, and unit cell dimensions. In 2024, the team plans to test electrodes and downselect several options, which will be integrated into an electrobioreactor test system to identify the best-performing design.

Co-Funders: DOE, Electrochaea

Start Date: 03/01/2022
End Date: 06/02/2026
Status: Active
2023 Funds Expended: **$225,000**
Total Project Cost: **$2,030,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$1,280,000**
Benefits:

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

NREL Biologically Derived Hydrogen From Organic Solid Wastes Research

Start Date: 12/01/2022
End Date: 01/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$400,000**
Total SCG Cost: **$195,000**
Total Co-Funding: **$205,000**
Benefits:

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 of ***Clostridium thermocellum*** and develop 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. In 2023, the team sourced >10 unique waste biomass feedstocks and screened their activity for hydrogen production. Additional activities included compositional analysis to quantify the feedstocks' chemical makeup, which will inform further research, such as microbial strain modification, in 2024.

Co-Funders: DOE/HFTO, NREL

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

Start Date: 05/01/2019
End Date: 10/04/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$4,469,940**
Total SCG Cost: **$769,940**
Total Co-Funding: **$3,700,000**
Benefits:

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, unnecessary hardware in producing hydrogen for this purpose. By co-locating the electrolyzer with a chemical reactor, some of the sub-systems normally needed to make 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. In 2021, NREL completed the electrolyzer balance of plant design for the mobile biomethanation system and incorporated these innovations before 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. In 2023, 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

- 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

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 of the RNG 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 team expects the new mobile bioreactor system to be commissioned in early 2024.

Co-Funders: NREL, Electrochaea

Start Date: 07/31/2019
End Date: 03/06/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$2,270,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$2,265,000**
Benefits:

STARS Corporation Electric Induction Steam Methane Reforming (SMR) Demonstration

This project aims 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 with 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. In 2023, the project focused on integrating hydrogen production tuning with existing equipment at Sunline Transit to achieve fuel-cell grade quality, productivity improvements, and completion of integrated tests with existing systems. The group estimates that hydrogen produced by STARS's reactors will fuel Sunline's fleet of fuel-cell buses in Q1 2024.

Co-Funders: STARS

Start Date: 04/01/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$70,604**
Total Project Cost: **$6,075,000**
Total SCG Cost: **$2,175,000**
Total Co-Funding: **$3,900,000**
Benefits:

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

The project's goal was to continue the development of the catalytic non-thermal plasma (CNTP) technology by building up a reactor capable of producing 10kg of hydrogen per day. This project follows up on CNTP technology developed in a previous project with the Jet Propulsion Laboratory, in which the technology was successfully demonstrated at a lab scale. The CNTP reactor uses plasma to improve the conversion of methane and water into hydrogen-rich syngas at much lower temperatures than other steam methane reforming technologies. Susteon also tested the use of the CNTP reactor in producing sustainable aviation fuel from carbon dioxide and methane, which would create an opportunity to utilize captured CO_2 to provide a new pathway to reduce greenhouse gas emissions in an otherwise difficult-to-decarbonize sector. The research team successfully operated the CNTP reactor using commercial nickel catalysts to demonstrate a hydrogen-rich product gas from methane and steam at 450°C for 200 hours. A 3-fold increase in methane conversion was observed with the introduction of plasma, reaching around 60% methane conversion. The team also investigated the use of the CNTP technology for Sustainable Aviation Fuel (SAF) production and collected important insights to direct the future investigation of this route. The team also performed an updated techno-economic analysis (TEA), resulting in a H_2 cost of around $2.65/kg.

Co-Funders: N/A

Start Date: 08/01/2021
End Date: 06/30/2023
Status: Completed
2023 Funds Expended: **$150,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$0**
Benefits:

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

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

This project aims 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 significantly reduce cost barriers to biomethane production. 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 project faced delays in 2023 due to delays in equipment manufacturing. The project is expected to be completed in 2024, with LLNL providing an updated techno-economic analysis and risk assessment of the technology to help inform future research and development activities.

Co-Funders: DOE

Start Date:	10/15/2019
End Date:	07/29/2024
Status:	Active
2023 Funds Expended:	**$0**
Total Project Cost:	**$750,000**
Total SCG Cost:	**$500,000**
Total Co-Funding:	**$250,000**
Benefits:	

UCR Speeding Anaerobic Digestion Through CO2 Microbubbles

This project aims to introduce carbon dioxide microbubbles to increase methane generation rates in anaerobic digestors significantly. The project team collaborates 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 normally. The second will be the experimental digester with 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. Early in the project, the team completed the design and fabrication of the microbubble equipment. In 2023, the project team faced long delays due to an industry-wide shortage of carbon dioxide. A suitable carbon dioxide supplier was identified late in 2023. Installation, commissioning, and equipment testing will be completed in 2024.

Co-Funders: CalSEED

Start Date:	06/01/2020
End Date:	04/30/2024
Status:	Active
2023 Funds Expended:	**$0**
Total Project Cost:	**$299,877**
Total SCG Cost:	**$149,877**
Total Co-Funding:	**$150,000**
Benefits:	

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

West Biofuels Renewable Gas Separation System and Techno-Economic Assessment

The objectives of this project were to 1) assess the separation efficiency of gas hydrates in producing high-purity renewable methane from mixed alcohol tail gas and 2) to develop an integrated techno-economic model to calculate production costs and identify key cost drivers within the West Biofuels biomass-to-mixed alcohol process. 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 suggested that alternative or supporting separation processes may be required. Modeling efforts 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. In 2023, a final report detailing the techno-economic analysis identified critical cost drivers and indicated that renewable natural gas produced through this process could reach costs as low as $12/MMBtu.

Co-Funders: CEC

Start Date: 10/01/2019
End Date: 09/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$2,200,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$2,000,000**
Benefits:

GAS OPERATIONS

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

SUB-PROGRAM: ENVIRONMENTAL & SAFETY

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 project data to determine the accuracy and effectiveness of the pipe-locating technology in identifying metallic cutters—which generate an intrinsic and unique fingerprint—in buried PE service tees. In 2022, sponsors provided a variety of service tees that were classified and tested, with the system yielding positive results in geospatial accuracy and pipe depth. The data were 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. The team presented the results in a webinar and delivered the testing and field demonstration reports to sponsors. The ability to locate subsurface metallics could benefit SoCalGas by aiding in reducing the potential of damage to its lines, thereby reducing damage to life, property, and community.

Co-Funders: OTD Members

Start Date: 02/01/2021
End Date: 02/16/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$220,000**
Total SCG Cost: **$25,287**
Total Co-Funding: **$194,713**
Benefits:

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 US Environmental Protection Agency's (EPA) compliance tool for estimating impacts from air pollutant emission sources. This model currently overestimates ground-level NO_2, 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 are supporting EPA as it implements model changes and then presents the results in a workshop disseminating the AERMOD modifications to the public. In 2023, the project team held several discussions with the EPA and produced an Air Waste Management Association educational webinar on the validity of recommended changes for AERMOD that are available to the public for a fee. In the discussions with the EPA, the agency will incorporate some of the recommendations in its scheduled 2024 AERMOD model updates and continue to discuss some of the more complex model modifications proposed. With an updated AERMOD, SoCalGas could use this tool to more accurately evaluate emissions in planning for air emission reductions.

Co-Funders: PRCI Members

Start Date: 12/14/2022
End Date: 2/13/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$61,732**
Total SCG Cost: **$34,050**
Total Co-Funding: **$27,682**
Benefits:

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

CEPM for Turbochargers (CPS-14B-08)

The objective of this project was to develop turbocharger performance models utilizing data collected from a variety of past Pipeline Research Council International (PRCI) projects, as well as new data collected at two compressor stations. The developed models provide early detection of decreased natural gas engine turbocharger performance. This approach enables operators to schedule maintenance and repairs before the engine cannot meet regulatory emissions limits. The team completed model development in 2020, but due to the COVID-19 pandemic, the project was delayed. The collection of additional data was needed to refine the model and then perform validation testing. The project team completed data collection in 2021 and model validation in 2022. The project team also looked at applying the models to turbines used to drive compressors, but further refinements would be needed to improve performance predictability for turbines. Therefore, the team abandoned the efforts on turbines and published the final report in the first quarter of 2023. This report included three models developed for turbochargers. SoCalGas has plans to utilize the models to monitor turbocharger performance.

Co-Funders: PRCI Members

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

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

The objective of this project is to assemble historical California climate data to improve two models for forecasting weather conditions. The improved models will enable utilities to assess infrastructure risks associated with exposures to short- and long-term extreme weather events. Weather forecasting models are used to find utility infrastructure vulnerabilities in extreme weather events. Such events include extreme dry conditions posing wildfire threats and extreme 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. The University of California San Diego and the Scripps Institution of Oceanography were awarded this California Energy Commission project. They will assemble climate data from California between 1980 and 2019 to improve both models for forecasting weather conditions. 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 2023, the project team made progress in completing the high-resolution datasets and model runs for several US regions and expanded the datasets to include 2020 and 2021. SoCalGas will use the results of this project as part of its geohazard risk management plan that protects 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
2023 Funds Expended: **$182**
Total Project Cost: **$1,366,550**
Total SCG Cost: **$3,000**
Total Co-Funding: **$1,363,550**
Benefits:

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

The objective of this project was to review national and international regulations, safety standards, and pipeline industry standards for the transportation of hydrogen and natural gas (H2NG) blends to identify and list gaps and provide potential solutions to the gaps. Regulations, safety standards, and pipeline industry standards that were identified as applicable to this project were Code of Federal Regulations Title 49 Parts 190, 191, and 192; the American Society of Mechanical Engineers; and the International Organization for Standardization. SoCalGas has prioritized reducing its carbon footprint and greenhouse gas emissions and is investigating using H2NG blends to achieve this goal. In pursuit of this, SoCalGas will need to understand potential impacts of H2NG blending on pipeline operations. Completed project tasks include interviews with national and international hydrogen system operators and natural gas utilities that are investigating, experimenting, or seeking to implement H2NG blending. The project team compiled applicable codes and standards into a spreadsheet that included an associated abstract summary. The project's final report includes 1) hydrogen codes, standards, and practices, and common terminology; 2) a gap analysis identifying regulations and standards which may need revisions for H2NG blending; 3) and recommendations for H2NG 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 H2NG blends, that would support the safety, reliability, and efficiency of H2NG operations. Project results could lead to the development of statewide hydrogen and H2NG blending standards.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 09/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$170,000**
Total SCG Cost: **$5,502**
Total Co-Funding: **$164,498**
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: 12/31/2024
Status: Active
2023 Funds Expended: **$24,797**
Total Project Cost: **$3,838,835**
Total SCG Cost: **$38,465**
Total Co-Funding: **$3,800,370**
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 2023, the SRP funded six new projects: Industry Best Practices for Making Temporary Repairs Permanent (MATR-3-15B); Evaluate Gas Venting for Common Meter Station Operation and Maintenance Activities (MEAS-5-29); Operating Flexibility-Improve Part Load Operating Efficiency and Reduce GHG Emissions (CPS-17-12); Literature Review-Advances in Plasma Technology (CPS-17-11); Evaluate In-Situ Valve Repair Techniques (CPS-17-09); and Centrifugal Compressor Station Efficiency Optimization (CPS-17-10). Work continues on Regulatory Support for GHG Emission Reductions (CPS-11-09), Continuous Monitoring and Diagnostics for Facility Efficiency (CPS-14-06), Reciprocating Engine Exhaust Methane Slip Reduction (CPS-17-08), and Assessment of Temporary Repair Methods (MATR-3-15A). Two projects were completed in 2023, with final reports on the PRCI website: High Flow Sampler Replacement (MEAS-9-03) and Low-Cost Instruments to Detect/Quantify Leaking Seals, Packing, or Dump Valve (MEAS-9-02). SoCalGas is implementing the recommendations from both of these projects. See the individual project summary for details on Reciprocating Engine Exhaust Methane Slip Reduction (CPS-17-08).

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: 3/31/2024
Status: Active
2023 Funds Expended: **$2,500**
Total Project Cost: **$203,617**
Total SCG Cost: **$103,117**
Total Co-Funding: **$100,500**
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 project team worked on developing a preliminary simulation model with improvements aimed at reducing computational time. The team verified the physics behind the simulations. In 2023, the project team continued to assess and fine-tune the conjugate heat transfer multi-physics model and performed validation testing on different simulated field scenarios. The simulation models were reviewed with project sponsors and the feedback was incorporated into the testing. Next steps will be completing and delivering the final report in early 2024. 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

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

Start Date: 03/01/2021
End Date: 04/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$17,578**
Total Co-Funding: **$132,422**
Benefits:

The objective of this study is to identify trace constituents that can cause odor-masking in natural gas. Natural gas contains many chemicals 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 odorants in natural gas and detecting 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. Previously, the team developed an odor masking test method to examine seven common masking agents found in gas processing plants. The team completed testing and identified the trace constituents of concern. Volunteers in laboratory sniff tests were to be employed to test those trace constituents, but this last task was delayed throughout 2023 due to health protocols, supplier issues, and resource constraints. The project team plans to complete the sniff test, along with the final report, in Q1 2024. Once SoCalGas receives the results, it will use them to determine if it needs to change its odorant program to mitigate odor masking.

Co-Funders: OTD Members

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

Improving HCA Classification Methods (8.21.f)

The objective of this project was to improve the accuracy of classifying high-consequence areas (HCA) and moderate-consequence areas (MCA) using modern data analysis and data sources. An HCA is an area where a release of natural gas would adversely impact the safety of populated areas. The current methodology used to define impacted areas was established by the Pipeline and Hazardous Materials Safety Administration. This methodology utilizes data that does not factor in fluctuating population dynamics or development patterns in urban areas that could result in misidentifying areas as non-HCA or non-MCA. There is a need to 1) enhance monitoring efforts in locating facilities that affect HCA and MCA and 2) explore alternative methods of monitoring the pipeline right-of-way for improving safety and compliance processes in accurately identifying an HCA. The project utilized cellular and satellite data and developed algorithms to automate the quantification of population or building use and size. The building detection algorithm generated from satellite-based imagery was reviewed for potential use-cases. Cellular data was evaluated in building structures and open spaces within the established pipeline buffer areas. The project showed there was promise in utilizing these two technologies, but both had pros and cons. The major hurdle to implementation is the cost of these monitoring methods. Additional research to improve imagery resolution and detection accuracy, as well as further development of the models is needed. SoCalGas will evaluate how this technology could supplement the current HCA Classification methodology.

Co-Funders: OTD Members

Start Date: 03/01/2021
End Date: 05/24/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$184,000**
Total SCG Cost: **$37,360**
Total Co-Funding: **$146,640**
Benefits:

Living Lab for Hydrogen (M2021-008)

The objective 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 infrastructure. This in-house project 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. Delays with compressor skid and engineering design have pushed the lead time for procurement of goods, with commissioning now scheduled to begin in late 2024. 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 with respect to safety and pipeline integrity, measurement, regulation, and procedures for safety and maintenance.

Co-Funders: NYSEARCH Members

Start Date: 12/13/2021
End Date: 12/31/2026
Status: Active
2023 Funds Expended: **$27,962**
Total Project Cost: **$1,222,402**
Total SCG Cost: **$300,000**
Total Co-Funding: **$922,402**
Benefits:

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

Low NOx Portable Analyzer

The objective of this project was to determine the feasibility of an electrochemical portable analyzer test to measure nitrogen oxide (NOx) levels of less than 5 parts per million (ppm) and carbon monoxide (CO) levels of less than 20 ppm. The Environmental Protection Agency (EPA) codified OTM-038 (Other Test Methods) and OTM-039 allowing the use of portable gas analyzers equipped with electrochemical sensors for the determination of oxygen, CO and NOx from stationary sources, including considerations for NOx measurement of "low" emitter (less than 20 ppm) testing. These two methods reduced the cost of demonstrating compliance with criteria pollutant limits. As combustion technologies improved, these technologies achieved emissions of less than 5 ppm for NOx and less than 20 ppm for CO. This project tested and developed recommendations for the use of portable analyzers to demonstrate compliance with ultra-low NOx and CO limits. SoCalGas tested the portable analyzer's limits of detection, stability, and repeatability in measuring ultra-low NOx and CO pollutant limits in an experimental setting. The project results showed that portable analyzers were capable of detecting NOx concentrations as low as 0.5 ppm and CO concentrations as low as 1.5 ppm. Although the project demonstrated the feasibility of using portable analyzers in ultra-low-limit applications, additional testing would be required before regulatory adoption of using portable analyzers to demonstrate compliance with ultra-low NOx and CO limits. SoCalGas intends to perform additional analysis in the future to pursue regulatory approval for using portable analyzers for ultra-low NOx and CO compliance that would benefit ratepayers by reducing the cost of regulatory compliance.

Co-Funders: N/A

Start Date: 9/1/2022
End Date: 5/31/2023
Status: Completed
2023 Funds Expended: **$18,580**
Total Project Cost: **$76,360**
Total SCG Cost: **$76,360**
Total Co-Funding: **$0**
Benefits:

Modify Pipeline Purging Program for Calculations of Methane Emissions Savings (5.17.m.2)

The objective of this project is to add new capabilities to GASPurge, the existing pipeline-purging software used to calculate values associated with the purging and clearing of a natural gas pipeline. The project will add a variety of features, including alternative purging and clearing processes and equipment options, feasibility break-even analysis, calculations of emissions savings, and quantification of gas not vented to the atmosphere. The updated software can support calculations for Greenhouse Gas (GHG) emissions and emissions saving reporting. Phase I of this project revamped the 1997 Gas Research Institute's Pipeline Purging Program, enabling its support by modern operating system platforms. The final Phase I deliverable was a commercially available software, GASPurge, that has been deployed and used by SoCalGas for gas purging operations. In 2023, the project team surveyed project sponsors to understand the type of equipment, methods, and processes they currently utilize for purging operations and alternatives to blow-downs. The survey feedback will be used for the next step to develop the software. SoCalGas anticipates using the updated software program when purging calculations are needed to determine safe purging parameters to improve safety and to support quantification of gas not vented to the atmosphere, a value needed for GHG emissions reporting.

Co-Funders: OTD Members

Start Date: 12/1/2023
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$17,072**
Total Project Cost: **$174,000**
Total SCG Cost: **$17,072**
Total Co-Funding: **$156,928**
Benefits:

Odor Detection Study for Blended Hydrogen (M2021-005)

The objective of this project is to determine if the introduction of hydrogen to natural gas blends changes the perception of natural gas 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. In 2023, the project completed the testing of one odorant and odorant blend. The project scope calls for the testing of a second odorant commonly used by the gas industry. This last test is scheduled to be completed in Q1 2024 along with the final report. SoCalGas will study project results to determine if adjustments to odorant levels are needed for hydrogen/natural gas blends to meet the safety standards for employees and customers.

Co-Funders: NYSEARCH Members

Start Date: 07/29/2021
End Date: 01/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$294,755**
Total SCG Cost: **$21,835**
Total Co-Funding: **$272,920**
Benefits:

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

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

The objective of this project was to understand how the introduction of conditional factors of odor adaptation and odor-masking agents affect the detection and recognition thresholds of natural gas odorants. Phase 2 of this natural gas odor detection threshold study used the odorant thresholds of human detection levels determined in Phase 1 as a reference. The team studied odor masking effects and odor adaptation effects in parallel, but results were provided independently to better understand each variable's effects. The project team studied the odor masking effects of d-limonene and ammonia. D-limonene is a common chemical found in housecleaning products. Ammonia was also studied because it is a chemical found in renewable natural gas. The results of the masking portion of the project determined that d-limonene or ammonia did not display a masking effect on natural gas odorants. The project also investigated the self-adaptation effects of odorants where exposure to the odorant reduced the ability to detect odorant in gas leaks. This adaptation study determined that pre-exposure does decrease a person's ability to detect and recognize an odorized natural gas. This project will help SoCalGas identify risks associated with odor masking components and validate previous studies on the effects of adaptation to meet the safety standards for employees and customers.

Co-Funders: NYSEARCH Members

Start Date: 11/16/2019
End Date: 12/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$468,950**
Total SCG Cost: **$48,100**
Total Co-Funding: **$420,850**
Benefits:

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

The objective of this project 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 further develop the technology to bring forward a commercially viable product for identifying obstacles in and around the path of an HDD drill rig, thus reducing third-party damage to underground utilities. The ORFEUS technology incorporates a forward- and side-looking ground-penetrating radar within the 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. In 2023, the project team completed the development and debugging of the data acquisition module and finalized the modifications of the ORFEUS detection algorithm and the angular sensor board. Calculating the pitch and angular speed in real time is now possible. Additional validation tests took place in Europe to confirm the performance of the recent upgrades. Field demonstrations in North America are planned for early 2024. Future enhancements of the technology incorporating the lessons learned from the field demonstrations are planned for a future phase of the project. The benefits of a successful technology would provide an opportunity to reduce HDD damages that would affect the integrity of SoCalGas' pipelines, reduce safety concerns, and reduce the release of emissions to the atmosphere.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2017
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$3,786,446**
Total SCG Cost: **$62,346**
Total Co-Funding: **$3,724,100**
Benefits:

Pipeline Blending CRADA Phase 2 (Task 3, 4)

The Pipeline Blending CRADA Phase 2 (a HyBlend Project) is a three-year effort amongst more than 20 industry partners and four National Laboratories to evaluate the costs, benefits, and environmental impacts of blending hydrogen into the natural gas grid as a decarbonization strategy. Tasks were defined for investigation. SoCalGas is participating in tasks: 3) Lifecycle Assessment and 4) Techno-Economic Analysis. The lifecycle analysis will assess hydrogen-natural gas blend leakage throughout the supply chain and study hydrogen global warming potential with the inclusion of embodied emissions for a blended gas supply chain. The techno-economic analysis will involve two efforts that build upon previous research by adding improvements and capabilities to the Pipeline Preparation Cost Analysis Tool and assessing hydrogen blending integration into existing regional energy systems and the impact on coupled natural gas pipeline network and power grid systems. Outcomes of this effort will help researchers quantify the impacts of each system and guide best practice development on how to effectively implement hydrogen-natural gas blending to reduce overall energy system emissions and enhance energy system reliability. SoCalGas will use the results of this research to support the development of its blending standard and to understand the economic and technical aspects of efficient and effective implementation of hydrogen blending.

Co-Funders: DOE, PRCI Members, Others

Start Date: 12/1/2023
End Date: 12/31/2026
Status: Active
2023 Funds Expended: **$75,000**
Total Project Cost: **$4,950,000**
Total SCG Cost: **$75,000**
Total Co-Funding: **$4,875,000**
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)

This project's objective 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 occur 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, which may damage PE cross-bores. This project kicked off in the second quarter of 2023, but progress has been delayed due to contractual issues. 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 the SoCalGas' Integrity Management Plan.

Co-Funders: OTD Members

Start Date: 12/14/2022
End Date: 9/30/2024
Status: Active
2023 Funds Expended: **$24,038**
Total Project Cost: **$125,000**
Total SCG Cost: **$24,038**
Total Co-Funding: **$100,962**
Benefits:

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

This project's objective is to research methane slip to investigate the cause and determine solutions to reduce unburnt methane from legacy compressor engines without affecting criteria pollutants. The results will be alternatives for retrofitting rather than replacing natural gas compressors and for reducing methane slip that could lead to greenhouse gas (GHG) emission reductions. The project tasks include: a literature review and state-of-the-art analysis of existing knowledge and technologies; technical studies to understand the characteristics of combustion and engine exhaust; feasibility assessments of possible control methodology and hardware modifications; and prototypes for laboratory and field testing. To date, the project team has completed the literature review, developed dynamic computational models simulating combustion for natural gas compressors, and completed several studies. In addition, the project team has determined that studying criteria pollutants better characterizes combustion, instead of focusing solely on methane slip. These results could lead to future nitrogen oxide (emission reduction efforts. In 2023, the project team modeled the use of supersonic jet nozzles to promote better fuel mixing. The next steps are to: refine the models using real-world data and determine the best design options to move forward on the path to developing a prototype. The results from this project could be used to retrofit legacy engines, which could lead to reductions in GHG emissions without increasing criteria pollutant emissions. Retrofitting legacy engines is less expensive than replacing them, benefiting SoCalGas ratepayers with a cost-effective, alternative approach to combating climate change and improving air quality.

Co-Funders: PRCI Members

Start Date: 08/31/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: $8,973
Total Project Cost: **$572,300**
Total SCG Cost: **$22,046**
Total Co-Funding: **$550,254**
Benefits:

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

The objective of this project is to develop technology with the capability to assess gas concentration outdoors, in manholes, and within buildings. Determining the gas concentration remotely at multiple locations will save time and improve safety. This project's goal is to commercialize two instruments, the "First Responder" and the "Un-attended Methane Monitor." In earlier phases of this project, the project team developed a methane detection system prototype to enable a leak investigator to remotely monitor methane levels at multiple points. In phase IV, the team seeks to develop: 1) pre-commercial units that can be tested by utility members; and 2) a wireless communication system to enable a leak investigator to remotely monitor methane levels at multiple points. The project developed the First Responder Mesh Network application known as the Gas Investigation Zone Monitor (GIZMo) and, in 2023, the project team presented the GIZMo prototype to sponsors and performed one field test of the device. Modifications to the device were made to reduce the cost of the unit and simplify recharging. Once development of GIZMO is complete, the team will begin further development of the Un-attended Methane Sensor. If the technologies are commercialized, they may provide an additional safety benefit to field employees and first responders. Upon project completion, SoCalGas will consider evaluating and demonstrating the technologies for use in the field.

Co-Funders: OTD Members

Start Date: 09/01/2019
End Date: 12/01/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$358,000**
Total SCG Cost: **$27,000**
Total Co-Funding: **$331,000**
Benefits:

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

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 consist of remote monitoring and control, with the capability 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. The project team demonstrated and validated the technologies required for a smart shutoff system and identified any gaps or barriers that needed 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. In 2023, the team completed project demonstrations, including testing safety system components in a residential and commercial setting. The project team also prepared a report of the LoraWan architecture and recommendations for network implementation. The next step is for the draft final report to be reviewed by the CEC, and then provided to project sponsors. 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. Understanding the challenges and barriers to implementation of smart equipment assists 1) technology providers as they refine their technologies and 2) utilities with planning for future utilization supporting system integrity and safety.

Co-Funders: OTD Members, CEC

Start Date: 08/04/2020
End Date: 01/31/2024
Status: Active
2023 Funds Expended: **$4,269**
Total Project Cost: **$1,434,202**
Total SCG Cost: **$20,429**
Total Co-Funding: **$1,413,773**
Benefits:

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

The objective 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 steel pipes. 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 Geographic Information System. In 2023, the project team received PE pipes with tags attached and installed both the 2-inch and 4-inch PE pipe sections via trenchless installation. The pipes were pulled through a bore hole and pulled back out for evaluation. In 2024, these pipe specimens will be further analyzed via hydrotesting. The project team plans to hold a meeting with project sponsors to review the recent results and discuss possible manufacturing options for intrinsically locatable plastic pipe to get direction from sponsors. The Pipeline and Hazardous Materials Safety Administration has granted an extension to the project end date. This project will help SoCalGas explore options with RFID tagged pipes with improved pipe locatability for minimizing the risk of third-party excavation damage and other purposes.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2019
End Date: 9/30/2024
Status: Active
2023 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 was to develop tracking software for Pipeline Safety Management Systems (PSMS) based on the American Petroleum Institute's (API) 1173 standard. This standard outlines the key elements of a PSMS and the continuous improvement process, of which one element is a PSMS performance assessment. The project team developed a prototype of the tracking software with key performance indicators and a scoring system to assist managers in evaluating the performance of their PSMS programs. The software concentrated on several key elements of API 1173: Record Keeping and Documentation, Management of Change and Control, Pipeline SMS Communications, Competence and Training Documentation, and Risk Management and Reporting. The developed software could aid in benchmarking PSMS performance for the continuous improvement process required under API 1173. SoCalGas evaluated the prototype and decided not to use the software but will use the system and process developed to benchmark its PSMS system.

Co-Funders: OTD Members

Start Date: 11/24/2021
End Date: 05/24/2023
Status: Completed
2023 Funds Expended: **$0**
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 objective of this project 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 Pipeline Research Council International 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 project encountered a delay due to turbine maintenance at SoCalGas's facility, pushing the project completion date and associated PEMS validation report to early 2024. In 2023, four months of data were collected and validation analysis started. Once completed, 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. 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: 4/30/2024
Status: Active
2023 Funds Expended: **$4,968**
Total Project Cost: **$64,819**
Total SCG Cost: **$19,819**
Total Co-Funding: **$45,000**
Benefits:

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

The objective of this project was 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. In addition, the project team was to prepare an implementation guide to support deployment of the technology. The project team developed VR training modules that are realistic, interactive, and immersive, utilizing the latest technology improvements and lessons learned from previous phases of the project. SoCalGas sees benefits with the use of VR technology to supplement its training program. This approach enhances the consistency of training delivered, allows operations to conduct training on demand, increases the number of real-life training scenarios available for trainees to experience, and reduces the risk of injury to trainees. In 2020, the project team developed nine training modules. In 2023, these modules were re-developed and two new modules were developed on a new provider platform. Due to the pandemic, the technology demonstration to the SoCalGas Training Department was delayed until 2023. GTI Energy presented the VR training modules, the new VR Training module platform, the implementation plan, and a hands-on demonstration of the technology using the wired system and 3DI (three-dimensional interaction) or "laptop mode" environments. SoCalGas intends to incorporate this VR technology into its long-term plan for its training program.

Co-Funders: OTD Members

Start Date: 11/01/2019
End Date: 06/23/2023
Status: Completed
2023 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)

The objective of this project was to compare the suitability of available technologies that could help prevent safety incidents and alert workers of work zone intrusions. With a steady increase in work zone crashes and fatalities, technologies other than traditional passive prevention technologies, such as cones and lights, are needed to improve worker safety. The project team conducted market research across the work zone safety space to identify new products and compile them into a matrix summarizing their features and capabilities. Additionally, the project team leveraged research papers from the transportation industry and feedback from sponsor evaluations to add details to the matrix regarding capabilities/features and advantages/disadvantages. The project team evaluated products by driving through mock work zones at the GTI Energy campus and at vendor-led demonstrations. The most effective products seemed to be those that connected to navigation systems, such as Waze or Google Maps, which alert the driver to an upcoming work zone and potentially offer alternative routes. The project team also identified a barrier to implementation: state Department of Transportation approvals for novel and unique products must be obtained before use, a process that can take considerable time. The team submitted a final report to sponsors. The report provided an overview of the available technologies and highlighted their features, advantages, and disadvantages. SoCalGas will analyze and review the results to determine if any equipment warrants further evaluation of their potential for incorporation into SoCalGas traffic control procedures and standards.

Co-Funders: OTD Members

Start Date: 11/19/2021
End Date: 12/13/2023
Status: Completed
2023 Funds Expended: **$1,069**
Total Project Cost: **$140,000**
Total SCG Cost: **$9,069**
Total Co-Funding: **$130,931**
Benefits:

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

SUB-PROGRAM: OPERATIONS TECHNOLOGY

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

The objective of this project, co-funded with California Energy Commission (CEC), was to develop 3D visualization software for mapping underground pipelines and improving asset management. 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 risks and preventing damage. GTI Energy developed the 3D visualization software. First, GTI Energy analyzed several existing and proven technologies and field tested them to create the Locate Technology Platform (LTP). This platform is intended to assist field users in visualizing infrastructure location data from various viewpoints. In 2022, data collection and field demonstrations of the LTP utilizing several locating devices were performed by two sponsors, including SoCalGas. In 2023, the CEC updated and approved the Pilot Demonstration and Analysis document that included the demonstration results. The project team also worked on technical knowledge transfer activities. The team anticipates delivering a final report to sponsors in Q1 2024. This technology could save field time, thereby lowering the cost of data collection. SoCalGas can potentially utilize this research to improve the three-dimensional geospatial accuracy of existing Geographic Information Systems data.

Co-Funders: OTD Members, CEC

Start Date: 06/30/2020
End Date: 03/29/2024
Status: Active
2023 Funds Expended: **$175**
Total Project Cost: **$2,082,774**
Total SCG Cost: **$83,338**
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. In 2023, the team completed the comparative analysis at the GTI pipe farm, demonstrating that the technology could accurately locate steel pipes and plastic pipes with tracer wires. Once the project team completes the final demonstration in early 2024, the team will deliver a final report that will provide an overall analysis, including statistical, and comparative results. 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: 3/31/2024
Status: Active
2023 Funds Expended: **$35,648**
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 project objective is to establish a framework and requirements for the installation, inspection, and integrity management of alternative steel and composite pipe in natural gas pipelines. The study addresses: 1) material testing, 2) construction requirements, 3) damage and assessment of defects, 4) degradation of pipe material, and 5) inspection and maintenance activities. The team designed the project to map the requirements under the 49 Code of Federal Regulations (49 CFR) Part 192, with the goal to identify and address the gaps in implementing a qualification process for non-steel and alternate-steel composite pipes similar to the ones currently used for steel pipes. The project is scheduled to be completed in 2024. In 2023, the project team completed testing to determine the maximum allowable operating pressures of composites and evaluated both the potential damage to composites during construction and their corrosion properties. In 2024, the project team will complete the remaining evaluation of the properties of composites' resistance to erosion, integrity threats, and degradation. The project team will also determine the inspection requirements for composites. The project results could be incorporated into the 49 CFR Part 192 to qualify composite pipes. If successful, this project could result in the acceptance of alternative steel and composite piping materials as alternatives to traditional pipeline systems, offering cost advantages and corrosion protection. If these materials are adopted as acceptable piping materials in 49 CFR Part 192, SoCalGas could use the results to evaluate the use of alternative steel and composite pipe systems for use in its pipeline repair program to provide cost savings to ratepayers and improve its pipeline integrity program.

Co-Funders: PHMSA, OTD Members

Start Date: 12/14/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$3,019**
Total Project Cost: **$1,167,770**
Total SCG Cost: **$11,019**
Total Co-Funding: **$1,156,751**
Benefits:

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

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

The objective of this project was 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 added 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 1; and 2) evaluation of the communication capabilities of the three meters from both Phase 1 and Phase 2. The project team evaluated the effectiveness of the smart shut-off valve and communication capabilities of all three meters. In 2021, the project team identified the locating and mounting mechanisms, developed a test matrix, 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. The project team completed all testing for the smart DRGM in 2022 and for the USM in 2023. The draft final report, issued in early 2023, identified the need for some retests. The final version of the final report was delivered to the sponsors in December 2023. SoCalGas anticipates using the project results and test matrix to supplement its evaluations of new metering technology for ultrasonic meters.

Co-Funders: OTD Members

Start Date: 12/02/2020
End Date: 12/29/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$129,000**
Total SCG Cost: **$5,375**
Total Co-Funding: **$123,625**
Benefits:

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 process (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. Existing processes have significant potential for errors and are not an efficient means of integrating fusion data into company systems, thus encumbering review and analysis. Furthermore, in cases of failure, the fusion data are 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 researched the process of data collection, storage, and integration into company systems. It was anticipated that the collected fusion data would allow real-time evaluation of fusion parameters supporting consistent quality of fusion joints before they are placed into service. The project team continued collecting fusion data, understanding data formats generated by the logger software, developing software to validate work orders, and training welding instructors. Additionally, SoCalGas started developing a plan for a pilot study, utilizing knowledge gained from this project to date. To support the pilot study, the project continues to the next step, which is developing software for importing fusion data into company's data management system, as well as developing training modules for data logger operators.

Co-Funders: N/A

Start Date: 06/15/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$42,735**
Total Project Cost: **$320,000**
Total SCG Cost: **$320,000**
Total Co-Funding: **$0**
Benefits:

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

The objective of this project, which is co-funded by the California Energy Commission (CEC), 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 existing 3D electromagnetic detection technology to locate buried pipelines. The project supplements the existing technology with an in-pipe mechanism to focus on congested areas and plastic materials. SoCalGas and Pacific Gas and Electric Company (PG&E) are partners in the project along with the CEC. SoCalGas is focusing on transmission infrastructure. PG&E is focusing on distribution infrastructure located in congested urban areas. This improved technology provides real-time 3D data encountered in the field, including different pipeline materials, buried depth, and surface cover. In 2023, the project team worked to evaluate the accuracies of the technology and of commercial electromagnetic locator tools following the potholing of three underground pipelines at pilot demonstration locations. The project team continued to examine the coordinate data of each locating technology for data accuracy. SoCalGas can use this research to add to the list of tools that enable the identification of steel assets without the need for excavation, an approach that will improve affordability, reliability and safety.

Co-Funders: OTD Members, CEC, Other

Start Date: 11/04/2020
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$4,812**
Total Project Cost: **$2,222,903**
Total SCG Cost: **$26,768**
Total Co-Funding: **$2,196,135**
Benefits:

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

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

The objective of this project was to review and affirm the underlying mathematical model and requirements within American Society for Testing and Materials (ASTM) F2897 and to make targeted enhancements to its completeness and efficacy. An additional goal was 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 was 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 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 reviewed the standard and verified that all the gaps were addressed, and that the standard provided the necessary information for all types of materials for successfully applying barcodes. In 2023, the primary focus was to ballot the necessary updates to support the implementation of the new requirements within ASTM F2897. The ballot successfully passed both the ASTM F17.60 subcommittee on gas and the F17 main committee. As a result, the standard was approved and published. SoCalGas plans to implement barcode scanning of materials in the field for improved tracking and tractability.

Co-Funders: OTD Members

Start Date: 06/17/2022
End Date: 12/1/2023
Status: Completed
2023 Funds Expended: **$7,827**
Total Project Cost: **$151,000**
Total SCG Cost: **$32,827**
Total Co-Funding: **$118,173**
Benefits:

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

The objective of this project was 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 would provide an additional layer of operational flexibility to gas utilities and enable the diversification of gas quality in the network. Microthermal technology that could accurately measure and self-diagnose varying gas compositions would benefit gas system operators, enabling them to transport cleaner, low-carbon fuels reliably. The microthermal gas meter module consists of a micro-electro-mechanical, systems-based, calorimetric microsensor. The sensor element uses temperature distribution characteristics to determine gas velocity and volume. In 2023, the project team completed the test plan, test matrix, and procurement of materials. A call was held with project sponsors to discuss the test plan and technical challenges associated with the testing. From the information learned on this project, SoCalGas has determined that it will not be deploying this technology and will be closing out the project.

Co-Funders: OTD Members

Start Date: 11/19/2021
End Date: 11/30/2023
Status: Completed
2023 Funds Expended: **$2,055**
Total Project Cost: **$132,000**
Total SCG Cost: **$12,055**
Total Co-Funding: **$119,945**
Benefits:

GNSS Consortium (5.7.p)

The objective of the Global Navigation Satellite System (GNSS) Consortium was to facilitate knowledge and information sharing on rapidly developing GNSS technology that could reduce the cost and complexity of deploying GNSS for routine utility construction operations and maintenance activities. The project team achieved this objective through technology evaluations and integrations, workshops, pilot projects, demonstrations, best practices and standards, and general information sharing. High-accuracy GNSS data collection is essential to a utility's geospatial data management and Geographic Information Systems integrity. In 2023, GTI Energy continued to perform demonstrations and inform project sponsors about the latest innovations and research in the geospatial technology industry. The project team uploaded all technology evaluation reports, multimedia materials, and training documentation to a web-based library. By staying abreast of current and advanced GNSS technology, SoCalGas gained the ability 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 internal stakeholders will review the final report to determine if any of the project results can be implemented. 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: 12/21/2023
Status: Completed
2023 Funds Expended: **$15,000**
Total Project Cost: **$245,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$230,000**
Benefits:

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

Guidance for H2/NG Blending Equipment Installation and Operations (5.23.p)

The objective of this project is to utilize the latest hydrogen research and information on natural gas blending technology to create guidance on blending that operators can include within their procedures. This project will develop procedures and recommended practices to guide operators in planning, estimating costs, and executing hydrogen-natural gas blending projects with respect to safety, equipment and operations. The financial analysis will also assist operators in understanding the investments required for implementation. The project deliverables will be a white paper including guidance documents and a cost estimating methodology for both capital and operating costs to implement hydrogen blending projects. SoCalGas will utilize the results of this research to inform company procedures, practices, and financial information related to the implementation of hydrogen blends in the natural gas system.

Co-Funders: OTD Members

Start Date: 12/1/2023
End Date: 5/31/2024
Status: Active
2023 Funds Expended: **$23,349**
Total Project Cost: **$179,000**
Total SCG Cost: **$23,349**
Total Co-Funding: **$155,651**
Benefits:

In-Situ Ultrasonic Gas Flow Meter Flow Verification (MEAS-6-17C)

The objective of this project is to develop and test a prototype for applying the gas tracer ultrasonic meter (USM) verification method from previous research efforts in a field setting. Previous research efforts (Pipeline Research Council International projects: MEAS-6-17, MEAS-6-17A, and MEAS-6-17B) tested the proof of concept for an in-situ gas tracer verification method for USMs in natural gas service using helium and achieved an average error of ±0.05%. A prototype for verifying USM field performance without service interruption would provide cost savings by identifying issues sooner and more quickly, and from not having to remove the USM from service for flow verification. The project team is developing a functioning prototype to deploy the gas tracer method of USM verification, will provide a final report that includes field data that illustrates the performance of the method and prototype, and will then propose this method to be used as a recommended practice within American Gas Association's published Report No. 9 (AGA 9), Measurement of Gas by Multipath Ultrasonic Meters. If the prototype and methodology are successful and adopted by AGA 9, SoCalGas would utilize this prototype verification method for calibration use for in-situ USMs if it is available as a service offering.

Co-Funders: PRCI Members

Start Date: 12/1/2023
End Date: 06/30/2025
Status: Active
2023 Funds Expended: **$14,465**
Total Project Cost: **$265,500**
Total SCG Cost: **$14,465**
Total Co-Funding: **$251,035**
Benefits:

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

The objective of this project was to perform a state-of-the-art study to identify technologies for walking and mobile leak survey instruments to detect up to 100% hydrogen within blended natural gas. Molecules of hydrogen are smaller than those of methane within natural gas. 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 retrofitting existing equipment. The natural gas industry needs research to identify the parameters for choosing the correct leak detection device for natural gas blends containing over 20% hydrogen. In 2023, the project team developed technology search requirements, examined over 40 detectors and sensors, and delivered a shortlist of five potential technologies for walking and mobile leak detection applications. The team also created a roadmap for each of the defined five technologies for further evaluation. The roadmap elements are designed to be utilized 1) to prove the efficiency of a commercialized detector or 2) to provide key characteristics needed for development of an innovative sensor and/or detector. This project benefits SoCalGas by providing potential hydrogen leak detection solutions for natural gas blends containing over 20% hydrogen, which could enhance safety, reduce emissions, and save time and capital in the transition to utilizing hydrogen blends. SoCalGas will evaluate the results to determine which of the technologies should be investigated further and to determine the next steps, such as demonstrating a detector when it is commercially available.

Co-Funders: NYSEARCH Members

Start Date: 11/23/2022
End Date: 10/31/2023
Status: Completed
2023 Funds Expended: **$0**
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: 3/30/2024
Status: Active
2023 Funds Expended: **$14,824**
Total Project Cost: **$130,000**
Total SCG Cost: **$42,824**
Total Co-Funding: **$87,176**
Benefits:

The objective of this project is to perform a review of the latest advancements in smart and remote equipment applications for distribution systems. With increasing amounts 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 natural gas infrastructure. The project scope includes 1) identifying operator requirements; 2) performing a market study to review the latest remote equipment and related communication systems; and 3) determining if products are in development or commercialized. During 2023, vendors have been largely unresponsive except for one who provided insight into what is needed to quote a district regulator system. Next steps will be to establish a path forward to address vendor non-responsiveness and delve further into the market study. The remote equipment includes on/off valves, regulation valves, pressure reduction gas stations, and backflow compressors. Coordination with project 7.23.l "Innovative Gas Analyzers for RNG Applications" will continue. Upon completion, the team will deliver a final report which will include the industry needs and market product gaps for remote flow monitoring technologies. SoCalGas intends to use this research for future district regulator station designs, which consist of proven remote monitoring and control equipment, to further enhance the operational safety and flexibility of the system and allow for RNG capacity.

Co-Funders: OTD Members

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

Start Date: 12/09/2022
End Date: 03/31/2026
Status: Active
2023 Funds Expended: **$4,500**
Total Project Cost: **$7,216,729**
Total SCG Cost: **$15,000**
Total Co-Funding: **$7,201,729**
Benefits:

The objective of this project is to develop safety practices for blending hydrogen into natural gas pipeline systems by identifying the requirements, steps, and procedures involved. The research will address this through: 1) a multi-disciplinary team conducting literature review and gap analysis; 2) model development for component performance; 3) system wide Quantitative Risk Analysis and Performance Assessment; and 4) two case studies and a techno-economic analysis. This project will deliver a systemwide quantitative risk analysis model that can be used to improve safety protocols and provide recommendations to support integrity management practices. SoCalGas intends to use this research in cooperation with other California utilities by incorporating the findings into a draft statewide hydrogen blending standard. 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 its natural gas infrastructure.

Co-Funders: CEC, Other Technology Providers

Technology Testing Assessment Facilities (AMI Smart Metering)

Start Date: 01/01/2019
End Date: 12/29/2023
Status: Completed
2023 Funds Expended: **$1,810**
Total Project Cost: **$124,300**
Total SCG Cost: **$124,300**
Total Co-Funding: **$0**
Benefits:

The objective of this project was to evaluate new technologies, tools, and equipment at SoCalGas's 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 test facilities that 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. The Measurement Technology Group evaluated the functionality and reliability of a residential ultrasonic gas meter and an advanced metering infrastructure (AMI) network at SoCalGas's Meter Test Rack. This proof-of-concept pilot project leveraged a new AMI network to receive real-time data from gas meters, multi-variable sensors, and cathodic protection test stations. It also supports an integrated distribution automation system. In 2023, the ultrasonic gas meter passed all SoCalGas acceptance testing and was approved for deployment. Due to their limited ability to communicate on SoCalGas' existing AMI network, however, it did not provide any improvements over diaphragm meters for SoCalGas. SoCalGas can use this research to supplement the list of technologies for customer meters, which will improve affordability, improve reliability, and reduce greenhouse gas emissions.

Co-Funders: N/A

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

SUB-PROGRAM: SYSTEM DESIGN & MATERIALS

A Framework for Improved Geohazard Monitoring, Data Integration, and Information Fusion at Scale (5.24.i)

The objective of this project is to investigate new methods and models in which new and existing geohazard data can be integrated to aid operators in managing their geohazard risks. The project aims to provide more system integrity knowledge to help operators proactively manage the risk of geohazard threats. There is a need to continue to enhance existing models or develop a new commercially available model that better integrates geohazard data. The proposed project will provide the framework and guidelines to achieve this goal. The project will deliver well-documented data, information, and model architectures that can be implemented on many commercially available platforms. Also, the project team will liaise with relevant standards organizations to establish an industry working group to evaluate the project output as a starting point for developing a governing standard to guide data and information fusion for geohazard modeling. The approach will improve geohazard monitoring and forecasting to mitigate geohazard risks and improve pipeline safety. SoCalGas could utilize the results of this project to evaluate implementation of a system to monitor, forecast, and mitigate geohazard risks. The results of this project will benefit the ratepayers as they will provide SoCalGas a more efficient and holistic way to monitor, in real time, any threats to its system and may provide early warning detection, allowing preventative measures to be taken in sufficient time.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/1/2023
End Date: 11/30/2026
Status: Active
2023 Funds Expended: **$4,929**
Total Project Cost: **$819,252**
Total SCG Cost: **$4,929**
Total Co-Funding: **$814,323**
Benefits:

Action Limits for RNG Specifications (7.23.k)

The objectives of this project are to monitor available literature, gather operational data to support renewable natural gas (RNG) action limits for trace constituents, and execute a test plan for experimental determination of the impact of vapor-phase constituents on components and materials found in end-use and natural gas pipeline equipment. 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, particularly mercury, on natural gas pipeline infrastructure and end-user equipment, including non-cryogenic end-user equipment. In 2023, the project team refreshed the literature review, conducted a funder survey to determine equipment of primary concern, and developed a test plan for laboratory testing at Southwest Research Institute, all compiled into a report. The next step will be to execute the developed test plan and analyze the results to inform the selection of appropriate constituent trigger and action levels for natural gas systems. 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: 6/30/2025
Status: Active
2023 Funds Expended: **$543,445**
Total Project Cost: **$1,256,000**
Total SCG Cost: **$543,445**
Total Co-Funding: **$712,555**
Benefits:

Alternative Caps for PE Service Tees (5.16.b)

The objective of this project was 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; 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 decided to pursue a different design. The team developed a new concept involving an electrofusion cap, but this design needs to be tested and verified. Due to limitations in the initial design aspect, sponsor needs, and manufacturers participating in the project, it was recommended to close out this project and start a new project to evaluate new designs with additional manufacturers. Therefore, this project concluded as a proof of concept for heat-fusing a cap as an alternate method for installing service tees. SoCalGas can use the knowledge gained from the evaluations and concepts discussed in this project to determine the need for an alternate design option.

Co-Funders: OTD Members

Start Date: 02/15/2016
End Date: 4/26/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$112,400**
Total SCG Cost: **$32,115**
Total Co-Funding: **$80,285**
Benefits:

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

ARPA-E REPAIR Program (TTSP)

Start Date: 10/01/2020
End Date: 9/30/2024
Status: Active
2023 Funds Expended: **$1,440**
Total Project Cost: **$32,564,637**
Total SCG Cost: **$10,000**
Total Co-Funding: **$32,554,637**
Benefits:

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 in comparison to pipes made from newer steel. The ARPA-E REPAIR program seeks to reduce natural gas leaks from these older pipes by developing a suite of technologies to enable the automated construction of new pipe inside existing pipes. 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 in the project is through the Testing and Technical Specification and Steering Panel (TTSP) Committee. The REPAIR 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 coating integrity. As part of this effort, the teams developed 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. Currently, the testing program of coating systems for rehabilitation of vintage pipe is in progress and developers are in process of completing their coating systems for testing. ARPA-E is providing additional funds to cover the cost associated with extending the project to September 2024.

Co-Funders: DOE

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

Start Date: 10/20/2022
End Date: 12/31/2025
Status: Active
2023 Funds Expended: **$100**
Total Project Cost: **$1,205,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$1,200,000**
Benefits:

The project objective is to develop an integrated approach to corrosion control in 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, more specifically pertaining to microbially and soil-property-influenced corrosion. The goals are to formulate a performance-based, cost-effective risk assessment and management approach and to 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. In 2023, the team used the Bayesian internal corrosion, external corrosion, and stress corrosion cracking models to create a risk assessment methodology for gas pipelines. Natural Gas Investor-Owned Utilities (NGIOU) provided a list of inputs for the models; the models are being tailored to fit NGIOU requirements. This methodology will be tested in 2024. SoCalGas believes that continued corrosion research is a necessary step in a good corrosion management process and that this research 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

Crack Management Analysis Tool

Start Date: 12/29/2023
End Date: 12/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$162,750**
Total SCG Cost: **$40,450**
Total Co-Funding: **$122,300**
Benefits:

The objective of this project is to support the development of an advanced web-based platform to help operators with post-processing in-line inspections (ILI) and non-destructive evaluation data for crack management. Utilities sometimes are limited to traditional Excel spread sheets to perform crack analysis or depend on third-party vendors to post-process sensitive information. This research will fill in the technology gap to help operators input large data sets and perform advanced analysis to help mitigate crack features on steel assets. The web-based platform will include crack evaluation, cycle counting analysis, refinement and evaluation of hard –to-spot crack features, probabilistic evaluation tools, flaw types (e.g., mechanical damage, corrosion), and multi-flaw remaining strength calculations. Project kickoff is scheduled for early 2024. Project deliverables include a web-based application, quarterly crack management workshops, and knowledge transfer. Results obtained from ILI inspections with crack detection tools will be deployed and evaluated using this web-based application. As SoCalGas increases its inspections of pipe segments using crack detection tools, the results of the research could optimize the effectiveness of inspection results and allow better understanding and assessment of pipe segments susceptible to cracking.

Co-Funders: Others

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

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

Start Date: 04/01/2019
End Date: 04/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,587,263**
Total SCG Cost: **$133,902**
Total Co-Funding: **$1,453,361**
Benefits:

The objective of this project is to develop Level 1 and Level 2 metal-loss assessment criteria that are easy to use and cover all pipe grades and construction eras. These criteria 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. This project's 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 developed 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 2023, the project team drafted coalescence criteria for adjacent and nested metal loss features and verified the coalescence criteria against historical full-scale test data. The next steps will be to establish and refine metal loss assessment methodologies and compare them against existing full-scale test data, including in-line inspection/non-destructive testing data. 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

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

Start Date: 11/19/2021
End Date: 04/30/2025
Status: Active
2023 Funds Expended: **$50,000**
Total Project Cost: **$645,629**
Total SCG Cost: **$54,858**
Total Co-Funding: **$590,771**
Benefits:

The objective of this project is to 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 that is based on the venting characteristics of standard internal relief valve regulators and not for vent-limiting regulators. The results from Phase I will determine if vent-limiting service regulators offer more options for outdoor installation by having a smaller footprint of ventilated gas that could justify reduced clearances. The project includes additional testing on two of the non-relieving gas service regulators to determine their sensitivity to trips caused by temperature increases. This research and testing will conduct a formal analysis and draw conclusions from the data. In 2023 the initial testing was completed. The next steps are to analyze the data and perform the temperature tests. SoCalGas can benefit from this research to improve safety, reduce costs, lower GHG emissions, and benefit ratepayers. The results would be used to develop a more detailed policy and criteria regarding the appropriate sites and usage of the non-relieving service regulators.

Co-Funders: OTD Members, PHMSA

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

Start Date: 11/10/2022
End Date: 11/29/2024
Status: Active
2023 Funds Expended: **$30,000**
Total Project Cost: **$320,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$290,000**
Benefits:

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. Each manufacturer defines the content and format of barcodes applied to its steel-pipe-containing asset attributes. This non-standardized approach makes it difficult for operators to use the data contained in the barcode consistently. The goal of this project is to achieve industry adoption of the 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. In 2023, the project team developed the traceability portal, enabling the automatic creation of a barcode with material attributes populated by an upload of MTR data. The team began the traceability barcode and data model pilot testing with one pipe mill and a utility sponsor. The team also worked on the Unique Identification (ID) and Smart Tag specification to provide a methodology to generate a universal Unique ID for steel pipeline components in the natural gas industry that can be incorporated into a Smart Tag marking system. Together with digital MTRs, as defined in API RP 5MT, this specification will provide a system for industry standard steel material traceability for manufacturers, distributors, pipeline operators, and other industry stakeholders. 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 quality assurance and quality control processes.

Co-Funders: OTD Members, JIP Members

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

Distribution System Analysis

This project's objective is to support future risk and threat analysis under different operating conditions by establishing families of pipes and components with specific characteristics that have similar risk profiles. The project will conduct a Critical Threat Review using a Phenomena Identification and Ranking Table (PIRT). This project will also develop an advanced probability-of-failure model by analyzing various parameters. Some of these parameters include material type, manufacturing process, prior pipeline inspection, operating histories, lab testing results, and existing probability-of-failure framework. By comparing the probability-of-failure of various pipelines, this project will help SoCalGas determine where replacements may be needed to accommodate future operations.

Co-Funders: N/A

Start Date: 12/1/2023
End Date: 5/31/2026
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$750,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$0**
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 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 will aid in understanding: 1) material compatibility impacts on gas meters and regulators in H2-NG blend service; 2) meter accuracy in H2-NG blends; and 3) feasible H2- NG blend limits between 0-20% for gas meters and service regulators. In 2022, the team finalized the bill of materials for three potential testing rig options. The sponsors chose two of the three test rigs, each with nine regulators and nine meters. The construction of the test rigs began late 2023. Project delays were due to project rescoping, supply chain issues on parts delivery, and the need to perform a comprehensive safety analysis, with the development of safety protocols. 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: 07/31/2024
Status: Active
2023 Funds Expended: **$11,482**
Total Project Cost: **$605,000**
Total SCG Cost: **$53,148**
Total Co-Funding: **$551,852**
Benefits:

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

The objectives of this project were 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 aligned 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 (LUAF) gas. Previously, there were 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 LUAF gas volumes from optimized end-treatment designs. The project team created computational fluid dynamic models of six end treatments. The project team then optimized and tested four out of those six end treatments in 2020. In 2021, two additional end treatments and the performance testing of the new clamp-on USM model were added to the project scope and test plan. The project team completed experimental testing in 2022. The project team published a final report on the PRCI website for members and presented the results at a webinar. 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: 08/27/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$236,000**
Total SCG Cost: **$4,971**
Total Co-Funding: **$231,029**
Benefits:

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

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

The objective of this project is to determine the precision, accuracy, and sensitivity of an online Gas Chromatography-Ion Mobility Spectroscopy (GC-IMS) siloxane sensor for biogas. 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, wherein the project team completed laboratory and field testing of the GC-IMS at a landfill site. The 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 team will collect and analyze samples and compare the online data to offline analytical techniques performed by independent laboratories. In 2023, The team received an updated version of the analyzer and began testing to validate that the hardware and calibration issues had been resolved. Planning for the field demonstration is ongoing as the project had delays from equipment and supply chain issues. Once complete, the team will disseminate the second field test results in a final report and presentation to project sponsors. SoCalGas has requested to host the second field test of the GC-IMS Analyzer and plans to test the analyzer at its Engineering Analysis Center before temporarily installing it at one of its biogas producer sites.

Co-Funders: PRCI Members

Start Date: 08/31/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$118,000**
Total SCG Cost: **$14,603**
Total Co-Funding: **$103,397**
Benefits:

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

The objective of this project was to investigate 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 was 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. The project team executed the three-year field exposure trials on three coating systems, two zinc-based coatings and a single-component, high-ratio, co-polymerized calcium-sulfonate alkyd coating. The coatings were tested in four distinct environments: regulator stations, a bridge crossing, and coastal and desert locations. Two coatings were tested on the bridge crossing and performed well in winter, road salt, and bird dropping conditions. The coatings at regulator stations performed well on live and dummy pipe with and without introduced coating defects (scribed). All three coating systems performed well in extreme desert heat and nighttime cold with morning condensation. Moving forward, SoCalGas will evaluate the zinc coating which meets the air quality limits of SoCalGas' service territory as it performed well. If continuing research identifies it as a promising coating system, SoCalGas will add it to the list of coatings available to minimize or mitigate corrosion on aboveground assets.

Co-Funders: OTD Members

Start Date: 09/06/2017
End Date: 06/30/2023
Status: Completed
2023 Funds Expended: **$1,428**
Total Project Cost: **$217,000**
Total SCG Cost: **$2,775**
Total Co-Funding: **$214,225**
Benefits:

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

Gas Machinery Research Council (GMRC)

The 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 has more than 70 member organizations, providing its members and the industry with 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, performance and efficiency of pipeline facilities and gas compressor stations. In 2023, GMRC's active projects included: Dry Gas Seal Reliability (Phase 5), Implementing the Virtual Orifice (VO) Standardization, Hydrogen (H_2) Blending on Compressor Stations, Reciprocating Compressor Lube Oil Optimization, and Lube Oil Gas Entrainment. The Implementing the VO Standardization project was field tested and found to improve the efficiency of pressure pulsation reduction in reciprocating compressors by up to 5%, therefore reducing CO_2 emissions. The next step is for manufacturers to consider marketing it. Also, the Hydrogen Blending on Compressor Station project resulted in a white paper that will be used as a living document referencing the impact of hydrogen blends (up to 20%) on compression equipment. All other active projects are ongoing. The GMRC benefits SoCalGas and the industry in one of three ways: 1) basic research useful to support other research or product development, 2) establishing design criteria, or (3) developing and evaluating products that it will use.

Co-Funders: GMRC Members

Start Date: 01/01/2019
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$3,840**
Total Project Cost: **$1,468,000**
Total SCG Cost: **$24,160**
Total Co-Funding: **$1,443,840**
Benefits:

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

The objective of this project is to develop a roadmap to guide future Pipeline Council Research Institute research in centrifugal components for gas turbine-driven centrifugal compressors. The previous roadmap was created in 2016 and does not reflect the current state of technology. The project team will perform a literature review under this new road map and survey the current state of gas-turbine-driven centrifugal compressors. The project will also identify gaps that will improve gas turbine-driven compressor safety, reliability, and performance. In 2023, the project team completed its review of the previous roadmap, incorporating the results of literature review of the current state of the technology, and started the process of identifying potential research projects to address the identified gaps. The project team expanded the project scope to include optimizing efficiency and performance of the compressors to support potential greenhouse gas (GHG) reductions and to help avoid costly replacements. Once the project team develops the roadmap, they will use it to identify and prioritize research to benefit gas utilities and the ratepayers. SoCalGas could potentially benefit from future research projects that improve the safety, reliability, and reduction of GHG emissions in its turbine-driven compressors.

Co-Funders: PRCI Members

Start Date: 12/14/2022
End Date: 3/31/2024
Status: Active
2023 Funds Expended: **$8,040**
Total Project Cost: **$89,040**
Total SCG Cost: **$16,912**
Total Co-Funding: **$72,128**
Benefits:

Guidelines for Selecting Trenchless Installation Methods (CNST-1-4)

This project's objectives are to develop a guideline outlining the currently available trenchless construction methods for pipeline installation, identifying their pros and cons, and to identify potential gaps or limitations that may lead to future trenchless technology innovation. Trenchless construction methods are used to install a pipeline around obstacles such as waterways, highways, and railroads, or to reduce potential environmental or community impacts. These methods may represent the most feasible and cost-effective option available. The project team intends to develop a guideline for the current state-of-the-art trenchless construction methods based on selection criteria that include geographical formations, pipeline specifications, elevations, and depths. The guideline will include detailed information on the benefits, limits, and risks associated with each trenchless method to help determine which trenchless method may be more appropriate to utilize. SoCalGas will use the guideline for selecting, verifying, and utilizing the most appropriate and cost-effective trenchless construction methods for installing new pipelines or replacing existing ones based on design and site conditions. This guidance should result in a safe and reliable pipeline installation, thereby minimizing environmental and community impacts that could cause disruptions in services or add additional costs to ratepayers.

Co-Funders: PRCI Members

Start Date: 12/1/2023
End Date: 04/17/2024
Status: Active
2023 Funds Expended: **$9,440**
Total Project Cost: **$118,000**
Total SCG Cost: **$9,440**
Total Co-Funding: **$108,560**
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: 9/20/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,050,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$1,020,000**
Benefits:

The objectives of this joint industry project (JIP) were to develop industry best practices for welding stub-on branch connections onto live gas mains (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 reduces costs and increases safety and reliability. Hot tap branch connections have long been an important aspect of pipeline and piping system operations. Previously, the team completed a report on in-service failures and guidance on fitting types and weld spacing. It also provided updated information to support the Pipeline Research Council International project "Update of the PRCI Pipeline Repair Manual (MATR-3-1A)." In 2023, the team revised the 22nd edition of American Petroleum Institute 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. Additionally, the project team worked 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. The use of this updated guidance document will increase the safety and reliability of newly constructed and repaired pipelines by avoiding misinterpretation of the requirements by users and regulators and will also allow the realization of significant economic and environmental benefits.

Co-Funders: JIP Members

HyBlend Collaborative Research Partnership (5.21.k)

Start Date: 09/01/2021
End Date: 09/28/2024
Status: Active
2023 Funds Expended: **$0**
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. Its goal is to evaluate technical and economic considerations related to transporting hydrogen (H_2) blends and other low-carbon fuels using existing natural gas (NG) infrastructure. The efforts to increase H_2 knowledge can lead to reduced greenhouse gas (GHG) emissions, such as occurs when coupling energy efficiency and decarbonized fuels. The project team is addressing high-priority research topics, including 1) H_2 compatibility with metals and polymers, 2) life-cycle analysis (LCA), and 3) techno-economic analysis (TEA). 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 H_2 and NG blends and alternative routes; and quantify the costs, opportunities, and alternative paths for H_2 production and blending with an NG network. In 2021, the project team established test plans and logistics for materials. In 2022, the project team published the literature review and gap analysis report and completed the TEA. Task 1 and Task 2 were completed in September 2023. The analysis, TEA manuscript, and technical report are expected to be published in early 2024. The final report is scheduled for release in Q2 2024. SoCalGas will use these results to support the development of an H_2 blending standard and to guide future research.

Co-Funders: OTD Members, DOE, NREL

- 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)

The objective of this project is to 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. Risk impact due to hydrogen blending must be quantified to allow operating procedures and associated budgets to be adjusted accordingly. In 2023, long-term strength tests, tensile tests, and several material tests were performed to observe the material's behavior in the hydrogen/natural gas blend to develop the lifetime prediction and risk models. Aldyl-A and HDPE pipe samples have been collected and the following tests for Aldyl-A samples completed: Oxidation Induction Time, Cross-Polarized Light Microscopy, and tensile. The same work continues for the HDPE pipe samples. An interim technical report for the Aldyl-A portion of the project is in progress and is expected to be completed in Q1 2024. The work on HDPE pipe samples will continue in 2024; a final report summarizing all the findings will be delivered at the end of the project. It is crucial for SoCalGas to understand the impact of hydrogen blends on existing PE infrastructure to maintain the integrity and safety of gas distribution pipelines.

Co-Funders: OTD Members

Start Date: 04/08/2021
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$134,724**
Total Project Cost: **$1,009,672**
Total SCG Cost: **$513,470**
Total Co-Funding: **$496,202**
Benefits:

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

The project objective was to characterize the Fatigue Crack Growth Rate (FCGR) behavior of different steel pipe grades when exposed to a range of hydrogen-methane (H2-CH4) gas blends containing a range of hydrogen by volume. The project determined the FCGR in the parent pipe, girth weld, and longitudinal seam welds at both the weld center line and its heat affected zone (HAZ). Each phase (Ph) tested one pipe grade: Ph1a (X70), Ph1b (New X52, X65, and Microscopy X65), and Ph2 (vintage X42 and vintage X52). The project team has completed all testing. Ph1a identified that the FCGR accelerated for various microstructures in hydrogen-blend environments, primarily due to hydrogen embrittlement mechanisms. This result led to an expansion in the project scope in 2021 to include a microscopy study for new API X65 steel samples for microstructural characterization, since defects in microstructure strongly influence crack initiation processes. Ph1b X52 testing baseline results of the base metal showed trends similar to those in the X70 and X65 pipes. The final report for Ph1b was delivered in December 2022; the final reports for the microscopy study and Ph2 were delivered in June 2023. Results identified that microstructural and fractographic examination of X65 line pipe helped researchers understand the difference in the crack propagation damage mechanism in the presence and absence of hydrogen. The project discovered that the FCGR increased even in the lowest studied hydrogen partial pressure and that the FCGR of all the studied pipe grades was impacted with the introduction of hydrogen. A strong trend tying FCGR with material strength grade was not observed. 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: 05/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,096,160**
Total SCG Cost: **$1,096,160**
Total Co-Funding: **$0**
Benefits:

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

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

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. They are commonly found in personal hygiene, health care, and industrial products that end up in landfills and wastewater treatment plants. When waste from these sources is anaerobically digested, siloxanes are formed in the resulting biomethane. In phase I, the project team completed selection of several analyzers, factoring a set of criteria and market availability. 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. Combustion of RNG containing siloxanes produces a silica deposit on downstream surfaces that could impact the safety and reliability of appliances and the efficiency of industrial equipment. Although five analyzers were selected, it was concluded that none of the analyzers met the project's criteria. The project was terminated as advancements with testing siloxanes from a portable analyzer, test site availability, and testing for American Society for Testing and Materials (ASTM) D8230-19 is being performed by other research consortia. Once approved, SoCalGas will use the ASTM standard to validate the Rule 30 trigger level for siloxanes. This research helped bridge the technology gap for monitoring siloxane concentration levels at RNG sites.

Co-Funders: NYSEARCH Members

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

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

The objective of this project was to determine if hydrogen natural gas blends cause any change in the presence or absence of leaks and in the leak flow rate for threaded connections that conform to National Pipe Thread (NPT) standards. This project developed the test protocols for both NPT and out-of-spec (non-NPT) connectors; performed tests to assess the change in a leak or leak flow rate with a 20% hydrogen blend; evaluated the impact of various pipe dopes and sealants and if hydrogen blends influenced this variable; and established procedures for creating threaded-connection leaks and methods to measure leak flow rates with hydrogen blends. Results showed the hydrogen in natural gas blends did not appear to create more leaks than natural gas. The project also addressed whether existing leaks have a higher gas flow rate with the 20% hydrogen blend of gases than with pure natural gas. Results of this inspection indicated a slight increase in flow rate with the blended gas. Following analysis, however, the difference was deemed statistically insignificant despite the significant differences observed in overall failure rates among the thread sealants. A proposal for further research is being developed. SoCalGas will use this research to support the determination of a hydrogen-natural gas blend limit for distribution systems that could contribute to a statewide hydrogen injection standard.

Co-Funders: NYSEARCH Members

Start Date: 08/09/2021
End Date: 09/27/2023
Status: Completed
2023 Funds Expended: **$0**
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 was to determine if blending hydrogen into natural gas would change the physical properties of elastomers in a natural gas delivery system, the most common of which are styrene-butadiene rubber (SBR) and acrylonitrile butadiene rubber (NBR). Both are used as seals in compression applications and as gaskets for flanges in joining pipes and fittings. There is a need for more research 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), and how they 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. In Phase II, the team carried 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, pressures, and temperatures. The results showed that under the studied conditions, the unrestrained (i.e., not under torqued pressure) SBR and NBR did not show any impact from exposure to hydrogen. Additionally, changing the gas composition did not have a major impact on SBR and NBR elastomer performance except at extreme temperature. Future steps include continuing research into the effects of hydrogen on elastomer materials. This project has helped 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: 07/13/2023
Status: Completed
2023 Funds Expended: **$280**
Total Project Cost: **$425,024**
Total SCG Cost: **$31,910**
Total Co-Funding: **$393,114**
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)

The objective of this project is to develop a standard data interchange template for transmitting a completely digital Material Test Report (MTR) in compliance with American Petroleum Institute (API) 5L Recommended Practice Standard (RP-5MT). API 5L RP-5MT is the standard for transmission pipes used in the natural gas and petroleum industries. It 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 1) a digital template to make the report available to customers electronically and 2) 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. In 2023, the project team completed the model for data exchange between pipe manufacturers to transmit the MTRs to its utility customers. In 2024, the project team will introduce the digital MTR at the API 5L conference scheduled in the first quarter. The introduction will ideally build up industry acceptance and lead to the future adoption of digital MTR. By using electronic test reports for pipes, SoCalGas anticipates speeding up materials approval and management, thereby improving operational efficiency.

Co-Funders: OTD Members

Start Date: 12/14/2021
End Date: 05/30/2024
Status: Active
2023 Funds Expended: **$4,554**
Total Project Cost: **$255,000**
Total SCG Cost: **$12,554**
Total Co-Funding: **$242,446**
Benefits:

Individual Packaging Requirement for all Bulk Packaged Plastic Fittings (5.24.g)

The objectives of this project are to develop the requirements for individual packaging of plastic fittings and incorporate the requirements in the applicable American Society of Testing and Materials (ASTM) standards. Joining polyethylene (PE) pipe is a fundamental activity performed by every gas utility across the country. Utilities are seeking to enhance the integrity of PE fusions. Although the failure rate for PE fusions is quite low, the consequences of these limited failures can be significant. Pipe and fitting contamination is one of the leading causes of joint integrity issues. Currently, there is no mandatory requirement or guidance for plastic fittings to be packaged individually when they are provided in "bulk" packaging. This can result in potential contamination or dislodged and/or missing components such as O-rings or fasteners. Requiring individual packaging of all products will improve overall system integrity by reducing the risk of fitting contamination and/or displaced fitting components. The team will work with the project sponsors to identify the ASTM standard(s) to update, create the appropriate packaging language to require individual component packaging when bulk packaging is used, and work to incorporate this new natural gas industry language into the appropriate ASTM standards. This project will improve the integrity of SoCalGas' plastic piping systems by minimizing or eliminating the risk of using potentially contaminated fittings during installations. It would also prevent or minimize the operations cost associated with repairing leaks due to contaminated joints.

Co-Funders: OTD Members

Start Date: 12/01/2023
End Date: 6/01/2025
Status: Active
2023 Funds Expended: **$83,079**
Total Project Cost: **$152,000**
Total SCG Cost: **$83,079**
Total Co-Funding: **$68,921**
Benefits:

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

The objective of this Pipeline Research Council International (PRCI) project was to assess softening of the heat-affected zone (HAZ) associated with welding when installing Type-B sleeves and performing hot taps for pipeline repairs, including branch connections. This research was intended to determine the impacts of HAZ softening on pipeline welds (i.e. girth welds) and modern pipeline materials and to use the results to update current welding procedure guidelines for vintage pipes, including best practices for welding modern micro-alloyed pipe during repairs to improve pipeline integrity. The project team performed 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 used in pipeline construction and repair; this research will enhance pipeline integrity by minimizing pipeline failures. The project characterized the causes of HAZ softening from welding and the variables that affect HAZ softening. The project team published the final report on the PRCI website. It includes recommended welding guidelines that could minimize the effects of HAZ softening and decrease the strength mismatch that affects the integrity of 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

Start Date: 10/13/2021
End Date: 12/7/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$177,000**
Total SCG Cost: **$13,587**
Total Co-Funding: **$163,413**
Benefits:

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

LUAF Study

The objective of this project is to characterize and estimate the measurement- and theft-related variables for lost and unaccounted-for (LUAF) gas volumes on the SoCalGas delivery system. The original SoCalGas study on determining LUAF gas volumes was developed by the Gas Research Institute in the early 1990's (GRI report 93/0115). An update to the report looking specifically at the measurement factor was conducted in 2006 by SoCalGas. Since then, equipment and operating practices have changed greatly, especially with the introduction of new technology. Historically, measurement has accounted for the greatest percentage of SoCalGas LUAF. However, the contribution of natural gas theft to LUAF estimates has been difficult to define; it is known that new methods of theft have been identified in recent years. This project will perform a detailed analysis of 1) the metering technology and components within SoCalGas for 2018-2022, and 2) the main areas of annual variability, identifying the factors and variables that affect SoCalGas customer service and theft-related distribution LUAF. The project deliverables will include two final reports: measurement-related LUAF and theft-related LUAF. Each report will include recommendations for future consideration (if warranted). The knowledge gained from the results will be used to provide recommendations for ways to make SoCalGas systems more efficient. If the results precisely identify the current contribution of the measurement and theft components of LUAF and identify the ways to reduce measurement and theft LUAF in the future, then SoCalGas would implement the identified areas of improvement.

Co-Funders: N/A

Start Date: 12/1/2023
End Date: 3/31/2024
Status: Active
2023 Funds Expended: **$22,222**
Total Project Cost: **$70,975**
Total SCG Cost: **$70,975**
Total Co-Funding: **$0**
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 is investigating 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 strain and stress to develop best practices to minimize them on pipelines. In 2022, the project completed a literature review of Pipeline and Hazardous Materials Safety Administration incident reports from uneven supports and conducted a member survey on current practices. In 2023, the project team completed the collection of in-line inspection and bending strain data and maintenance records and started analyzing the data. The team plans to deliver a final report with recommended practices and procedures to prevent pipeline failure from uneven supports to sponsors in Q1 2024. After publication of the report, the team plans to hold a workshop to train utilities on implementing the best methods for minimizing 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: 05/31/2024
Status: Active
2023 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 was to provide software tools to assist operators in complying with the Maximum Allowable Operating Pressure (MAOP) and materials verification requirements proposal of the Integrity Verification Process (IVP). The proposed guideline allows the use of Engineering Critical Assessments (ECA) instead of hydrotesting, 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 developed a set of models using the ASME B31G-modified (wall loss defects) and the Maxey-Folias Leak-Rupture Boundary model. The design work completed the development of an application to help operators. The project team also identified a new compiler to replace Fortran/Ruby language-based tools to improve computer performance for new and existing computer programs. The project team has completed importing a 10-million-point dataset and is using it in model calculations. The project deliverables included a developed application, "ECA Tools," and a final report. SoCalGas could use this tool as a reference for ECA, depending upon the final version of the rule.

Co-Funders: OTD Members

Start Date: 09/08/2017
End Date: 2/28/2023
Status: Completed
2023 Funds Expended: **$7,000**
Total Project Cost: **$118,054**
Total SCG Cost: **$11,364**
Total Co-Funding: **$106,690**
Benefits:

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

Multi-Compound Green Corrosion Inhibitor for Gas Pipeline

The objective of this Pipeline and Hazardous Material Safety Administration co-funded project is to develop a novel "green" corrosion inhibitor, optimize its implementation in gas pipeline environments, and evaluate the inhibitor's effectiveness and compatibility through laboratory testing and nondestructive evaluation measurements. Compared to traditional chemical inhibitors, green corrosion inhibitors may offer great potential to mitigate internal corrosion, while being environmentally friendly. This project will evaluate and test multi-compound green inhibitors derived from renewable feedstocks for performance. The project team will simulate the implementation to recommend best practices for different pipe geometries, inhibitor properties, and operational factors. Validation testing will include inhibitor coating thickness, gas properties, and pipeline properties. In 2023, the project team worked on the design and synthesis of green inhibitors and explored potential candidates for green corrosion inhibitors suitable for gas pipeline protection. The next step is to develop the test protocols. SoCalGas anticipates using environmentally friendly alternatives to prevent corrosion in pipelines. The research could help identify features for Integrity Management, which will benefit ratepayers by improving operational efficiency and safety, while reducing the environmental impact of using corrosion inhibitors to protect the pipelines.

Co-Funders: PHMSA

Start Date: 12/01/2023
End Date: 09/29/2026
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,004,000**
Total SCG Cost: **$4,000**
Total Co-Funding: **$1,000,000**
Benefits:

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

The objective of this project is to perform the product development of the selected analyzer and test the modified analyzer for the monitoring of unconventional trace contaminants. In past phases of this project, the team completed validation testing of several online biomethane analyzers to identify which would have the potential to detect unconventional trace constituents (TCs). 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 Phase III, the analyzer manufacturer will modify its 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-nitroso-di-n-propylamine. The analyzer was selected in 2022; the subcontract with the manufacturer for product development was executed in October 2023. The next steps will be to set up the testing environment, perform laboratory testing, compile data for the report, and deliver the final report to the project sponsors. SoCalGas needs to continuously monitor TC levels to determine the variability of the TC concentration. If this project shows that the concentration exceeds the limits, SoCalGas may require biomethane quality monitoring systems to make sure gas quality is consistent.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
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 (PRCI) established this Strategic Research Priority (SRP) to coordinate 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. In 2023, work continued on Improvements to Mechanical Damage Engineering Assessment Tool (MD-2-4) and Analysis of Pipeline Operator and Prior RD&D Data (MD-2-5). Three projects were completed: Verification of Screening Tools for Classification of ILI Reported Dents with Metal Loss Features (MD-5-04); Improve ILI Sizing Accuracy (NDE-4-19); and Development of Guidance Document for Performing ECA in Accordance with Mega-Rule, CFR 192.712 (c) (MD-5-03). One project was both initiated and completed: Validate In-Line Inspection (ILI) Capabilities to Detect/Characterize Mechanical Damage (NDE-4-18). SoCalGas will evaluate the completed projects for possible deployment via its integrity management program. Final reports for the completed projects are available on the PRCI website. See the individual project summaries for details on NDE-4-18 and NDE-4-19.

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$35,593**
Total Project Cost: **$2,042,507**
Total SCG Cost: **$49,040**
Total Co-Funding: **$1,993,467**
Benefits:

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

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

The objective of this research is 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 focuses on four core areas: susceptibility, inspection, management, and assessment and remediation. In 2023, twelve new projects were funded: three in susceptibility, four in inspection, three in assessment and remediation, and two in management. Work continued on Evaluation of Selective Seam Weld Corrosion Susceptibility (NDE-4-22), Crack Dormancy and Prevention of Crack Growth for SCC (SCC-02-15), and Hard Spot Susceptibility Review-Pipe Manufacturers, Pipe Type, Vintage (MAT-7-2). Two projects were completed in 2023 with reports on the PRCI website: Continuous Improvement of ILI Capabilities (NDE-4-12), and Recent Pipeline Failures Where Hydrogen Was Identified as a Contributor (MAT-8-3B). NDE-4-12 developed new test methods to evaluate ILI tools. MAT-8-3B identified causes of pipeline failures, which could aid future work in failure prevention. Once the continuing and new projects are completed, SoCalGas plans to evaluate the results and recommendations for implementation in its Integrity Management Program to improve safety and reliability of services for ratepayers.

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$23,631**
Total Project Cost: **$5,193,400**
Total SCG Cost: **$73,095**
Total Co-Funding: **$5,120,305**
Benefits:

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

The objectives of this joint industry project (JIP) are to develop an improved model for pipeline seam weld anomalies and to improve the existing Pipeline Research Council International (PRCI) MAT-8A fracture mechanics model and its input parameters. The final product will be a cloud-based software tool that can perform probabilistic assessments of cracks and crack-like flaws in pipelines. This software tool implements the modified MAT-8 fracture model, which accounts for surface cracks with arbitrary depth profiles. In 2023, the team updated the cloud-based software to incorporate both detected and undetected crack defect populations on pipeline segments. The team also developed a methodology to model undetected populations of defects using extreme value analysis. Additionally, a JIP member shared the results of study it funded on the growth of crack profiles with the project team. At the conclusion of this project, the team will deliver a report and updated model in the form of cloud-based software 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 the regulatory requirements of the Gas Transmission Safety Rule.

Co-Funders: PRCI Members

Start Date: 09/01/2019
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$621,695**
Total SCG Cost: **$67,645**
Total Co-Funding: **$554,050**
Benefits:

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

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

The objective of this project is to develop weld acceptance test criteria to verify acceptable weld strengths and use the results to propose revisions to current welding standards, including American Petroleum Institute (API) Standard 1104 and Canadian Standard Association (CSA) Z662. This project continued 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 (i.e., 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 research 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 2023, the project team completed the testing and analysis of tensile strain capacity to quantify weld strength and performance to determine the strength capacity of welds experiencing HAZ softening. The scope of work was expanded to increase the confidence level in the project results. The project team will perform additional sample testing and then develop acceptance criteria for girth welds that meet performance standards and improve pipeline integrity. The project's final deliverable will be a final report with recommendations and acceptance criteria for girth welds. SoCalGas will evaluate the results and recommendations for additional testing methods to determine if changes are needed to welding practices to improve its Integrity Management Program.

Co-Funders: PRCI Members

Start Date: 10/05/2021
End Date: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$212,400**
Total SCG Cost: **$14,350**
Total Co-Funding: **$198,050**
Benefits:

PRCI Emerging Fuels Institute

Pipeline Research Council International (PRCI) established the Emerging Fuels Institute (EFI) in April 2021 to address the challenges of transitioning to clean fuels. The EFI will focus on infrastructure related to various emerging fuels, such as renewable natural gas (RNG), ammonia, and biofuels. The EFI focuses on 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 2023, the EFI funded several new projects, which included: EFI Guidance Document (JEFI-00-02); Emerging Fuel Measurement (JEFI-02-03); B31.4, B31.8, B31.12, and Emerging Fuels Discussion (JEFI-04-10); the Department of Energy's SHASTA Program (JEFI-05-02); and Implement Fiber Optic Technology for Underground Gas Storage Well Monitoring, a Pipeline and Hazardous Materials Safety Administration project. Additionally, work continues on the following previously funded projects: RNG Trace Components Database (EFI-02-01); NewGasMet/PRCI Collaboration; and EFI Talking Points (EFI-00-01). Participation in the EFI enhances SoCalGas' knowledge and expands its knowledge library to assist in improving the safety of its pipeline network infrastructure.

Co-Funders: PRCI Members

Start Date: 06/15/2021
End Date: 12/31/2026
Status: Active
2023 Funds Expended: **$175,000**
Total Project Cost: **$5,475,000**
Total SCG Cost: **$675,000**
Total Co-Funding: **$4,800,000**
Benefits:

PRCI Guidance Document for the Twenty-Second Edition of API 1104 (API-1-2B)

The objective of this project is to update the Pipeline Research Council International guidance document for the Twenty-second Edition of American Petroleum Institute (API) Standard 1104 – Welding of Pipelines and Related Facilities (API 1104). The development of the updated guidance document will enable both users and regulators to better understand the intent regarding the interpretation and rationale behind the requirements. The use of this updated guidance document will increase the safety and reliability of newly constructed pipelines by helping avoid misinterpretation of requirements. It will also enable users to confidently tailor welding procedures to better fit the requirements of their specific needs within the bounds of API 1104. This may, in turn, reduce the cost of pipeline construction and maintenance activities. The milestone deliverables include: 1) outline of guidance to address industry needs, 2) outline of guidance required for the Twenty-second Edition, and 3) summarizing the changes between the Twenty-first and Twenty-second Editions of API 1104. In 2023, the project team developed an outline to address industry needs for the Twenty-second Edition and compiled a summary of the changes between the Twenty-first and Twenty-second. Anticipated ratepayer benefits include integrity, safety, reliability, and improving affordability through cost reductions. SoCalGas will deploy these results to update its existing welding procedures that reference API 1104.

Co-Funders: PRCI Members

Start Date: 12/1/2023
End Date: 05/02/2024
Status: Active
2023 Funds Expended: **$9,963**
Total Project Cost: **$241,900**
Total SCG Cost: **$9,963**
Total Co-Funding: **$231,937**
Benefits:

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

Product Standards for Plastic Tapping Tees (5.24.f)

The objective of this project is to develop a draft product standard document for tapping tees to be used by operators as purchasing specifications and which may also be used to develop American Society of Testing and Materials standards. Currently, there is a standard for tapping tees to ensure a level of joint integrity, but there is no defined product standard for the manufactured tapping tee fitting itself. The materials used and the overall design and dimensions of these tapping tees can impact the performance of these fittings. History has shown that improper selection of materials or poor fitting designs can lead to premature failure of the fitting. Creating a product standard for conventional heat fusion tees will support the overall integrity of a polyethylene piping system. The project team, using sponsor input, will determine the types of tees to focus on (saddle, electro-fusion, mechanical, etc.) and how they are designed, manufactured, and tested. Next, specifications will be developed incorporating design criteria, design stresses for the components, and methodologies to address the potential types of failure for each component. The project deliverables include test protocols for each component and a draft tapping tee product standard. This project will help SoCalGas in the review of its material specification requirements for tapping tees.

Co-Funders: OTD Members

Start Date: 12/1/2023
End Date: 12/1/2025
Status: Active
2023 Funds Expended: **$66,265**
Total Project Cost: **$220,000**
Total SCG Cost: **$66,265**
Total Co-Funding: **$153,735**
Benefits:

Reserve Strain Capacity Determination (PHMSA)

The objective of this project is to develop a model for measuring accumulated strain on existing pipelines. The project will employ: 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. All four are required to develop a model to measure accumulated pipeline strains. 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 2023, the project team submitted an interim report on optical strain measurement and ground movement measured from satellite data to PHMSA. Information gained from satellite data was successfully fused with additional information sources on ground movement and pipeline strain to create functioning Bayesian networks for strain demand and capacity determination. Currently, the team is focused on developing the information fusion network to capture the interacting threats that act on high-strength steel transmission pipelines where strain-based design principles are employed. Initial sponsor feedback on the results to date 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: PHMSA, OTD Members

Start Date: 03/30/2022
End Date: 10/30/2024
Status: Active
2023 Funds Expended: **$100**
Total Project Cost: **$1,936,008**
Total SCG Cost: **$2,500**
Total Co-Funding: **$1,933,508**
Benefits:

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

The objective of this project is to demonstrate the operation and benefits of the Utonomy Smart Regulator (USR) through laboratory testing and field trials. The use of the USR could provide operators with the ability to remotely monitor and control district regulator stations. The project included both laboratory and field testing with Utonomy. In 2023, the project team completed the evaluation of the USR at a sponsored utility and completed a product needs report. In early 2024, the team will meet with project sponsors to discuss the USR evaluation results and schedule additional, post-project field demonstrations. This project has the potential to enhance efforts to bring remote monitoring and control to SoCalGas' distribution system. Further, it aligns with the recently published Pipeline and Hazardous Materials Safety Administration Advisory Bulletin titled Pipeline Safety: Overpressure Protection on Low-Pressure Natural Gas Distribution Systems [Docket No. PHMSA-2020-0025].

Co-Funders: OTD Members

Start Date: 01/31/2021
End Date: 01/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$291,800**
Total SCG Cost: **$76,644**
Total Co-Funding: **$215,156**
Benefits:

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

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 project team is updating the program language of the software to C++ and used a cloud-based platform, which should fix the issues. These updates will delay the project completion date to the first quarter of 2024. Once the team completes the GUI and cloud-based platform, 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: 03/31/2024
Status: Active
2023 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's 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 to enter the pipeline system; 4) help RNG interconnectors provide RNG to SoCalGas; and 5) support SoCalGas 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. In 2023, the project team finalized skid design and began procurement of materials. In 2024, the project team will begin testing shortly after receiving the skid. The project team will deliver the results in a final report that includes experimental data, analysis of data, re-assembly of 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. This method and plan can potentially reduce greenhouse gas emissions and improve air quality, which benefits SoCalGas and its ratepayers.

Co-Funders: N/A

Start Date: 11/17/2022
End Date: 2/28/2025
Status: Active
2023 Funds Expended: **$149,032**
Total Project Cost: **$400,000**
Total SCG Cost: **$400,000**
Total Co-Funding: **$0**
Benefits:

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

The California Energy Commission (CEC) awarded two projects that aim to develop seismic risk assessment software tools using different risk models. Slate Geotech and the University of California (UC) Berkeley were awarded the first project to produce an open-source analysis tool easily usable by regulators and utilities. The software utilizes updated methodologies for assessing seismic risk to underground and aboveground natural gas infrastructure, considering fault displacement, liquefaction, and landslides. It can be used to identify areas of highest risk overlaid with population information to help regulators and utilities prioritize seismic retrofit projects. In 2023, the project team hosted a workshop to launch the developed software and demonstrate the features of the open-source seismic risk tool (OpenSRA). The final report and software are available on the UC Berkeley website. SoCalGas provided data and technical expertise for this project. UCLA was awarded the second project in 2019, which considers four hazards: earthquake ground shaking, fault displacement, landslides, and liquefaction. It developed a comprehensive set of pipeline fragility curves and an open-source risk assessment tool based on a probability-based methodology. In 2023, the project team completed development of a state-wide probabilistic earthquake fault displacement hazard tool that can be used for decision-making to reduce the potential of pipeline failures and decrease the potential for unacceptable interruptions in gas caused by a major earthquake. The project team published the databases and reports to the UCLA website. SoCalGas is participating in the Technical Advisory Panel for both of these projects. The final task for both projects is publishing the final reports on the CEC website.

Co-Funders: CEC, LBNL

Start Date: 06/01/2019
End Date: 5/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$5,202,752**
Total SCG Cost: **$8,000**
Total Co-Funding: **$5,194,752**
Benefits:

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

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

The objective of this project was to characterize the impact of varying hydrogen blends (up to 20% by volume) with natural gas (NG) and renewable natural gas (RNG) on different types of residential and commercial NG meters. Blending hydrogen in NG and RNG will change gas properties. These altered gas properties may affect the flow measurement performance of NG flow meters and interfere with meeting the California Public Utilities Commission (CPUC) requirement of ±2% accuracy in gas delivery to customers. The project team gathered gas property data required to calculate a mass flow rate output from a gas flow meter, compared the results with existing equations of state (EOS), and provided recommendations for best practices and setting appropriate values of uncertainties with various EOS. The project team also evaluated the suitability and integrity of two residential-type and two commercial-type meters by determining measurement errors and trends when hydrogen content varies with NG and RNG. The results of these two tasks were communicated via a final report to project sponsors. One of the commercial flow meters accurately reported the measured blended flow rate within 1% relative error to the baseline. The remaining three meters underreported the total gas measurement. Further testing was recommended for Phase 2 to investigate variations in density at low temperatures and pressures and the source of the error in the underreporting meters. Once the data have been converted to therms, this project will inform SoCalGas and other gas utilities on determining an accurate and repeatable way to measure and bill the energy delivered to their customers with varying gas supplies.

Co-Funders: NYSEARCH Members

Start Date: 04/22/2022
End Date: 05/11/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$367,250**
Total SCG Cost: **$32,640**
Total Co-Funding: **$334,610**
Benefits:

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 common TCs within RNG to identify any gaps and will perform preliminary laboratory testing on those gaps. Results will be delivered in a white paper. 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, and impact study, and has begun testing. The testing includes: 1) volume swell testing; 2) visual inspection and dimensions; 3) mass change; 4) Shore D Hardness; and 5) tensile testing. The gap analysis identified TCs that may require test data to improve their justification and may assist SoCalGas in determining whether RNG specifications need modification. The majority of testing was completed in 2023. However, due to procurement issues, testing of consumer gas appliances will not occur until 2024. An interim report for the materials compatibility testing and the recommended TC limits needed to mitigate the risk were released to project sponsors in June 2023. The preliminary results support SoCalGas' existing limits. After the appliance testing, safe TC limits will be re-evaluated. If the project is successful, SoCalGas plans to use the results to either justify or request changes to 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: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$606,810**
Total SCG Cost: **$71,390**
Total Co-Funding: **$535,420**
Benefits:

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

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 project 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 standard publication date. In Phase 2, the project team will complete the ILS and field-test an online siloxane analyzer. Initially, the scope of work only included one field test, but the project team added a second field test in collaboration with Pipeline Research Council International's (PRCI) MEAS-15-04 project. In 2023, the team continued with the ASTM D8230 ILS by confirming siloxane components and concentrations in the ILS gas mixture. The team received an updated analyzer and started testing to validate that the hardware and calibration issues had been resolved. The discussions on the field demonstrations schedules are ongoing, as the project had delays due to equipment and supply chain issues. SoCalGas intends to use the research to determine repeatability and reproducibility levels of the siloxane analysis. Once approved, SoCalGas will use the ASTM standard to validate the trigger level for siloxanes. This research will also help bridge the technology gap to monitor siloxane concentration levels online in real-time at RNG sites.

Co-Funders: OTD Members

Start Date: 05/01/2019
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$253,000**
Total SCG Cost: **$49,608**
Total Co-Funding: **$203,392**
Benefits:

Updating Lost and Unaccounted-For (LUAF) Estimates in the Distribution System (5.23.t)

The objective of this project is to update the factors that contribute to the lost and unaccounted-for (LUAF) gas volume in a natural gas distribution system and apply the factors to a case study with participating utilities based on estimates of fugitive and vented emissions, meter readings and characteristics, and other contributing factors. The original study on determining LUAF gas volumes was performed by the Pacific Gas & Electric Company and SoCalGas in the early 1990's (GRI reports 90/0067 and 93/0115). Estimating the contribution of gas leaks supports emissions reporting and more efficiently directs resources to address causes. More accurate estimates of LUAF gas result in better inventory planning, which saves the supply costs. The project outcome will provide a clearer understanding of the current causes of annual gas volume variabilities and help reduce LUAF gas volumes. The project team will provide a final report that includes: 1) the description of the case study process, data collected, and general findings; and 2) quantification of the effects of different sources (i.e., measurement, leakage, accounting, and theft) of LUAF gas and identification of areas of concern or improvement. If the final report precisely identifies the current contribution of the accounting and theft components of LUAF and identifies ways to reduce their contributions to LUAF in the future, then SoCalGas would implement the identified areas of improvement to reduce the area's contribution to LUAF.

Co-Funders: OTD Members

Start Date: 12/01/2023
End Date: 08/31/2025
Status: Active
2023 Funds Expended: **$55,884**
Total Project Cost: **$230,000**
Total SCG Cost: **$55,884**
Total Co-Funding: **$174,116**
Benefits:

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

SUB-PROGRAM: SYSTEM INSPECTION & MONITORING

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 the Pipeline Research Council International to develop a Multi-String Well Integrity Platform that provides a circumferential measurement of corrosion and isolation of external casing strings. The deliverable will be an advanced technology sensor capable of acquiring data in a single run without pulling out the production string. In 2022, the engineering review, design, and assessment of through-tubing technology was completed. In 2023, the project team developed the preliminary framework for reliability-based casing integrity assessment. Tool performance evaluation for several logging tests is ongoing. Prior to the test well setup, casing modules were assembled into individual casing joints by following a predetermined order of the metal-loss features for the third round of tests. The development of this technological advancement will save Underground Gas Storage 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 2024. 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: 03/14/2025
Status: Active
2023 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)

The objective of this project is to understand and advance leak-sensing technologies to detect hydrogen and natural gas blends as utilities move towards decarbonization. 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 hydrogen and hydrogen-natural-gas blends increases. The project team, consisting of GTI Energy and SENSIT Technologies, seeks to perform the following tasks: 1) evaluate leak detection equipment currently used by natural gas pipeline operators; 2) guide new and altered usage protocols; 3) validate the hydrogen blending threshold at which these devices become ineffective; 4) quantitatively map out the impact of varying amounts of hydrogen on the calibration and analytics of currently used leak detection equipment; and 5) develop a proof-of-concept hydrogen detection scheme to remedy technology gaps. In 2023, the project team completed tasks 1, 2, and 3. Upon completion of tasks 4 and 5, the project team will deliver new leak detection sensing schemes, statistical analyses of laboratory and field testing, and a final report. It will also host a closeout 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: 12/31/2025
Status: Active
2023 Funds Expended: **$87,896**
Total Project Cost: **$1,562,946**
Total SCG Cost: **$87,896**
Total Co-Funding: **$1,475,050**
Benefits:

Aerial Methane Monitoring of High-Pressure Distribution System

This project aims to perform a comparative analysis of 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. 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. In 2023, the project team performed an AMM GML survey on six miles of pipeline. Due to resource constraints a survey using current mobile leak survey practices was not performed, so the comparison has been removed from the project scope. The survey results are being analyzed with the final deliverable of a final report expected in early 2024. 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: 1/31/2024
Status: Active
2023 Funds Expended: **$16,369**
Total Project Cost: **$16,369**
Total SCG Cost: **$16,369**
Total Co-Funding: **$0**
Benefits:

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

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

Start Date: 11/30/2018
End Date: 12/11/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$377,683**
Total SCG Cost: **$10,982**
Total Co-Funding: **$366,701**
Benefits:

The objective of this project was 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 benchmarked the performance of an end-to-end automated threat detection system on both conventional patrol aircraft and long-endurance Beyond Visual Line-of-Sight (BVLOS) unmanned aircraft systems (UAS) that are capable of flying along hundreds of miles of pipeline right-of-way (ROW) on a single flight. In 2023, the fourth and final flight campaign was completed, flown over a 78-mile pipeline corridor, on both manned and unmanned aircraft, on the same day and at the same patrol altitudes. Through four separate flight campaigns, the project team developed new methodologies to automatically detect and report on multiple imminent threats including machinery threats, liquid and gas leaks, fire, farming, logging, and flooding. Data from this final flight test campaign were also used to support an application to the Federal Aviation Administration for approval of routine, commercial aerial pipeline patrol operations using the AiRanger (UAS), a medium-altitude, long-range BVLOS. The Final Report was completed and submitted to sponsors in December 2023. The results of this project provided 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. SoCalGas will utilize the study's results to evaluate potential operational cost savings associated with automated pipeline patrol and surveillance technologies.

Co-Funders: PRCI Members

Alternate Crack Sensor (M2016-004 Ph IV)

Start Date: 08/09/2021
End Date: 11/28/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$491,324**
Total SCG Cost: **$70,190**
Total Co-Funding: **$421,134**
Benefits:

The objective of this project was to develop technology to review crack-like flaws, including those from seam welds (SWs), which are the third leading cause of pipeline failure and several recent, high-profile accidents. The goal of Phase 4, the final phase, was to improve the existing sensor probe system by revising the mechanical design, weld detection capability, and 20/26 Explorer Robot integration and operation. In the first three phases—concept, prototype, and improvement—the project team developed a sensor probe system for crack detection in longitudinal SWs in 20" to 26" diameter natural gas pipelines. In Phase 1, the team developed a concept to integrate the crack sensor probe with the Explorer robotic inspection platform. In Phase 2, the team built and successfully tested a prototype sensor to identify cracks in all SWs except for electric resistance welds (ERWs). In Phase 3, the team improved SW sensor ride and data quality, the data analysis tools, and ERW detection. In 2023, the team 1) tested two robot configurations of the 20" sensor (with and without dual SW sensors) in helical travel; 2) successfully optimized the sensor unit with the ability to detect defects at a reduced magnetization level within a smaller body; and 3) determined the design best suited to move to commercialization. The final result was that the 16" to 24" Explorer robot with one probe SW crack detection will be commercialized. SoCalGas RD&D held a webinar on the technology in August 2023 and posted it online for further viewing. These improvements will benefit the SoCalGas in-line inspection program by increasing the tool options available for assessing longitudinal seams.

Co-Funders: NYSEARCH Members

- 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 objective of this project was to develop and populate a database to include burst and fatigue tests from pipes with corrosion, cracking, dents, and interacting defects. Burst and fatigue tests typically validate improvements in defect assessment or modeling. Sourcing the appropriate pipe samples for testing can be time-consuming, expensive, and challenging. The project developed a uniform format for burst test data collection and supported future defect assessment and modeling efforts. Attributes for corrosion, stress corrosion cracking (SCC), and dents were examined as metadata and burst test data. In 2023, the project team created data management procedures for burst test data and uploaded them into the database. The project completed data gathering, data entry, and personnel training, as well as burst test database demonstration with sponsors. This project provides consistent and relevant data for future Pipeline Research Council International research in defect assessment and crack growth modeling. The project resulted in a database of burst and fatigue tests—with open access to members—that provides sponsors, including SoCalGas, cost savings on future research projects.

Co-Funders: PRCI Members

Start Date: 11/19/2021
End Date: 09/13/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$147,500**
Total SCG Cost: **$8,780**
Total Co-Funding: **$138,720**
Benefits:

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

The objective of this project was to develop guidelines and procedures that utilities can use to implement the three levels of validation for the qualification and validation of tools for In-Line Inspection (ILI) systems in standard API 1163. This standard covers the selection, reporting, verification, and three levels of validation associated with ILI systems. It also outlines the complexity and cost increase associated with each level of validation. The project's emphasis was to develop guidelines and statistical methods for Level 1, 2, and 3 analyses and software for performing the statistical analyses. The project team completed the guidelines for API 1163 and a spreadsheet tool for performing statistical analysis outlined in API 1163. Both were published in a report available to the public. The project team also held a webinar to introduce the tool and the statistical methods to project sponsors. An API 1163 committee has been formed to review the findings and determine whether to revise API 1163 by incorporating the results. The guidelines and the tool could aid utilities in implementing the requirements of API 1163 to optimize integrity management resources and reduce risk. Ratepayers could also benefit from safer and more cost-effective pipeline operations. SoCalGas has reviewed the recommendations from the project's final report and is developing a plan for comparative testing of the new tool using existing methods. Once this testing is completed, implementation into SoCalGas' Transmission Integrity Management Program will be evaluated.

Co-Funders: PRCI Members

Start Date: 03/25/2022
End Date: 03/25/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$154,108**
Total SCG Cost: **$6,313**
Total Co-Funding: **$147,795**
Benefits:

Downhole Inspection Tool Performance Evaluation

The objective of this project is to enhance the understanding of established and new downhole inspection tools used to assess the integrity of gas storage wells. Inspection tools are being tested by running them inside fabricated tubing and casing that have known manufactured anomalies and natural corrosion anomalies. Measured inspection results will be compared with known anomaly dimensions to evaluate the tools' performance and accuracy, i.e., "pull testing." In 2022, proof of concept work was completed for a novel high-resolution ultrasonic thickness (UT) inspection tool which was run in several gas storage wells; results were compared to those from established UT and magnetic flux leakage tools. This tool has been added to the list of tools to be pull tested. In preparation for upcoming pull testing, the tubing and casing test strings were fabricated with manufactured anomalies of known dimensions; the test string also included natural corrosion features of known dimension. In 2023, casing, tubing, and through-tubing pull tests were completed for multiple technologies, and the results are currently being analyzed, with the final reports expected in early 2024. Having through-tubing technologies available as an option for well integrity assessment could improve cost-effectiveness, mitigate well entry risk, and support service reliability and affordability for customers. Through this research, SoCalGas will enhance its knowledge of established and new inspection tools' performance and limitations, which will support and enhance gas storage well integrity assessment.

Co-Funders: N/A

Start Date: 1/08/2022
End Date: 5/31/2024
Status: Active
2023 Funds Expended: **$1,495,432**
Total Project Cost: **$2,092,938**
Total SCG Cost: **$2,092,938**
Total Co-Funding: **$0**
Benefits:

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

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

The objective of this project was to develop an automated non-destructive examination (NDE) tool—one that does not require operators with specialized training in NDE—to inspect the integrity of butt-fusion (BF) joints. Pipe fusers can join polyethylene (PE) pipes by melting both ends and forcing the ends together to form a BF joint. The integrity of the BF joint is important for long-term performance. 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 pipe joint interrogation. This project received a portion of the defective BF joint samples developed under NYSEARCH Project M2019-009 and completed scans of standard and defective joints to continue the integration of automated defect recognition. A comprehensive set of samples featuring simulated lack of fusion (aluminum disks), oil/grease contamination, coarse and fine particulate contamination, and cold fusion flaws was scanned and analyzed using an optimized projection-focused, phased-array technique designed for inspection of medium-density-PE and high-density-PE BF joints. The results indicated that all common joint flaws can be robustly detected using the prototype system and that features present in flawed samples can be readily isolated and used to train a machine-learning algorithm to detect these defects. The development of this technology can improve the integrity of BF joints constructed by SoCalGas since any defect in the joint would be identified before placing the pipe into service. SoCalGas will utilize the knowledge gained in this project for possible in-house evaluations when a prototype is available in the future.

Co-Funders: NYSEARCH Members

Start Date: 01/31/2020
End Date: 03/31/2023
Status: Completed
2023 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)

The objective of this project is to perform an initial feasibility evaluation, numerical modeling, system benchtop prototyping, and performance evaluation for Electromagnetic Time Domain Reflectometry (EM-TDR) for inspecting transmission natural gas pipelines. EM-TDR is a mature technique developed to identify and locate faults in metallic cables. Lawrence Berkeley National Lab proposes applying this technique within the natural gas industry. Previously, the project team completed the initial feasibility evaluation and numerical modeling, and the project passed the Go/No Go milestone. In 2023 the team tested the full-scale engineering prototype on both buried and aboveground pipes with known defects. The team is analyzing test results and comparing them to a database of the actual pipes' defects. The results will be used to complete numerical simulations in preparation for a second field trial in early 2024. This study provides information on the ability to obtain more data 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 pipes 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, which further reinforces the safety and reliability of its pipeline network infrastructure.

Co-Funders: NYSEARCH Members

Start Date: 05/01/2021
End Date: 03/29/2024
Status: Active
2023 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 objective of this project was to conduct a feasibility study to identify technologies that generate 3 to 5 watts of power by harvesting energy from available "background" resources (e.g., vibration, flow, temperature differences, etc.). The project evaluated technologies and related devices in areas where utility power is limited or non-existent. This approach would remove the need to replace batteries. In phase I, the team initiated a feasibility study to determine if energy harvested using the available energy 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 evaluated the technologies for practicality and commercial availability. The thermo-electric and in-flow turbine generators equipped with existing natural gas showed promise of energy harvesting in the field. Commercially available units were purchased for field testing and installed at a sponsor's facility. The thermo-electric generator site is currently operating, but the differential pressure generator proved to be non-optimal for this application. SoCalGas reviewed the results and concluded that these technologies require further development in order to provide the continuous, reliable power necessary for unattended, long-term, and complete monitoring of the natural gas distribution infrastructure.

Co-Funders: NYSEARCH Members

Start Date: 12/01/2016
End Date: 7/13/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$293,235**
Total SCG Cost: **$27,931**
Total Co-Funding: **$265,304**
Benefits:

Explorer Automation Demonstration

The objective of this project is to perform a field demonstration of the Explorer in-line inspection (ILI) tool equipped with Inertial Measurement Unit (IMU) technology. The IMU technology was developed in a previous NYSEARCH project, M2017-002 - Explorer Automation, to improve pipe mapping and the collection of x-y-z location data during in-line inspections. When anomaly locations are more accurate, the number of digs in incorrect locations is reduced, which results in cost savings associated with integrity inspections. An additional benefit of capturing this information is that it can be used to analyze ground shifts or strain on the pipeline in areas of potential geohazard risks. The methodology is to select a 30" pipeline, already scheduled for ILI inspection, to demonstrate and validate the ILI tool and its ability to gather data such as GPS coordinates for pipe and feature location, and to evaluate its potential to provide data for pipe and bend strain analysis, thereby expanding integrity management capabilities. The demonstration is scheduled for late 2024. SoCalGas can use this research to add to its list of tools for identifying features for integrity management, which will benefit ratepayers by augmenting operational efficiency, reliability, and improved affordability.

Co-Funders: N/A

Start Date: 12/01/2023
End Date: 12/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$800,000**
Total SCG Cost: **$800,000**
Total Co-Funding: **$0**
Benefits:

Explorer Wireless Range Extender (M2021-006)

The objective of this project was to build upon initial research to take the Explorer Wireless Range Extender through the technology readiness levels to commercialize the existing Explorer In-Line inspection robot with expanded wireless communication range while deployed in the gas pipeline. To date, the project team has completed a feasibility study and developed a prototype that can be field tested in a controlled environment. The feasibility study showed that a significant communication range extension was possible with combinations of wireless technologies and in-pipe antenna deployment via range extender modules. The next step is to carry out field trials of the prototype. The results of this stage of the research will deliver a pre-commercial Wi-Fi range extension system integrated onto Explorer 20/26, a report detailing the tests carried out, analyzed field testing results, and recommendations for next steps. SoCalGas will benefit from this project by using the commercialized prototype to increase the efficiency of its pipeline inspection and reduce overall inspection costs.

Co-Funders: NYSEARCH Members

Start Date: 04/22/2022
End Date: 12/15/2023
Status: Active
2023 Funds Expended: **$59,675**
Total Project Cost: **$542,400**
Total SCG Cost: **$59,675**
Total Co-Funding: **$482,725**
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"-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"-14," 16"-18," and 30"-36" diameter pipe, respectively. The team will analyze the robots' power consumption and tow force under various operational conditions and their ability to generate energy for themselves within different pipe sizes. The team will also investigate the mechanical design of the EH system and its impact on the overall weight of the robots, quantify the power and energy generated for different pipe sizes under different operating conditions, and modify the EH system's electronics, if necessary. It will also 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. This report will include 1) key parameters for an EH system for different pipe sizes of the Explorer fleet; 2) remedies for technical obstacles that EH systems need to overcome to be successfully developed in future phases; and 3) recommendations on next steps. In 2023, the project resumed work and began analysis on the power consumption and tow force of the robots in variously sized pipes and conditions. This project, if successful, will expand the inspection capabilities of the Explorer robotic tools and enable 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: 05/01/2026
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$193,948**
Total SCG Cost: **$19,395**
Total Co-Funding: **$174,553**
Benefits:

Ground Cover Change Detection for Transmission Pipelines (8.23.k)

The objectives of this project are to evaluate existing manual, time-consuming, and costly processes for monitoring pipelines and to automate the processes for identifying threats around transmission pipelines. The project will identify cost-effective modern technologies and methodologies that may enhance the monitoring of critical assets and help identify previously undetected threats. The project team held a kick-off meeting and determined the project would address weather-related outside forces in ground cover detection for potential landslide, erosion, and change detection of pipeline crossing agriculture land. The project team conducted the project scoping and developed the research methodology to focus on short-range (instrument attached to a vehicle) and remote (satellite) detection technologies. The next step is to perform market research of commercially available technologies for ground coverage change detection, object detection, and other similar use cases that might have applications for transmission pipeline monitoring. The project deliverables include: 1) project scoping, 2) market research, 3) lab testing, 4) a field demonstration within SoCalGas territory, and 5) a final report. Identifying processes that simplify and improve these monitoring activities will improve the safety, reliability, and cost-effectiveness of our operations. SoCalGas will use this research to improve processes that could aid in identifying threat areas caused by potential mechanical damage and weather-related outside forces.

Co-Funders: OTD Members

Start Date: 12/1/2023
End Date: 3/31/2025
Status: Active
2023 Funds Expended: **$48,100**
Total Project Cost: **$190,000**
Total SCG Cost: **$53,100**
Total Co-Funding: **$136,900**
Benefits:

Hard Spot Detection (MAT-7-2A)

The objective of this project is to assess various inline inspection (ILI) tools with hard spot detection capabilities to provide guidance on their usage and identify areas of improvement for these tools and analytics. Hard spots are areas on the pipe with hardness levels higher than the surrounding pipe. These spots can be more susceptible to cracking mechanisms such as bending strain and corrosion. ILI tools that can identify hard spots, as well as recognize metallurgical properties, grade determination, and fracture behavior, are important elements to any integrity management program. The project consists of three phases: 1) build a robust framework for hard spot management following a gap analysis of key variables; 2) evaluate commercially available hard spot ILI tools identifying potential areas for improvement; and 3) develop a model using the results of phases 1 and 2 to enhance operator guidance. This research project supports the recommendations of NTSB report NTSP/PIR-22/02 to improve hard spot detection and sizing. SoCalGas anticipates using the results of this project in its integrity management program for guidance on pipeline segments with susceptibility to hard spots and selection of hard spot detection tools.

Co-Funders: PRCI Members

Start Date: 12/1/2023
End Date: 5/31/2025
Status: Active
2023 Funds Expended: **$15,000**
Total Project Cost: **$900,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$885,000**
Benefits:

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

High Resolution MFL for Explorer Series of Robotic Platforms – Feasibility Study (M2021-009)

The objectives of this project are to conduct 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 a) the design selected to validate optimal integration into the magnetic bars and b) 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. In early 2022, the project team began the feasibility study for building and testing a proof-of-concept prototype. In 2023, the project was delayed due to resource constraints. The feasibility study is still in progress with anticipated completion in early 2024. The project 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 benefit the SoCalGas In-line Inspection program because smaller sensors will enable higher spatial and circumferential resolution, as well as detectability of smaller defects with higher resolution. As a result, operators will have higher confidence levels in obtained measurements.

Co-Funders: NYSEARCH Members

Start Date: 11/15/2021
End Date: 8/1/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$215,084**
Total SCG Cost: **$23,900**
Total Co-Funding: **$191,184**
Benefits:

ILI-Based Generic External Corrosion Growth Rate Distribution for Buried Pipelines (EC-01-13)

The objective of this project was to provide the industry with generalized In-Line Inspection- (ILI) based corrosion growth rate distributions and associated causal factors. The growth rate distributions were based on actual data from successive ILI runs provided by Pipeline Research Council International members. The project developed a probabilistic model for estimating external corrosion growth (ECG) rates via successive ILI runs. The team identified four key parameters and associated elements that could be used to establish generic Corrosion Growth Rates (CGRs): 1) pipeline service time; 2) corrosion control system effectiveness; 3) environmental aggressiveness; and 4) ILI results, if available. These parameters were identified in the report, with classifications assigned to each parameter. The project provided a supplemental document, "PR-186-213600-E01 Generic External Corrosion Growth Rate Distributions Parameter Guidelines," as a sample matrix that provides different combinations of results for the elements for each parameter that can be assigned a classification. The report emphasized that these combinations are just guidelines; users can develop their own metrics. The results of this project could be utilized by pipeline operators to establish data-driven and justifiable ECG rates on pipelines in which rates are not able to be calculated from historical and/or ILI run-to-run comparisons. SoCalGas can utilize this research study to increase the accuracy of ECG rate calculations used to determine the remaining life of pipelines and apply them to pipelines that are new to the Transmission Integrity Management Program with only one ILI run or that are difficult to inspect and currently assessed by External Corrosion Direct Assessment.

Co-Funders: PRCI Members

Start Date: 06/23/2021
End Date: 12/15/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$193,662**
Total SCG Cost: **$19,308**
Total Co-Funding: **$174,354**
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 was to understand the probability of detection of internal anomalies in steel pipes using state-of-the-art In-Line Inspection (ILI) tools. It is important to understand the likelihood of identifying abnormalities in 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 safe operation of pipelines; and 3) allow for more efficient utilization of resources. Research outcomes will improve ILI sizing accuracy of cracking, crack-like anomalies, and corrosion anomalies, allowing 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. The results of this project demonstrated that the Magnetic Flux Leakage (MFL) systems captured more leak conditions than the Ultrasonic (UT) system, while the UT system captured more rupture conditions than MFL systems. Not all the problematic profiles identified appeared to be challenging for the ILI technologies evaluated, although most do have some technological limitations. The project process and results effectively demonstrated and supported a current industry integrity assessment approach, where ILI system integrity assessment performance can be improved when a sample of high-quality, detailed-profile reference data was returned to the ILI technology providers, helping them improve their ILI systems. SoCalGas can utilize this research to improve ILI sizing accuracy, which helps more accurately assess targeted excavations to identify potentially immediate repair conditions.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 06/30/2023
Status: Completed
2023 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 was to provide a high-level, concise framework for pipeline operators to utilize in managing geohazards. Currently, no best practices or recommended procedures for geohazard data management exist. The deliverables included detailed recommended practices and guidelines for implementing a geohazard land movement management program. A secondary goal was to support potential rulemaking by the Pipeline and Hazardous Materials Safety Administration related to geohazard management. In March 2023, the project team produced a document titled "Framework for Geohazard Management" for the development of a high-level framework for the management of multiple types of geohazards and associated implications to pipeline structural integrity. A second document was completed in April 2023 that provided recommendations for the management of landslide hazards for operating onshore welded steel pipelines. The recommendations in this document are applicable for onshore transmission pipelines conveying natural gas, hazardous liquids, and carbon dioxide. If implemented appropriately, these practices will reduce the potential of landslides damaging pipelines and causing unintentional releases. The two recommended best practices could aid SoCalGas with its geohazard management framework and landslide threat evaluations.

Co-Funders: JIP Members

Start Date: 07/18/2022
End Date: 09/26/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$562,996**
Total SCG Cost: **$37,996**
Total Co-Funding: **$525,000**
Benefits:

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

The objectives of this project are to develop: 1) a computational pipeline monitoring system (CPM) with 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 to correct zone balances shift from changes in system flow that will be used to identify meters that are most likely contributing to measurement flow errors; and 4) recommended practices for facilities to troubleshoot meters with high error probabilities. The project addressed the following current technology gaps in CPMs: difficulty in retrofitting inline flow measurement systems; challenges with changes in gas pipeline systems inventory or distinguishing measurement errors from leaks; minimal number of balance zones covering large areas; and unavailable, infrequent, or asynchronous data. Addressing these gaps may enhance the leak detection methods associated with CPMs by detecting and locating leaks more accurately and quickly. In 2023, the project team performed a literature review for leak and other lost and unaccounted for (LUAF) gas in Pipeline Systems, developed and tested algorithms and methods on simulated systems, and then validated them on a gas pipeline system. The next step is to prepare the final report, which will include recommendations and best practices that help minimize error and methods to perform ***in situ*** calibration of measurement devices. This research could reduce LUAF gas volumes and negative impacts on safety and the environment. The developed algorithms and methods could be used in SoCalGas measurement accounting systems.

Co-Funders: PHMSA, PRCI Members

Start Date: 9/29/2022
End Date: 9/28/2025
Status: Active
2023 Funds Expended: **$8,544**
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 project's objective was to review existing processes and data associated with "potentially corrosive constituents," as identified in Title 49 of the Code of Federal Regulations (49 C.F.R.) § 192.478, to evaluate whether changes should be implemented to comply with recent amendments to federal regulations. Potentially corrosive constituents include, but are not limited to: carbon dioxide, hydrogen sulfide, sulfur, microbes, and liquid water. In 2023, the project team completed its review of SoCalGas' internal corrosion management procedures. The project deliverables included: a white paper discussing known limits for constituents, a flow diagram of the data being collected, and an analytics calculator with operational documentation to aid SoCalGas in evaluating multiple pipeline segments for risk of internal corrosion. Recommendations and suggestions for next steps were also provided. SoCalGas will use the project results to support the internal corrosion management program.

Co-Funders: N/A

Start Date: 11/17/2022
End Date: 11/30/2023
Status: Completed
2023 Funds Expended: **$88,833**
Total Project Cost: **$88,833**
Total SCG Cost: **$88,833**
Total Co-Funding: **$0**
Benefits:

Low Flow EMAT ILI Tool Demonstration

The objective of this project is to demonstrate the capabilities of the 12-inch and 16-inch free-swimming Electromagnetic Acoustic Transducer (EMAT) tool in a field demonstration by inspecting SoCalGas transmission pipelines. Common In-line-Inspection (ILI) technologies use a Magnetic Flux Leakage (MFL) detection method to measure wall loss on metallic pipelines from internal and external corrosion. In previous research projects, an EMAT sensor and robotic platform were developed capable of identifying small defects in small-diameter, non-piggable pipelines that traditional MFL tools were incapable of in-line inspection (ILI). Building upon this research, the project team developed a free-swimming version of the EMAT tool. Free-swimming tools are propelled by the flow of internal pipeline pressures, which reduces energy usage and extends the range of the tool. SoCalGas Integrity Management department completed a feasibility review of the EMAT tool in 2023 and outlined a plan for its demonstration in 2024. If the demonstration is successful, SoCalGas will have another tool for performing pipeline inspections on non-piggable pipelines, thereby improving its integrity management program.

Co-Funders: N/A

Start Date: 11/26/2021
End Date: 9/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$225,000**
Total SCG Cost: **$225,000**
Total Co-Funding: **$0**
Benefits:

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 enable 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 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. In 2023, the project team completed an assessment report capturing information on the current state of MIC that focused on sample collection methods, bacteria testing, and MIC mitigation at SoCalGas. Two sets of field samples were collected. These samples are being used in the laboratory to develop and optimize test kit assays and the sample preparation protocol for the test kit. The goal is to ensure that sample preparation methods and test kit assays achieve high sensitivity and specificity on a range of sample types obtainable in gas utility facilities. 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 MIC in natural gas systems.

Co-Funders: CEC, Others, SoCalGas

Start Date: 10/25/2022
End Date: 09/30/2026
Status: Active
2023 Funds Expended: **$38,854**
Total Project Cost: **$1,518,920**
Total SCG Cost: **$75,000**
Total Co-Funding: **$1,443,920**
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 Pipeline Research Council International (PRCI) project was 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. Project tasks included 1) field verification of scour and erosion prediction from hydrology hydraulics and fluvial geomorphology; and 2) field validation of Vortex-Induced Vibration (VIV) initiation within waterways to determine pipeline limitations and VIV avoidance criteria. The project provided benefits by allowing 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. A prototype website-based alert dashboard was developed and can be used as a screening tool to plan new waterway crossings. The results of this project could supplement the guidance provided in API RP 1133, Managing Hydrotechnical Hazards for Pipelines Located Onshore or Within Coastal Zone Areas. Overall, the project team delivered nine final reports to PRCI members, all of which are available on the PRCI website. The final closeout webinar was held in April 2023; a recording can be found on PRCI's website. 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: 04/17/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$740,035**
Total SCG Cost: **$24,119**
Total Co-Funding: **$715,916**
Benefits:

NDE Tool for Electrofusion Fittings (M2022-004)

The objective of this project is to develop a non-destructive evaluation (NDE) technique for visual examination of the internals of polyethylene (PE) pipe electrofusion (EF) fittings using a digital x-ray. Inspecting PE EF fitting joints is an important quality control check that helps confirm a proper fusion has been performed, ensuring the joint's long-term performance. Without direct observation of each step in preparing the PE pipe and EF fitting, there is no opportunity to assess a post-fusion EF joint's internal condition, since the material bonding cannot be visually inspected internally. However, NDE methods are available that can observe 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 tests and interpret the results. A method of NDE inspection is desired to enable a non-NDE expert to assess EF joints internally to observe the general configuration and confirm that an acceptable fusion has been performed. In 2023, the team researched an NDE digital x-ray and quality control interpretation method, performed a field procedure with selected utilities involving personnel who are non-experts in NDE, and discussed new methods of detecting contamination in EF fusion joints. As the project continues, the team will complete the standards procedure and image library of defects and develop 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 joints in the group, supporting pipeline safety and integrity.

Co-Funders: NYSEARCH Members

Start Date: 8/30/2022
End Date: 3/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$156,575**
Total SCG Cost: **$16,925**
Total Co-Funding: **$139,650**
Benefits:

NJIT Advanced Terahertz (THz) Imaging & Spectroscopy for Non-Destructive Evaluation of Polyethylene Pipes (M2018-009)

The objectives of this project are to continue the development of terahertz (THz) time-domain spectroscopy and imaging for the non-destructive evaluation (NDE) of polyethylene (PE) gas pipeline butt fusion (BF) joints and to combine the advancements of the instrument with pre-commercial adoption for hardware development and the development of a prototype for demonstration and commercialization. Technology advancements may be useful in assessing the quality of questionable BF joints and may prevent unnecessary cutouts of good BF joints with the appearance of a bad fusion. The project team evaluated the THz capability on BF joint samples with inclusions at the acceptance criteria threshold by performing extensive NDE inspections of specific PE joint defects containing a lack of fusion. The birefringent application to the THz NDE process was advanced with improved inspection procedures and analytical signal processing. The project team improved signal resolution to identify potential defects, including "cold" or lack of fusion within the BF. Based on the findings, using the cross-polarization methodology for detecting stress-induced birefringence, THz photo-elastic measurements were distinguished between 'normal' BF joints and cold-fusion joints. Cold fusion joints exhibited higher internal stress compared to 'normal' BF joints. Sand defects exhibited more structure compared to perfect joints. Artificial Intelligence approaches need to be adapted to automate the decision process. However, THz characterization of plastic disk defect joints will require more research. SoCalGas will utilize the knowledge gained to perform a demonstration and incorporate the THz technology into the existing processes and procedures.

Co-Funders: NYSEARCH Members

Start Date: 07/01/2020
End Date: 03/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$902,581**
Total SCG Cost: **$76,530**
Total Co-Funding: **$826,051**
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)

The objective of this project was to develop and test the expansion of the 20/26 Explorer robot's capability to continuously inspect pipelines without needing to halt for liquid removal. The InvoDane 20/26 Explorer robot currently is capable of inspecting "difficult-to-inspect" pipes while remaining in service. Prior to this research project, inspections could experience delays whenever liquids were found in the pipeline. Before the inspection could continue, the liquids would need to be removed. With regulatory-driven due dates, delays in completing assessments can result in non-compliance. During the project, pre-commercialized, liquid-capable drive tracks and magnet bars were designed and tested for retrofitting onto an Explorer 20/26 robot. The project team manufactured components, conducted liquid-capable testing of modules, and performed final tests to verify the validity of the design. With the successful completion of the submersion, pressure, and overall system-level tests, the modules will advance into the commercialization phase where Intero plans to incorporate these upgrades into future robot builds. These improvements in the Explorer robot fleet could allow SoCalGas to perform inspections with minimal delays if liquids are encountered in the pipeline without compromising data quality or inspection performance.

Co-Funders: NYSEARCH Members

Start Date: 05/06/2021
End Date: 08/15/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$339,000**
Total SCG Cost: **$79,765**
Total Co-Funding: **$259,235**
Benefits:

Plastic Pipeline Inspection for Pipeline Integrity Management (GFO-22-503, Group 2)

The objective of this project is to demonstrate the probability of detection of different categories of anomalies in plastic pipe assemblies when using Phased Array Ultrasonic Testing (PAUT) non-destructive evaluation (NDE) tools for inspecting both plastic pipe and fusion joints. The most common modes of material failure for polyethylene piping systems are slow crack growth and non-ductile fusion joint failure. Current NDE methods for plastic piping are not as well developed as they are for steel piping systems. This project will also identify the correlation of expected residual lifetimes for assets, given the indication of defect, by utilizing the information provided by NDE inspections allowing for input into risk assessment models. The project will focus on extensive testing of a relatively mature PAUT tool capable of identifying cracks in pipe walls and defects in fusion joints. The fieldwork will be supported by extensive laboratory testing aimed at verification of inspection results and accelerated lifetime testing of the pipe assemblies where indications of defects may be identified. SoCalGas will provide pipe samples for this project and serve on the Technical Advisory Panel. If the results are fruitful, SoCalGas will deploy the technology to enhance the safety of plastic pipelines by introducing new NDE inspection tools for both plastic pipe and fusion joints.

Co-Funders: CEC, OTD Members, Others

Start Date: 12/01/2023
End Date: 8/18/2026
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,610,713**
Total SCG Cost: **$15,000**
Total Co-Funding: **$1,595,713**
Benefits:

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 2023, the project team completed the pull/flow loop testing with the ILI tools at Pipeline Research Council International's Technology Development Center. It also completed destructive testing of the test strings. The next step is to analyze data from the ILI vendors. SoCalGas can use the results of this research and identified tools to better detect SSWC in its pipelines, thereby improving safety and reliability.

Co-Funders: PRCI Members

Start Date: 10/06/2020
End Date: 6/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$810,000**
Total SCG Cost: **$34,713**
Total Co-Funding: **$775,287**
Benefits:

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

Sensing Liquid Accumulation in Mains (5.24.e)

The objective is to identify non-contacting, level-sensing technology that could be used in natural gas systems to detect liquids. Utilities install drips to collect liquids, so customers are not impacted. A low-cost system is needed to alert the utility of liquids levels in near real-time, and this project is the first step toward this goal. The project team will test and verify the identified sensors in the laboratory. The sensor testing results and a reference design for a field system will be provided that could be incorporated into a remote monitoring system in the project's next phase. The project tasks include: 1) identifying commercially available level-sensing/ranging sensors, 2) bench-testing a selection of the sensors, 3) performing an analysis of the data to determine the accuracy and whether the sensor is a viable option for this use case, and 4) developing a field prototype design for sensor(s) passing testing. SoCalGas is anticipating that the field-deployable sensor system will be demonstrated at its test facility, and, if the test is successful, will be evaluated for possible deployment. The project benefits are expected to be reduced costs and improved reliability of service to ratepayers.

Co-Funders: OTD Members

Start Date: 12/01/2023
End Date: 12/01/2024
Status: Active
2023 Funds Expended: **$20,000**
Total Project Cost: **$100,000**
Total SCG Cost: **$20,000**
Total Co-Funding: **$80,000**
Benefits:

Subsidence Study

The objectives of this project were to perform analytical modeling to estimate levels of relative displacement between a transmission pipeline and five tap locations, and to compare the results to those of earlier studies. Buried natural gas pipelines can be damaged by soil displacement resulting from sudden extreme events, such as floods, landslides, and earthquake fault rupture, as well as by 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 SCG's transmission pipelines at general locations, but recommended further study of tap points identified as having the largest relative axial displacements. This project tasks included 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 analyses used simulation software with typical pipe elements and non-linear springs to represent soil restraint. The current study concluded that the future impact of subsidence on the taps is negligible except for one tap location of concern, which the project team recommended for further study in more detail. The pre-emptive management of the subject tap location has the potential to 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: 05/19/2023
Status: Completed
2023 Funds Expended: **$14,000**
Total Project Cost: **$17,200**
Total SCG Cost: **$17,200**
Total Co-Funding: **$0**
Benefits:

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

This project supports the new Pipeline Research Council International (PRCI) 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 it faces in enhancing the safety and integrity of 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 make progress 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, such as NDE-4-18 Validate ILI Capabilities to Detect and Characterize Mechanical Damage. In addition, a virtual TDC has been created which consolidates data collected during physical testing at the TDC into databases. This approach allows PRCI members streamlined access to the data and summary reports. In 2023, the TDC held an open house to showcase its value and capabilities. This event highlighted how PRCI members advance safety and integrity within the industry through the TDC and introduced stakeholders to advanced technologies and research aimed at enhancing pipeline safety and reliability.

Co-Funders: PRCI Members

Start Date: 01/01/2015
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$7,400**
Total Project Cost: **$3,440,727**
Total SCG Cost: **$42,709**
Total Co-Funding: **$3,398,018**
Benefits:

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

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

The project objective was 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 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, which requires excavation and exposure. An ILI tool option that characterizes mechanical properties—including fracture behavior and metallurgical properties—can support confirmation of maximum allowable operating pressure (MAOP), support operators with a better evaluation of their systems for potential transportation of hydrogen-blended gas, and potentially support utilization of pipelines for hydrogen transportation. The project team reviewed one robotic hardness and five ILI testing technologies to understand the capabilities for material property determination. This review identified tools purported to be able to determine material properties such as yield strength and tensile strength, fulfilling regulatory requirements for grade determination. The next step in the process is to develop a project to test the identified tools, validating how well they determine the material properties of the inspected pipe segments. SoCalGas benefits from this project by identifying tools that have the potential to obtain information about pipe material properties essential for MAOP verification and understanding the properties of the transmission pipeline system. If the tools perform well, they will provide an option to gather information on pipeline materials at a lower cost by removing requirements for excavation, supporting SoCalGas in meeting pipeline regulations for the Transmission Integrity Management Program.

Co-Funders: PRCI Members

Start Date: 07/28/2022
End Date: 07/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$59,000**
Total SCG Cost: **$15,265**
Total Co-Funding: **$43,735**
Benefits:

UCLA Monitoring and Risk Assessment for Natural Force Damage to Pipelines (GFO-22-503, Group 1)

The objective of this project is to mature the seismic risk assessment software tools developed under the past CEC-funded project, "Seismic Risk Assessment and Management of Natural Gas Storage and Pipeline Infrastructure in CA (PIR-8-002)," by adding various data obtained from monitoring technology, including satellites, LiDAR, fiber optics, and pipeline sensors. The project will also use ground-motion measurements to predict pipe strain support, which can be used to expand and update the fragility database to combine direct and indirect measurements. The project will update the software platform created in project PIR-18-002 to work in near-real-time data and to provide training to California gas operators and industry partners on how to use the software. SoCalGas will use the results of this project to cover a wider range of ground motion scenarios and perform near real-time risk assessment based on reading field data which can reduce the risk of pipeline failure caused by natural hazards.

Co-Funders: CEC, Others

Start Date: 12/01/2023
End Date: 10/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$3,964,749**
Total SCG Cost: **$15,000**
Total Co-Funding: **$3,949,749**
Benefits:

Underground Natural Gas Storage and Risk of Corrosion/Souring (7.22.i)

The objective of this project is to better understand the risk and opportunities of microbial-hydrogen interactions in a storage reservoir. The project will focus on pure and natural-gas-blended hydrogen storage in the three commonly used storage types, aquifers, depleted hydrocarbon reservoirs, and salt caverns. The work will include 1) laboratory experiments simulating reservoir conditions using high-pressure bioreactor systems to collect data on changes in gas composition and microbial activities and 2) chemical and microbial analysis of the data. The deliverable will be a final report. In 2023, the project team held a kick-off meeting to identify field test sites and the associated reservoir parameters, temperature and pressure range. SoCalGas will provide field samples from at least two SoCalGas storge fields. The next step is to collect the field samples. The project team intends to use clean, renewable hydrogen for the laboratory tests. SoCalGas anticipates using the results of this research to identify solutions to manage integrity risks. SoCalGas will also use this research to gather information regarding the potential loss/conversion of hydrogen in a storage reservoir.

Co-Funders: OTD Members

Start Date: 12/01/2023
End Date: 7/31/2025
Status: Active
2023 Funds Expended: **$31,724**
Total Project Cost: **$460,232**
Total SCG Cost: **$50,224**
Total Co-Funding: **$410,008**
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)

The objective of this project was to expand 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 generated data to support the Pipeline Research Council International's (PRCI) research and development projects pursuing the development of revised dent response criteria. Additionally, it addressed recommendations issued to Pipeline and Hazardous Materials Safety Administration by the National Transportation Safety Board to promulgate new regulations that address dent acceptance criteria. Vendors performed trial runs with their tools through mechanical damage test strings built at PRCI's Technology Development Center. Results showed the benefits of a controlled testing program to demonstrate the performance of ILI systems and that the trial protocols and assessment procedures developed in this project should serve as the basis for future testing. In addition, the performance of existing technologies demonstrated they are capable of supporting fitness-for-purpose assessments. The feedback and reference data provided to the participating ILI service providers may support performance enhancements. In addition, the approaches developed and applied in this project may support further development of ILI standards—such as American Petroleum Institutes (API) 1163 and API Recommended Practice 1183—and provide uniformity in feature reporting. SoCalGas can benefit from this research if the project results in revised dent response criteria based on engineering knowledge of the pipe conditions. Furthermore, SoCalGas can 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: Completed
2023 Funds Expended: **$0**
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)

The project objective is to evaluate 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) 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 current use of NDT technologies on PE fusion joints with a survey. The team held a stakeholder workshop to review the capabilities of existing NDE technologies and to develop a roadmap for next steps in evaluating them. Next, the team selected test sample types. Several NDT technology vendors have shown interest in participating in this study. Based on recent communications with vendors and on the method they use, the team determined that it should first develop appropriate acceptance criteria for test samples. In 2023, the team worked on developing butt-fusion processes to consistently generate good and bad joints for the evaluation of the NDT technologies. The team prepared multiple "good" and "bad" joints and subjected them to drop-weight impact, side-bend, burst, and long-term hydrotests. 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 vendor. Additionally, the team will identify potential technology enhancements that would make the NDT technology for PE pipe more reliable, which will benefit SoCalGas by supporting the integrity and reliability of the distribution system.

Co-Funders: OTD Members

Start Date: 10/01/2020
End Date: 04/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$17,054**
Total Co-Funding: **$182,946**
Benefits:

CLEAN TRANSPORTATION

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

SUBPROGRAM: OFF-ROAD

Arthur D Little Turning Ontario Airport into a Hydrogen Ecosystem Assessment

This project examined developing a hydrogen ecosystem at Ontario International Airport (OIA) to support the growth of zero-emission regional and short-range aviation and transportation starting in 2030. The project analyzed the total energy demand and fuel consumption to support zero-emission aviation and transportation, addressed opportunities and challenges for the deployment of electric and hydrogen aircraft and vehicles, and identified associated infrastructure needs to help the growth of zero-emission transportation (electric grid, hydrogen supply, storage, and distributed energy resources). By 2030, airports have the potential to become hydrogen hubs for zero-emission transportation – providing hydrogen to hydrogen-fueled vehicles and reliable and resilient electricity for airport infrastructure and BEV charging. The advent of hydrogen and its large-scale usage poses challenges for airports since it will revolutionize how their infrastructure is designed and operated. Even though hydrogen for long-haul aviation won't be used at a large scale before 2050, all new passenger cars, trucks, drayage/cargo trucks, off-road vehicles, and equipment sold in California will be zero-emission by 2035. Zero-emission electric and hydrogen aircraft will primarily focus on regional and shorter-range aircraft until 2035. Hydrogen can enable the next steps towards more sustainable transportation and aviation before 2035. A technical advisory committee (TAC) was formed to coordinate among industry experts, utilities, city and community leaders, and local, state, and federal agencies. The final report was presented publicly at the 2023 Hydrogen and Fuel Cell Seminar in Long Beach, California. It was also presented during a public webinar hosted by HYSKY.

Co-Funders: N/A

Start Date: 08/31/2021
End Date: 02/10/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$409,500**
Total SCG Cost: **$409,500**
Total Co-Funding: **$0**
Benefits:

CALSTART Hydrogen Zero Emission Tugboat Design

CALSTART has assembled a consortium of leading maritime stakeholders to design a hydrogen fuel-cell-powered zero-emission tugboat and 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. 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. In 2023, the project team produced a feasible design for a 90-bollard-ton tugboat. The vessel was designed to be entirely powered by fuel cells and batteries with hydrogen stored on board in liquid form. The project team also completed the cost-benefit analysis, identified technical and regulatory barriers to using liquid hydrogen for this specific application, and created a knowledge transfer plan. The team shared project details at two industry conferences in 2023 and issued the draft final report to the CEC in Q4. The team will meet with the CEC in Q1 2024 to complete the project.

Co-Funders: CALSTART, CEC

Start Date: 01/01/2021
End Date: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$623,309**
Total SCG Cost: **$100,000**
Total Co-Funding: **$523,309**
Benefits:

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

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 significantly shorter refueling times. GTI Energy worked with DMI throughout the project 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 the H2@Scale project. 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. GTI Energy presented this project at the Hydrogen and Fuel Cell Seminar in February 2023. A short video was also produced and can be found in the list of references in this annual report.

Co-Funders: N/A

Start Date: 09/30/2020
End Date: 01/31/2023
Status: Completed
2023 Funds Expended: **$6,250**
Total Project Cost: **$257,062**
Total SCG Cost: **$257,062**
Total Co-Funding: **$0**
Benefits:

GTI Energy Hydrogen Fuel Cell Switcher Locomotive Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: Ballard, CEC, LCRI, Sierra Northern Railway, SMAQD

Start Date: 01/01/2021
End Date: 12/31/2025
Status: Disallowed
2023 Funds Expended: **$0**
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 goal of this project was to validate the commercial readiness of zero-emissions hydrogen fuel cell electric yard trucks operating in a demanding, real-world cargo-handling application. Yard trucks are the largest source of emissions across all cargo handling equipment classifications. This project aimed 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. The project team, led by GTI Energy, accomplished these goals by successfully developing and deploying two fuel cell yard trucks 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. A temporary refueling station was deployed on-site to ensure reliable refueling of the vehicles and to generate experience for proper evaluation of the impacts of the new technologies on port operations. The researchers credit future generations of hydrogen fuel cell-powered yard truck designs by Capacity largely to the information gathered and lessons learned by the technical project team. The team also gained experience with the hydrogen station permitting process and fueling operations with insight into future technology deployments in off-highway, industrial, and cargo-handling applications. Extensive public outreach was conducted to share the results of this project, including a video, conference presentations, and webinars. The final report was published and is on the list of publications in this annual report.

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

Start Date: 01/01/2019
End Date: 06/05/2023
Status: Completed
2023 Funds Expended: **$10,750**
Total Project Cost: **$12,017,657**
Total SCG Cost: **$372,500**
Total Co-Funding: **$11,645,157**
Benefits:

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

ZEI Harbor Craft Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: CEC, Ocean5 Naval Architects, ZEI

Start Date: 01/01/2021
End Date: 12/31/2025
Status: Disallowed
2023 Funds Expended: **$0**
Total Project Cost: **$3,400,116**
Total SCG Cost: **$198,938**
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 because fuel storage systems are typically the largest individual cost component. Developing these technologies could yield the following benefits: increased volumetric energy density, reduced storage vessel costs, and lower weight, resulting in increased payload and improved fueling efficiency. The project team completed Phase 1 in 2023 and selected which technologies to pursue a more detailed evaluation in 2024.

Co-Funders: N/A

Start Date: 11/28/2022
End Date: 09/30/2024
Status: Active
2023 Funds Expended: **$0**
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 material-based hydrogen storage solutions as alternatives to high-pressure hydrogen gas or liquid storage for Class 7 and 8 heavy-duty fuel cell electric trucks and rail. It aims to lay the groundwork for developing hydrogen storage systems for these applications. Building on past DOE-funded research on materials-based storage for light-duty vehicles, the team focused on metal hydrides for Class 7 and 8 trucks. It assessed nanoporous sorbents and liquid organic hydrogen carriers for rail applications. Metal hydrides emerged as the most promising solution. The team evaluated three rail use cases: yard switchers, long-haul locomotives, and tenders, finding the most potential for metal hydrides in tenders. Metal hydrides store hydrogen at much lower pressures than gaseous storage, reducing the need for heavy and expensive high-pressure tanks. Low-pressure storage also has the potential to minimize compression costs at fueling stations and improve the overall energy efficiency of electric fuel cell vehicles. A specific metal hydride/carbon composite was identified as a candidate for heavy-duty trucks. System modeling showed strong potential to meet or exceed the volumetric and gravimetric capacity of 700 bar gaseous storage, indicating the feasibility of designing a Class 8 truck hydrogen storage system capable of a range of approximately 480 miles. These findings suggest a potential to accelerate hydrogen vehicle adoption if hydrogen storage can be affordably increased without impacting cargo capacity. The project team recommends further material, system testing, and detailed techno-economic analyses to advance this research area. Project results were shared at industry conferences, with final reports to be published in 2024.

Co-Funders: DOE (HyMARC)

Start Date: 11/30/2020
End Date: 02/29/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,875,000**
Total SCG Cost: **$575,000**
Total Co-Funding: **$1,300,000**
Benefits:

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

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), which is 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 2023, fuel gauge displays were installed on eight concrete delivery trucks. The fuel gauges use data from the sensors installed on the vehicle and engine data (distance traveled and fuel mass flow rate). Distance-to-empty is predicted using readings from these sensors combined with operating history data. This distance-to-empty calculation has been validated to be accurate within the upper and lower bounds displayed. A custom end plug incorporating an in-cylinder temperature sensor was also designed. This approach will enable the temperature data to be uploaded through the CAN system without requiring an expensive data acquisition unit.

Co-Funders: UTD Members, DOE

Start Date:	01/01/2021
End Date:	02/29/2024
Status:	Active
2023 Funds Expended:	**$0**
Total Project Cost:	**$1,030,427**
Total SCG Cost:	**$15,400**
Total Co-Funding:	**$1,015,027**
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

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

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

Start Date: 05/20/2021
End Date: 04/30/2025
Status: Disallowed
2023 Funds Expended: **$0**
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

This project aimed 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 provided market projections and described market scenarios for the new truck technology. It also compared fuel cell trucks to equivalent battery-electric vehicles to explore differences in cost, emissions, performance, and operational success between these zero-emission solutions. The MD/HD Hydrogen Refueling and Infrastructure Roadmap recommended strategically locating hydrogen fueling infrastructure and estimating future demand for the medium- and heavy-duty trucking industry. It also analyzed 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. CALSTART published the final report in March 2023.

Co-Funders: N/A

Start Date: 04/30/2020
End Date: 03/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$216,000**
Total SCG Cost: **$216,000**
Total Co-Funding: **$0**
Benefits:

CALSTART CNG Hybrid Class 8 Truck Demonstration

This study was part of a DOE funding opportunity, specifically focused on reducing emissions in and around the Port of Los Angeles and the heavily traveled I-710 corridor. 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. This target was ideal for alternative fuel technologies. The project team 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, 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. The team collected three data streams to evaluate the vehicle's performance, emissions, and user acceptance. The Plug-In Hybrid adequately performed the standard drayage duty cycle, completed the most trips the baseline vehicles could, reached a maximum daily range of 285 miles (compared to 400 miles), and demonstrated increased 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, DOE, Industry Partners

Start Date: 06/16/2015
End Date: 03/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$20,009,820**
Total SCG Cost: **$250,000**
Total Co-Funding: **$20,009,820**
Benefits:

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

CTE Fuel Cell Electric Delivery Van Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

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

Start Date: 01/05/2022
End Date: 12/31/2024
Status: Disallowed
2023 Funds Expended: **$250,000**
Total Project Cost: **$15,138,212**
Total SCG Cost: **$750,000**
Total Co-Funding: **$14,388,212**
Benefits:

Cummins Integrated Fuel Cell Electric Powertrain Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: DOE, Cummins, SCAQMD, Navistar

Start Date: 02/01/2022
End Date: 12/31/2025
Status: Disallowed
2023 Funds Expended: **$0**
Total Project Cost: **$3,764,624**
Total SCG Cost: **$240,000**
Total Co-Funding: **$3,524,624**
Benefits:

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

The goal of this project is 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. The project team issued a draft final report to the CEC, expected to be accepted and published in 2024.

Co-Funders: CEC, US Hybrid, CWI, SCAQMD

Start Date: 11/01/2019
End Date: 3/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,765,438**
Total SCG Cost: **$161,250**
Total Co-Funding: **$1,604,188**
Benefits:

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

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

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

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

Start Date: 11/01/2022
End Date: 12/31/2024
Status: Disallowed
2023 Funds Expended: **$200,000**
Total Project Cost: **$5,148,158**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,648,158**
Benefits:

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 has managed and analyzed digital and paper records from fleets and telemetry data from prior SCAQMD-funded studies. They have also built a model to account for vocational and duty cycle inputs to provide vehicle recommendations. The team is in the process of completing the analysis and will provide a final report in 2024.

Co-Funders: DOE, SCAQMD

Start Date: 01/01/2020
End Date: 06/30/2024
Status: Active
2023 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

This study aimed 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 the 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 final report was approved by SCAQMD in 2023.

Co-Funders: SCAQMD, Agility Fuel Systems, Landi Renzo

Start Date: 11/30/2019
End Date: 12/15/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$3,021,247**
Total SCG Cost: **$320,413**
Total Co-Funding: **$2,700,834**
Benefits:

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

SCAQMD Heavy Duty Truck Engine In-Use Emission Study

This project aimed to collect robust and empirical information that could better characterize and help understand heavy-duty vehicles' real-world vehicle activity data and emissions profiles (HDVs) and further understand causes for higher-than-design emissions, especially NOx. Working separately and jointly, the University of California, Riverside, and West Virginia University research teams collected and analyzed test data from over 200 in-use HDVs. The monitored vehicles included various engine types across various HDV applications commonly found in Southern California. The data analysis helped assess the emissions reduction efficacy of HDV technologies (engines, drivetrains, fuels, and after-treatment systems) under commonly encountered driving and operational conditions in the South Coast Air Basin. The project results will help inform emission reduction pathways for in-use HDV fleets and recommend new non-zero-emission HDVs. Additionally, the vehicle emission measurements collected can provide important new data to improve air quality planning. Specifically, results and data from both test teams will inform the development of reliable, accurate emissions inventories derived from real-world studies. This aspect is critical to the world-leading efforts in California and the South Coast Air Basin to systematically improve ambient air quality and achieve various other state and local environmental goals. A report was published and is listed in the reports section of this annual report.

Co-Funders: CEC, CARB, SCAQMD

Start Date: 11/01/2015
End Date: 07/15/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$3,285,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$2,785,000**
Benefits:

SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study

This research aims 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 assesses 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 reduce 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 impacts of H-CNG blends on emissions compared to the baseline on regulated engine test duty cycles. CWI provided the test engine, after-treatment systems, engineering, 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 2023, the UCR team sourced all of the gas storage and blending equipment and the hydrogen and CNG. They completed the installation of all diagnostic sensors on the test engine and began running preliminary steady-state baseline testing.

Co-Funders: SCAQMD

Start Date: 11/21/2019
End Date: 09/30/2024
Status: Active
2023 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 2023, the UCR team sourced all of the gas storage and blending equipment and the hydrogen and CNG. They completed the installation of all diagnostic sensors on the test engine and began running preliminary steady-state baseline testing.

Co-Funders: PG&E

Start Date: 03/06/2020
End Date: 09/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$489,977**
Total SCG Cost: **$364,977**
Total Co-Funding: **$125,000**
Benefits:

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

US Hybrid CNG Plug-In Hybrid Electric Truck Demonstration

The objective of this project is to develop and demonstrate an advanced Plug-In Hybrid Electric Truck (PHET) powertrain with an existing Cummins Westport Inc (CWI) L9N Near-Zero Emission (NZE) Compressed Natural Gas (CNG) engine on a Freightliner Cascadia sleeper-cab truck in a parallel hybrid configuration. The truck was optimized for over 1,000 miles of total range—including 35 miles of all-electric range—along with more than 600 horsepower to accommodate trucks that require more torque and power. The electric motor, coupled with the L9N CNG engine, will exceed the performance of existing 13-liter diesel engines while reducing carbon dioxide and NOx emissions and additional benefits if run on renewable natural gas. The team will use the truck as a demonstrator for fleets and events. The team will also 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 being demonstrated in real-world conditions and has received positive reviews from the host fleet operator. The team will publish a final report at the end of the demonstration period 2024.

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

Start Date:	03/31/2020
End Date:	07/31/2024
Status:	Active
2023 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 will 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 responsible for safely fueling any hydrogen-fuel-cell vehicle. Commercial hydrogen refueling stations use the SAE J2601 Lookup Table (LT) method with limited temperature and pressure boundaries to safely refuel vehicles. 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. To date, the team, led by the National Renewable Energy Laboratory (NREL), has 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 whether the actual station's dispenser pressure data is accurately controlled with the MC Formula logic. In 2023, the team finalized the fueling protocol and validated performance with a hydrogen storage tank and an HD dispenser. The team conducted tank testing in Germany and dispenser testing at NREL.

Co-Funders: DOE, Frontier Energy/CAFCP, SCAQMD, Shell, Sunline Transit, Luxfer

Start Date: 01/01/2021
End Date: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$705,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$625,000**
Benefits:

GTI Energy CNG Smart Station Demonstration

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

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

Start Date: 01/31/2019
End Date: 05/31/2024
Status: Disallowed
2023 Funds Expended: **$0**
Total Project Cost: **$3,037,049**
Total SCG Cost: **$268,754**
Total Co-Funding: **$2,768,295**
Benefits:

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

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: DOE, UTD, GTI Energy

Start Date: 12/19/2022
End Date: 12/31/2024
Status: Disallowed
2023 Funds Expended: **$0**
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 to better understand the potential of integrating hydrogen with multiple platforms throughout the economy. First, the project will include the demonstration of numerous hydrogen generation and end-use applications co-located at the University of Texas, Austin. Demonstrated technologies include 100% renewable hydrogen generation (electrolysis and steam methane reformation of RNG), a 100kW fuel cell powering a data center, and hydrogen dispensers for fuel cell electric vehicles 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 majority of equipment was delivered and installed at UT Austin in 2023. The project team began commissioning and testing the installed systems. The team will collect system data once the remaining equipment is installed in Q1 2024.

Co-Funders: DOE, Industry Partners

Start Date: 11/01/2019
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
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

This project aimed to develop a computational fluid dynamics model of a cryo-adsorbed hydrogen boil-off management system and initial demonstration design. Immaterial, a research, experimental development, and engineering firm built at the University of Cambridge (UK) has a unique technology, providing a step-change in the performance of Metal-Organic Framework (MOF) materials. 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. This strategy has 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. Immaterial developed second-generation optimized materials for boil-off conditions and a high-level techno-economic model. Immaterial began testing two MOFs through this project to select the most optimal for boil-off capture. The team also identified long-haul trucks as potential impactful candidates for deploying MOF boil-off capture, either recycling the captured H2 at fueling stations or using the H2 onboard. The team recommends future real-world demonstration testing to confirm the feasibility and effectiveness of the proposed system.

Co-Funders: N/A

Start Date: 01/01/2022
End Date: 10/31/2023
Status: Completed
2023 Funds Expended: **$95,572**
Total Project Cost: **$254,572**
Total SCG Cost: **$254,572**
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 enabling fleets to track a vehicle's fuel consumption more accurately. 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 has also integrated smart components with GTI Energy's CNG station to conduct testing with precooling to achieve full fills of CNG vehicles in advance. In 2023, data loggers were fully installed on CNG vehicles. The team received data and developed automated processing software to organize and analyze its large volumes. The smart dispenser module has been installed in a laboratory test cell and is connecting to the CNG cylinders and transmitting that data to a LabVIEW dispenser.

Co-Funders: UTD Members

Start Date: 09/01/2019
End Date: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$250,000**
Total SCG Cost: **$40,714**
Total Co-Funding: **$209,286**
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 Bloom Energy's new solid oxide electrolyzer cell (SOEC) coupling with an existing Bloom solid oxide fuel cell (SOFC). A 240kW SOEC will utilize grid electricity to generate hydrogen, blend it with natural gas, and supply it 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 2023, Bloom completed constructing and installing the SOEC, mixing system, and critical components. The team successfully commissioned the system in Q4 2023 and is undergoing a 15-month test and evaluation period.

Co-Funders: Bloom Energy

Start Date: 04/19/2021
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,000,000**
Benefits:

EPRI ORC Waste Heat Recovery Demonstration

This project aimed to demonstrate the technical and economic feasibility of a cost-effective Organic Rankine Cycle (ORC) package to recover low-grade waste heat from natural gas industrial processes. The project team 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. While the ORC system was reinstalled at the customer site and commissioned in Q4 2022, the project introduced numerous complexities that were not anticipated nor budgeted for. The team documented the project work in the final report and recommended a future development phase to ensure the ORC can operate continuously. The final report can be found in the publications list of this final report.

Co-Funders: CEC

Start Date: 12/01/2015
End Date: 08/18/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,168,739**
Total SCG Cost: **$172,000**
Total Co-Funding: **$996,739**
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 Q2 2024.

Co-Funders: Kyocera

Start Date: 12/14/2020
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$350,026**
Total SCG Cost: **$350,026**
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. The team has completed the lab setup and installed safety interlocks. One of two fuel cell units has been successfully commissioned and will be tested for one year. The second unit remains in the troubleshooting phase. Upon completion of the testing, GTI Energy will issue a final report to SoCalGas RD&D documenting their findings.

Co-Funders: Kyocera

Start Date: 12/19/2022
End Date: 03/31/2025
Status: Active
2023 Funds Expended: **$50,000**
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 project's first phase, during which 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 is measuring and verifying emissions data. A site for the 4.5kW Marathon system has been selected. The team is undergoing permitting efforts and is scheduled to install and commission the unit by late Q2 2024.

Co-Funders: CEC, Marathon Engine Systems, AO Smith Corporation, EC Power, MES/Axiom

Start Date: 07/01/2018
End Date: 12/01/2024
Status: Active
2023 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 emission-intensive diesel backup generators with fuel cell systems with virtually 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 support other customer functions during non-emergency conditions, including battery electric vehicle charging, peak shaving, and replacement for fossil-based backup power. The project has experienced a delay due to a Stop Work issued by the CEC. The resolution of the order is in progress by the project team, and they expect the project to restart by late Q2 2024.

Co-Funders: CEC, EPRI

Start Date: 12/21/2022
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
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 aimed 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 modified for testing with natural gas. Unlike other SOFC systems, Upstart claims they created 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. This project is considered complete and will be followed by a new project to test the latest model.

Co-Funders: N/A

Start Date: 08/17/2020
End Date: 08/31/2023
Status: Completed
2023 Funds Expended: **$22,355**
Total Project Cost: **$212,355**
Total SCG Cost: **$212,355**
Total Co-Funding: **$0**
Benefits:

Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration

This project aims to demonstrate Mainspring Energy's 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, occasionally dropping below 150 kW. A third party across the building load range achieved and verified low-emission operation. This project and parallel research and development have led to several design improvements 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, which is pending acceptance and publication by the CEC.

Co-Funders: CEC, Mainspring Energy

Start Date: 01/01/2021
End Date: 06/30/2023
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$3,767,791**
Total SCG Cost: **$100,000**
Total Co-Funding: **$3,667,791**
Benefits:

Noble Thermodynamic Systems Ultra-Efficient CHP using a Novel Argon Power Cycle Development

This project aims 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 building the integrated system for testing and is expected to commence testing in June 2024.

Co-Funders: DOE, Private Investors, Noble Thermodynamic Systems

Start Date: 08/14/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$5,615,494**
Total SCG Cost: **$500,000**
Total Co-Funding: **$5,115,494**
Benefits:

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

QSI Nano-Power Generation System Proof of Concept

This project aimed 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 scope included re-designing the reactors to withstand the higher temperatures required for the testing and measuring exhaust composition and output voltage from the EEDs. In 2022, QSI moved its laboratory and dedicated time to securing permits for its new location. The project concluded due to challenges in advancing facility permitting and establishing a proof of concept of the technology. The contract naturally terminated on June 30, 2023, without an extension.

Co-Funders: N/A

Start Date: 09/09/2019
End Date: 12/01/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$50,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$0**
Benefits:

UCI Capstone H2 Blending Research

This project aimed to build upon past research to understand better and address the emissions impact of blending H2 into Capstone microturbines. Prior research indicated that 20% blend levels could be achieved in the C-65 and C-200 models without any observed flashback. However, NOx increases were observed and controllable up to a limit via system settings. Beyond 20% blending has demonstrated the need for additional system modifications to control emissions. The team was able to correlate mixing performance with NOx emissions, showing why NOx levels with 100% H2 testing and H2 injectors may have been elevated compared to NG injectors. The findings suggest minor retrofits can be made on fielded engines via injector modifications to improve mixing. The team has completed the final report and will present the results at the ASME TurboExpo conference in late Q2 2024.

Co-Funders: N/A

Start Date: 12/01/2022
End Date: 03/31/2024
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$100,393**
Total SCG Cost: **$100,393**
Total Co-Funding: **$0**
Benefits:

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

This project investigates the impact of hydrogen-blended natural gas on the performance of selective catalytic reduction (SCR) units for removing 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. The team 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. The team demonstrated that the process was beneficial in terms of increasing NOx conversion when SO2 was present. The project has been extended to explain why NOx conversion increases with water vapor and SO2 present. In 2023, the team ran in-situ characterization experiments to study the SCR reaction mechanism and how it would be influenced using hydrogen-natural gas blends. They have shown that the reaction mechanism changes when increased water vapor is present in the flue gas due to the addition of hydrogen to natural gas. In 2024, the team will continue their characterization experiments to explain the behavior of the catalyst when SO2 is present in the flue gas.

Co-Funders: N/A

Start Date: 10/05/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$75,000**
Total Project Cost: **$300,000**
Total SCG Cost: **$300,000**
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 aimed to evaluate and characterize the performance of the newly launched 200 kW Capstone C200S Signature Series microturbine as a pathway for GTI to scale up its FlexCHP technology. GTI's microturbine FlexCHP technology is an industrial steam/hot water solution that has the potential to enable grid-independent operation with high energy efficiency without the need for costly post-combustion treatment. The research team successfully characterized the 200kW unit at a host site and utilized its microturbine's exhaust composition data findings to simulate exhaust composition. This correlation allows the research team to scale up the FlexCHP technology in a lab setting. The research team believes the 200kW microturbine is now ready for larger demonstrations to evaluate the benefits of integrated CHP at an end-user site. GTI will request additional funding from the U.S. Department of Energy to facilitate the research activities needed to scale the technology up to 1 MW capacity.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 06/29/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$185,000**
Total SCG Cost: **$19,800**
Total Co-Funding: **$165,200**
Benefits:

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

This project evaluated the merits of residential and small-commercial scale fuel cell systems (<50kW), prioritized them based on fitness for the North American market, and conducted 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 systems based on electrical efficiencies, manufacturer reputation, successful field demonstrations, and North American market fit. Based on these prioritizations, GTI Energy identified two systems for evaluation in the lab. The lab evaluation focused on characterizing their power and thermal capacities, efficiencies, and capabilities. The first system demonstrated power output slightly below the manufacturer's spec due to an external transformer required for integration. However, it met emission regulations and load-following requirements. The second system faced technical barriers during evaluation but showed promise with the available data captured during an assessment. The research team recommends advancing these technologies for further product development to enable North American market fit.

Co-Funders: UTD Members, PERC

Start Date: 07/01/2020
End Date: 06/29/2023
Status: Completed
2023 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. Evaluation metrics 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 specifications different from those originally proposed. Neither EnviroPower nor BRASH could provide GTI Energy with prototypes of their mCHP systems despite attempts to procure test units. Additionally, both companies have demonstrated difficulty maintaining solvency. The team has recommended utilities pursue other technology opportunities for small-scale distributed energy.

Co-Funders: UTD Members, BRASH, EnviroPower

Start Date: 07/01/2019
End Date: 06/30/2024
Status: Active
2023 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 Mobile Resilient Gas-fired Power Generation Development (2.23.B)

This project aims to design, engineer, and demonstrate the performance of two or more state-of-the-art 1.4 MW agile mobile power generation (MPG) units at a US Army Energy facility. The specific objectives include designing and building a containerized MPG module using a state-of-the-art reciprocating engine that can be transported by various means such as road, rail, large heavy-lift helicopter, and cargo or military transport plane. The project also aims to enable a seamless connection to existing electric infrastructure to deliver uninterrupted power, enhance power supply resiliency, and provide critical power in emergencies or anytime auxiliary power is needed, thus speeding up response and adding resiliency to facilities. Additionally, the project involves conducting short-term tests and longer-term performance monitoring to evaluate and document effectiveness. The key performance indicators for project success will be to demonstrate that the modules can deliver 1.4 MW of uninterrupted backup power (not including parasitic loads) when tied into the building's electric infrastructure and that the system can operate while meeting the following targets: power generation efficiency ≥36% at full load based on lower heating value and under data sheet conditions, NOx emissions in the range of 1.0 g/hp-hr, and noise at 23 ft ≤85 db. The project will also prepare a case study to assess the technology for federal and private sector facilities.

Co-Funders: UTD Members, DoD, CERL

Start Date:	12/01/2023
End Date:	11/30/2025
Status:	Active
2023 Funds Expended:	**$0**
Total Project Cost:	**9,345,428**
Total SCG Cost:	**$27,801**
Total Co-Funding:	**$9,317,615**
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

Start Date: 10/18/2021
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$493,635**
Total SCG Cost: **$250,000**
Total Co-Funding: **$243,635**
Benefits:

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 project phase 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 the National Renewable Energy Laboratory, 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 resulting in larger waste heat needs. The project team issued a draft final report in December 2023. The project will be closed out in 2024 after finalizing the report.

Co-Funders: CEC

Blue Frontier Fuel Cell Powered HVAC Development

Start Date: 11/01/2019
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$540,527**
Total SCG Cost: **$540,527**
Total Co-Funding: **$0**
Benefits:

This project aims to develop further the Blue Frontier Air Conditioning (BFAC) system 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 the National Renewable Energy Laboratory (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 and tested a prototype system at NREL. The team tested 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 project team issued a draft final report in December 2023 and will be closed out in 2024 after finalizing the report.

Co-Funders: N/A

- 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 the National Renewable Energy Laboratory's (NREL) 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 be stored in the HY2MEGA system and compressed storage. 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 and received delivery of the metal hydride storage tanks. The design and construction of the HY2MEGA storage system and the integrated energy system at NREL are ongoing and are planned for commissioning in Q3 2024.

Co-Funders: DOE, GKN

Start Date: 01/01/2022
End Date: 06/30/2025
Status: Active
2023 Funds Expended: **$150,000**
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 maintaining and regulating voltage and frequency for grid parts 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 the National Renewable Energy Laboratory'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). In 2023, a draft version of the interoperability standards was submitted to SoCalGas, DOE, and IEEE Hydrogen Working Group. In addition, the team has completed building the power hardware-in-the-loop setup that will be used for the interconnection requirements in the final year. The setup can show the transition between grid-forming and grid-following mode in a simplified microgrid model. The team will continue to execute the test plan in 2024.

Co-Funders: DOE, UCI

Start Date: 01/01/2022
End Date: 03/31/2025
Status: Active
2023 Funds Expended: **$175,000**
Total Project Cost: **$1,749,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,249,000**
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 to see if they 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 2023, UCI established communications between the demonstration infrastructure and control equipment. UCI also developed optimal nanogrid operations specifications to benchmark the control equipment performance. UCI will continue to complete the test facility and begin testing in 2024.

Co-Funders: UCI, Technology Partners

Start Date: 10/18/2021
End Date: 06/28/2024
Status: Active
2023 Funds Expended: **$0**
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 Centers Research

Start Date: 10/01/2019
End Date: 12/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$540,000**
Total SCG Cost: **$190,000**
Total Co-Funding: **$350,000**
Benefits:

This project aimed to explore the real-world feasibility of using integrated solid oxide fuel cells (SOFCs) to provide power, cooling, and dehumidification to a data center. The project was conducted in a laboratory at the University of California, Irvine. 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 BlueGEN 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 integrating the SOFC and absorption chiller to minimize annual carbon emissions intensity, levelized utility cost, and maximize the primary energy savings (PES) ratio. The team summarized the project results in a final report in December 2023.

Co-Funders: Microsoft Corporation

UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research

Start Date: 11/22/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$50,000**
Total Project Cost: **$562,442**
Total SCG Cost: **$362,442**
Total Co-Funding: **$200,000**
Benefits:

This project aims to demonstrate that hydrogen-based renewable fuels—with a low-cost and renewable power supply on the electric grid—provide the best techno-economic and long-term solution to meet 100% renewable energy goals and stringent reliability requirements for essential services like data centers and hospitals. University of California, Irvine (UCI) will design and optimize a fully integrated energy system for a data center. The 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 (electric, gas, water). Optimizations and comparisons will be based on technical capabilities, achieved reliability, and cost. In 2023, UCI completed identifying various critical infrastructures and characterizing the dynamics of these critical loads. UCI identified the utility grid networks (electricity and gas) that provide energy to these loads. It continued optimizing system sizing for hydrogen production, transmission and distribution infrastructure, and equipment that could deliver reliable energy. In the next year, the UCI team will design control systems for power generation units coupled with electric and gas markets and grid infrastructures. Testing will include consideration of component degradation. UCI will also perform modeling to formally assess reliability and resiliency at the beginning-of-life and end-of-life stages, comparing long-term resiliency performance with a reference scenario. Finally, the team will accomplish economic, environmental emissions, and societal value analyses for the reliability and resiliency scenarios established.

Co-Funders: Microsoft Corporation

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

UCI Integrated SOFC, Solar, and Storage System in ZNE Residential Nanogrid Design

The goal of this project was to design and analyze a residential "nanogrid" that integrates a solid oxide fuel cell combined heat and power (CHP) system, PV solar, and battery storage to achieve zero net energy (ZNE). The project team 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 project results have shown that the All Electric: PV + Battery scenario results in impractical surface area requirements for PV to achieve ZNE. The research revealed that ZNE could be more easily attained by the Mixed Fuel scenarios, where gas is used for heating. The Mixed Fuel: PV + SOFC + Battery scenario resulted in the least reliance on the electrical grid while meeting ZNE requirements. The project results showed a need to develop control strategies and systems to manage energy production, storage, and export dynamically. Results have also demonstrated that the overall energy cost for a utility customer will decrease over time due to the availability of lower-cost onsite generation options. In 2023, the UCI team augmented the work by developing a novel nanogrid optimization tool. Results bolstered previous work by examining how to optimally select SOFC, battery, and solar PV systems to minimize the cost of achieving ZNE. Results showed that a solution using all three technologies achieves the lowest cost for all climate and building scenarios. Building scenarios included both high-efficiency gas and fully electric residential buildings. The team completed and submitted the final report.

Co-Funders: N/A

Start Date: 10/01/2019
End Date: 11/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$325,000**
Total SCG Cost: **$325,000**
Total Co-Funding: **$0**
Benefits:

UTD Blue Frontier RTU w/ Integrated Fuel Cell System Evaluation (1.23.B)

The project aims to partner with Blue Frontier and a fuel cell OEM to develop a packaged rooftop HVAC system prototype. This system will utilize desiccant latent cooling and indirect evaporative cooling and will be integrated with fuel-fired, fuel-cell-based micro-CHP and thermochemical energy storage. The operation and performance of the prototype unit will be demonstrated and evaluated in GTI's laboratory under varying load conditions. When commercialized, the unit will provide resilient, high-efficiency HVAC for commercial applications, including high-performance buildings. Key Performance Indicators of success include achieving 7.5 tons of cooling capacity on or off-grid using heat and power provided by a 10kW solid oxide fuel cell micro-CHP system, achieving a cooling COP of at least 1.4 when tested per industry standards, characterizing potential energy, cost and greenhouse gas savings along with potential electricity demand reduction, publishing results of the research in a technical paper and presenting the results in at least one industry conference, and deepening support for Blue Frontier and the fuel cell OEM to commercialize the unit. GTI Energy is working with Blue Frontier to engineer an equipment integration strategy.

Co-Funders: UTD Members, Blue Frontier

Start Date: 10/01/2023
End Date: 12/01/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$470,000**
Total SCG Cost: **$449,400**
Total Co-Funding: **$21,000**
Benefits:

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. This approach aims 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. It used 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. Using thermal heat recovery from the micro-CHP system, the ASHP, and supplement from the tankless heater, GTI Energy targets annual coefficients of performance greater than 1.0. This approach can serve heating loads down to 5,000 BTUs per hour. GTI Energy is implementing a test plan to determine the performance of various system configurations: grid parallel, islanded, and integrated with simulated solar PV generation. In 2023, the project team formalized a Project Test Plan with Enginuity; secured an Enginuity E-ONE mCHP system along with automated electric and thermal load banks to perform simulated use testing of E-ONE; and completed modeling of nanogrid systems to understand control options and quantify cost/GHG benefits. The team will install the EONE in a nanogrid testbed and begin simulated use lab evaluations in 2024.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$450,000**
Total SCG Cost: **$95,769**
Total Co-Funding: **$354,231**
Benefits:

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

UTD Integrated CHP System for Multi-Family Buildings (1.20.J)

This project aimed to evaluate a laboratory microgrid design featuring an EC Power/Lochinvar XGRi25micro combined-heat and power (mCHP) unit within a multi-family context, coupled with best-in-class electric heat pumps (EHPs) responding to heating and cooling demand. 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 results demonstrated that integrating the mCHP with an EHP could yield a Coefficient of Performance (COP) exceeding 100%. Additionally, the microgrid exhibited the potential to reduce electric loads by 27%, lowering installation costs by 43% and achieving GHG emission rates equivalent to 25% of the U.S. national grid average. The team completed and submitted the final report and presented results in a technical paper delivered at ASHRAE's 2024 Winter Conference.

Co-Funders: UTD Members

Start Date: 06/01/2020
End Date: 08/30/2023
Status: Completed
2023 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 to show resiliency and efficiency benefits in a microgrid configuration. The system will be designed and evaluated in both grid-connected and islanded configurations. Efforts underway during Phase 2 are to continue to collect performance data for the 2023/2024 heating season, engage modeling tasks to estimate performance across multiple climate zones in the U.S. and develop design guidelines as part of the deliverables, including a report and another conference paper.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 06/28/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$7,480,000**
Total SCG Cost: **$139,249**
Total Co-Funding: **$7,340,751**
Benefits:

CUSTOMER END USE APPLICATIONS

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

SUBPROGRAM: ADVANCED INNOVATION

METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration

Start Date: 08/31/2020
End Date: 04/30/2025
Status: Active
2023 Funds Expended: **$164,259**
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. The METRON-EVA platform captures and processes all types of data from industrial equipment (boilers, chillers, compressed air, dryers, etc.). 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% energy savings (electric and gas combined). 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. During the site analysis, the project team identified several pathways for significant energy savings, including parameter modifications that affected various processes. In 2022, the team worked on the instrumentation, connectivity, and energy optimization of steam generation and incinerator processes. In 2023, the energy optimization resulted in an annual recurring energy savings of $150,000 and a reduction of 1,000 metric tons of carbon dioxide annually. The project is pending completion upon delivery of the final report. The project team submitted several journal publications about the project.

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: 09/29/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$415,000**
Total SCG Cost: **$4,000**
Total Co-Funding: **$411,000**
Benefits:

This project aims to develop a gas-fired liquid desiccant dedicated outdoor air system (LDDOAS) that addresses many 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 water vapor mixing in the air at the tower's exit 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 to build a second packed bed column tower 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 to accelerate market transformation and implementation tools along with action plans to help inform decision-makers related to 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. The team continued dialogues with experts in this project's multifamily new construction market. It sought to create actionable tools for UTD members to better serve multifamily homeowners, architects, and builders. 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. The project is complete. Final Reports summarized the progress achieved in each phase. The team issued the Phase 4 Final Report in March 2023 and provided an informational webinar to UTD members in May 2023. The tools, templates, and information developed in this project offer resources to UTD members to better support multi-family developers and customers in their service territories on an on-going basis.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 03//22/2023
Status: Completed
2023 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

Start Date: 09/01/2021
End Date: 01/31/2024
Status: Active
2023 Funds Expended: **$34,612**
Total Project Cost: **$203,066**
Total SCG Cost: **$173,066**
Total Co-Funding: **$30,000**
Benefits:

The primary objective of the engine test research was to evaluate the impact of hydrogen blends on emissions and performance in a rich-burn engine equipped with a non-selective catalytic reduction catalyst (NSCR). The goal was to explore how different fuel-to-air ratio control processes could mitigate adverse effects. In the SoCalGas service territory, approximately 2,000 engines operate, serving purposes such as water pumping, distributed power generation, and pipeline gas compression. Researchers posit that more sophisticated systems and controls are necessary to accommodate hydrogen blends while complying with air quality regulations. In 2022, the research team successfully set up the hydrogen blending system and conducted engine tests. By 2023, they had produced a draft final report for SoCalGas RD&D and submitted a research paper to the Society of Automotive Engineering's 2023 conference. Blending H2 with natural gas (NG) in a rich-burn engine yielded positive results. During steady operation, greenhouse gas emissions significantly decreased, while post-catalyst levels of nitrogen oxides (NOx) and carbon monoxide (CO) remained relatively stable. However, some operators may face challenges in controlling the λ (lambda) parameter. Fortunately, an engine configuration with an advanced λ control system demonstrated good tolerance to hydrogen. Although unique scenarios involving sudden spikes in hydrogen content might concern certain operators, most will not be overly troubled by abrupt increases in H2 levels. A journal article was published.

Co-Funders: Caterpillar

GTI ENERGY Gas Heat Pump Water Heating and Space Cooling in Restaurants Demonstration

Start Date: 04/17/2017
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,090,294**
Total SCG Cost: **$226,000**
Total Co-Funding: **$864,294**
Benefits:

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). It has an estimated Annual Fuel Utilization Efficiency of >140% in prior laboratory testing and field applications for space heating. 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. 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

GTI ENERGY Model-Based Control Hospital Decarbonization Demonstration

Start Date: 12/01/2020
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$42,000**
Total Project Cost: **$6,768,954**
Total SCG Cost: **$161,250**
Total Co-Funding: **$6,607,704**
Benefits:

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 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, system design, and engineering. They completed system installation and commissioning in 2023.

Co-Funders: CEC, Kaiser & OEM

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

Momentum Gas Heat Pump Demonstration

The project aims to optimally deploy a hotel's state-of-the-art natural gas heat pump technology. This technology can greatly reduce greenhouse gas emissions and air quality impacts to local communities and populations collocated with this facility while demonstrating energy savings of at least 35% in 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. The group received bids for the procurement and install of the GHP components in 2023.

Co-Funders: CEC, SoCalGas Customer Programs

Start Date: 06/30/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$1,201,850**
Total SCG Cost: **$55,000**
Total Co-Funding: **$1,146,850**
Benefits:

UTD Advanced Nozzle Burner for Commercial Water Heaters - Phase 2 (1.18.C.2)

The overall goal of this project was 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 was 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 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 unstable; 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 addressed ignition and stable operation within the water heater. In 2023, the β-prototype burner was 3D-printed, and the team prepared the test setup for ignition and emissions testing of the nozzle.

Co-Funders: UTD Members, ORNL

Start Date: 06/01/2020
End Date: 08/17/2023
Status: Completed
2023 Funds Expended: **$0**
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 and to 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 facility 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 advance the distributed carbon capture market. 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: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$120,000**
Benefits:

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

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 American Society of Heating, Refrigerating and Air-Conditioning Engineers 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 Stone Mountain Technologies, Inc. The initially planned host site pulled out from participating in this field study. The project team has identified a replacement host site for the demonstration and is taking steps for project execution.

Co-Funders: UTD Members, PERC, DOE

Start Date: 07/01/2021
End Date: 06/30/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$886,000**
Total SCG Cost: **$4,707**
Total Co-Funding: **$881,293**
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 integrates 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 incorporating data from the 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: 01/31/2025
Status: Active
2023 Funds Expended: **$0**
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 a prototype 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 achieve a 2.0 coefficient of performance. 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. In 2022, the research team completed the initial design of an integrated burner and evaporator 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. In 2022-2023, the team designed, built, and tested a breadboard prototype with the anticipation of building and testing an alpha prototype in early 2024.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2020
End Date: 05/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$2,080,000**
Total SCG Cost: **$19,125**
Total Co-Funding: **$2,060,875**
Benefits:

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

UTD High-Efficiency Thermo Vacuum Commercial Clothes Dryer - Phase 2 (2.17.C.2)

This project developed and tested a prototype high-efficiency, natural gas-fired thermo-vacuum clothes dryer and demonstrated 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 helping to 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 key components were specified. 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: UTD Member

Start Date: 07/01/2019
End Date: 11/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,975,000**
Total SCG Cost: **$15,225**
Total Co-Funding: **$1,959,775**
Benefits:

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 and 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 for 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. 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. In 2023, the team completed commissioning the test stand for Phases 2 and 3, and as of the beginning of Q3, had initiated tests with hydrogen blends in a hearth and gas furnaces.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 03/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$179,900**
Total SCG Cost: **$18,900**
Total Co-Funding: **$161,000**
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)

Start Date: 07/01/2021
End Date: 3/29/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$4,350**
Total Co-Funding: **$145,650**
Benefits:

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. In 2023, the team completed commissioning the test stand for Phases 2 and 3, and as of the beginning of Q3, had initiated initial tests with hydrogen blends in a hearth and gas furnaces. Results to date for this project were presented at a seminar at ASHRAE's Winter Conference in February 2023.

Co-Funders: UTD Members

UTD Ionic Liquid Absorption Heat Pump for Commercial Water Heating (1.21.I)

Start Date: 12/31/2021
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$225,000**
Total SCG Cost: **$2,400**
Total Co-Funding: **$222,600**
Benefits:

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 refining the product definition, considering codes, standards implications, and control 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 was prepared to apply instrumentation and complete the test rig assembly for testing. Researchers hold frequent design meetings to discuss product-definition challenges and designs for the desorber and condenser, including results from modeling, analysis, and desorber system and component testing.

Co-Funders: UTD Members

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

UTD Low Emission Efficient Burner for Ovens and Dryers (2.20.A)

Start Date: 06/01/2020
End Date: 10/31/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$23,800**
Total Co-Funding: **$176,200**
Benefits:

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, Preheat Inc.

UTD Membrane-Based Ionic Liquid Absorption Heat Pump for Commercial HVAC (1.20.I)

Start Date: 08/01/2020
End Date: 08/21/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,800,000**
Total SCG Cost: **$24,033**
Total Co-Funding: **$1,775,967**
Benefits:

The objective of this project was 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 to lead this technology development effort through project management, technical design and shared laboratory development with GTI Energy. The project team demonstrated 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. The project team built this absorption system upon a compact membrane-based heat and mass exchanger without desiccant entrainment. The compact size facilitates retrofitting existing building infrastructure. The system's regeneration is driven by efficient heating (natural gas, propane, waste heat, solar, etc.). A leading commercial HVAC OEM provided 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

UTD Next Generation Infrared Burner - Phase 3 (2.16.A.3)

Start Date: 06/01/2020
End Date: 02/28/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$9,200**
Total Co-Funding: **$290,800**
Benefits:

This project aims 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 source energy emissions and end users' operating costs. This project aims 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. In 2023, Solaronics and one of its customers are testing a preproduction version of the new burner at a host site in California and have collected preliminary results. Simultaneously, durability testing at an industrial laboratory is in progress for hundreds of hours to further evaluate the material and burner unit's market readiness. The project team is also setting up laboratory tests to fire hydrogen and has ordered instrumentation and controls to support that effort.

Co-Funders: UTD Members, Solaronics

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

UTD Sequestering Non-Condensable Gases for Enhanced GHP Reliability - Phase 2 (1.19.E.2)

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: 6/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$240,000**
Total SCG Cost: **$2,364**
Total Co-Funding: **$237,636**
Benefits:

UTD Thermoelectric Generator for Self-Powered Water Heater - Phase 4 (1.17.B.4)

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 approaches to integrating the thermoelectric generator with a storage-type water heater were analyzed. As this research continues, opportunities will be sought to leverage UTD's funding with potential prime funding from governmental agencies interested in funding research in resilient, high-efficiency water heating. In 2023, the team disassembled a tankless water heater unit with the combustion chamber. Different sections of the water heater were reviewed to understand integration approaches better. The team also identified certain hardware sections and reviewed the integration of the TEG assembly. A design assembly and a solid model of the TEG with the water heater were developed.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$280,000**
Total SCG Cost: **$6,000**
Total Co-Funding: **$274,000**
Benefits:

UTD Triathalon 2030 5-ton Cold Climate Gas Heat Pump (2.19.D)

The objective of this project was to assist in the prototype design of a new 5-ton natural gas engine-driven cold climate heat pump. The project involved developing market and functional design requirements, a detailed design review, and an energy and economic modeling of the proposed design. The first stage of this project was to develop a product design to determine the performance, reliability, serviceability, and cost targets. The Triathlon 2030 design focused on heating and cooling applied to small commercial building load profiles, including office, lodging, restaurants, fitness, health care, box retail, strip malls, light commercial, and education. The major technical design challenge was re-designing and improving engine-heat recovery for cold-climate operation. Researchers developed Energy Plus™ models to compare energy costs and full-fuel-cycle greenhouse gas emissions for the GHP prototype design vs. conventional equipment, considering the current and future power-generation mix and the natural gas supply. Based on published laboratory data, the GHP prototype design has the potential to achieve seasonal efficiencies of 1.6 COPg cooling and 0.9 to 1.2 COPg heating. A draft report on the Triathlon 2030 GHP design and its value proposition for New York State was developed and presented to the NYSERDA project team meeting in July 2021. A more detailed project description can be found in the 2023 UTD Annual Report.

Co-Funders: UTD Members, NYSERDA

Start Date: 07/01/2019
End Date: 9/15/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$994,368**
Total SCG Cost: **$3,487**
Total Co-Funding: **$990,881**
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: 03/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$2,202,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$1,852,000**
Benefits:

The project aims 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 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: 12/31/2024
Status: Active
2023 Funds Expended: **$55,000**
Total Project Cost: **$305,000**
Total SCG Cost: **$305,000**
Total Co-Funding: **$0**
Benefits:

The proposed work aims 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. Afterburner development, phase two will include the development of a commercial prototype and involve a commercialization partner to help with that 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 separately in the literature for various applications. However, a study must be conducted to evaluate fuel blends, resulting in 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. In 2023, the research team evaluated different catalyst substrates while optimizing burner and system prototypes.

Co-Funders: N/A

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

UTD Advanced Controls for Residential Kitchen Ventilation Systems (1.23.M)

This project aims to address indoor air quality (IAQ) issues related to residential cooking by developing better ventilation control systems to improve IAQ, save energy, and reduce carbon footprint. The main tasks of the project are as follows. First, evaluate novel advanced controls for demand-controlled kitchen ventilation systems. Second, energy input for cooking appliances and local IAQ must be monitored. Third, the appliance control panel logic can be developed to adjust the ventilation flow rate and identify issues with the appliance. Fourth, evaluate hood performance during modulation and measure capture efficiency using a shadowgraph system. The key performance indicators to measure the project's success include a 30% improvement in capture effectiveness compared to standard ventilation hoods, a 10% reduction in conditioned air losses compared to standard ventilation hoods, and energy savings through winter and summer heating and cooling loads. The deliverable for this project will be a quick response control system that can automatically modulate the ventilation rate based on the cooking activity and the appliance energy measurement method that can monitor the energy consumption of the cooking appliances.

Co-Funders: UTD Members, PERC

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: $0
Total Project Cost: $200,000
Total SCG Cost: $10,000
Total Co-Funding: $190,000
Benefits:

UTD CFS Burner Technology Carbon Reduction Including Hydrogen Blending (1.21.H)

In this project, the team aimed 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 under another project phase.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 04/07/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$40,000**
Total Co-Funding: **$110,000**
Benefits:

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 producing 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: 03/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$160,000**
Total SCG Cost: **$10,000**
Total Co-Funding: **$150,000**
Benefits:

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

UTD CFS Burner Technology Carbon Reduction Including Hydrogen Blending - Phase 3 (1.21.H.3)

The project aims to determine the potential decarbonization of commercial food service (CFS) appliances when using 100% hydrogen or blends of up to 30% hydrogen in natural gas. Phase 3 will focus on full appliance testing and cooking performance impacts and will build on the testing of standalone burners and controls in Phase 1 and appliances in Phase 2. GTI, through its contacts at NAFEM (North American Foodservice Equipment Manufacturers), will work with CFS manufacturers to identify and supply appliances for testing. 100% hydrogen appliances will come from outside North America. Specific tasks to complete include testing a 100% hydrogen fryer from Falcon and a grill from Heatlie, expanding existing appliance blend tests with a to-be-determined manufacturing partner, and determining if cooking with hydrogen or hydrogen blends causes degradation of cooking utensils. Some key performance indicators to measure the success of Phase 3 will include the results of testing the 100% hydrogen fryer and grill, performance data for up to five CFS appliances from these equipment types with hydrogen and hydrogen-enriched natural gas (measuring efficiency and emissions such as O2, CO2, CO, NOx, and evaluating cooking performance and flame appearance) and communicating findings to CFS manufacturers. The deliverables for this project will be data, calculations, and experimental test results that support the decarbonization of CFS appliances using hydrogen blending. The results will show if hydrogen or hydrogen blending harms combustion performance, cooking performance, and safety.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$28,000**
Total Co-Funding: **$122,000**
Benefits:

UTD CFS Decarbonization Tool Development and Demonstration (1.23.K)

The goal of this project is to demonstrate and promote the value of efficient, clean, burning gas-fired cooking equipment and advanced Commercial Foodservice (CFS) equipment to the CFS industry. The project will modify demonstration tools with Hydrogen-blended gas and source-based energy calculations. The project will measure its success by quantifying the benefits of natural gas (NG) and NG/Hydrogen blends in high-efficiency gas-fired CFS appliances, including calculating carbon footprint improvement and energy savings. The modification of Foodservice Energy Monitoring System (FEMS) Software to show the carbon footprint, source efficiency, and source emissions for electric, natural gas, and NG/hydrogen blended CFS appliances. The tool will then be able to provide a source-based total impact of tested appliances as they are cooked live and provide lifecycle cost savings and payback periods for any location across the country. The installation of FEMS capability at one utility test kitchen and the conduct of a live cooking demo with updated FEMS and NG/H2 to show the large carbon reduction capability of high-efficiency gas-burning CFS equipment. The team will compare the performance, food quality, and quantity of electric appliances. The project will provide the following deliverables: updated FEMS Software with source-based energy use, emissions, and carbon impact and expected lifecycle payback for both NG and NG/H2; installation at one utility test kitchen; and a demonstration of software cooking on high-efficiency CFS appliances with both NG and NG/hydrogen as well as electric appliances.

Co-Founders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$5,357**
Total Co-Funding: **$119,643**
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 restaurants 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. In 2022-23, the team delivered a high-efficiency fryer to a restaurant in Detroit, and the FEMS system was upgraded to be able to print a pdf report of the results of live testing; this report can be instantly printed for end users to take with them and help make informed equipment purchase decisions.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 7/31/2024
Status: Active
2023 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 is to develop a gas-fired prototype of a conveyor-type warewasher (dishwasher). Door-type (low-volume) and conveyor-type (high-volume) warewashers represent 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 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 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 apply the design to additional models or prove its performance and reliability in a field test.

Co-Funders: UTD Members

Start Date: 06/30/2020
End Date: 07/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$175,000**
Total SCG Cost: **$8,529**
Total Co-Funding: **$166,471**
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 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: 06/30/2021
End Date: 07/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$145,000**
Total SCG Cost: **$19,938**
Total Co-Funding: **$125,062**
Benefits:

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 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 in 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, which 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 incorporate a heat exchanger to recover heat from the flue and feed it 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: 06/30/2021
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$215,000**
Total SCG Cost: **$49,111**
Total Co-Funding: **$165,889**
Benefits:

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

UTD Low NOx Ribbon Burner - Phase 3 (2.12.M.3)

This project aimed 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: 06/30/2019
End Date: 05/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$33,000**
Total Co-Funding: **$92,000**
Benefits:

UTD Next Generation Commercial and Residential Range Top Burner (1.23.N)

The project aims to work with commercial and residential range manufacturers to commercialize advanced range burner designs developed during the current UTD project (1.17.H Residential Cooking Indoor Air Quality – Phase 4) for cooking with natural gas and propane. Potential partners include several leading manufacturers. Key performance indicators for success include incorporating the new burner design in prototype commercial and residential ranges, demonstrating a 20% improvement in energy efficiency, and a 75% reduction in NOx emissions. Performance testing will be completed in partnership with one or more leading OEMs.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$13,600**
Total Co-Funding: **$186,400**
Benefits:

UTD Technical Assistance to Advance Gas Foodservice Equipment (1.23.L)

This project aims to provide technical assistance and education to Commercial Food Service (CFS) and Residential Food Service equipment OEMs, end users, and burner manufacturers on the benefits of energy-efficient equipment and potential decarbonized fuels. The project will also support the technical development of advanced food service equipment and systems in partnership with UTD members. The project will cover topics such as CFS COVID recovery, higher efficiency/lower emissions burner solutions, decarbonization options, energy efficiency and emissions, and advanced ventilation systems. The project will measure its success by the number of food equipment manufacturers assisted, meetings attended, technical presentations given, and tools and calculators updated or maintained. The project will target the large and stable commercial and residential food service market, a major source of revenue for utilities and a significant consumer of natural gas. The project will help maintain the advantage of gas over electricity in the face of new decarbonization codes and standards. Since the CFS industry is predicted to be above $800 billion in 2023, with growth significantly ahead of other commercial sectors, optimizing fuel sources will be essential for overall energy efficiency.

Co-Funders: UTD Members, PERC

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$120,000**
Total SCG Cost: **$16,000**
Total Co-Funding: **$104,000**
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 help manufacturers meet SCAQMD CFS low NOx regulations. The project team will also work with CFS manufacturers and end users to provide data and education. Some topics GTI Energy will address and participate in include decarbonization through hydrogen blending, energy efficiency, emissions, and ventilation requirements. In 2023, the team helped inform technical issues by continuing to serve as the chair of the Fuels committee for NAFEM, supplying information and data for developing energy efficiency measures for range tops in California and providing information and expertise on potential NOx emissions rules at the state level.

Co-Funders: UTD Members

Start Date:	08/30/2022
End Date:	08/30/2024
Status:	Active
2023 Funds Expended:	**$0**
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

Darcy Partners Industrial Decarbonization Engagement

SoCalGas and Darcy Partners conducted a strategic analysis of technologies impacting industrial decarbonization and leveraged various data sources to understand the impact of emergent industrial energy transition technologies. They identified three areas of priority: thermal energy storage, distributed hydrogen production, and point-source carbon capture. For each of these, Darcy explored early-stage companies working on these solutions and built out innovator comparisons, identifying the key innovators and how their solutions differ. SoCalGas and Darcy hosted a webinar to share the research findings on November 16, 2023. The final report has been published and can be found in the publications list of this annual report.

Co-Funders: N/A

Start Date: 08/31/2022
End Date: 12/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

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 about system design, baseline testing, and a field test plan to the CEC. By the end of 2021, the project team had made progress toward completing 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. In 2023, after several project setbacks, the CEC and SoCalGas decided to terminate the project. Project decommissioning activities are underway.

Co-Funders: CEC

Start Date: 11/30/2020
End Date: 12/30/2023
Status: Canceled
2023 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 results until the CEC approves.

Co-Funders: CEC, UTD Members

Start Date: 08/31/2020
End Date: 12/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$1,694,999**
Total SCG Cost: **$74,999**
Total Co-Funding: **$1,620,000**
Benefits:

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

GTI Energy Hydrogen Commercial and Industrial Market Characterization End-Use Research

Start Date: 09/01/2022
End Date: 09/01/2026
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$3,807,500**
Total SCG Cost: **$752,500**
Total Co-Funding: **$3,055,000**
Benefits:

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: CEC, PG&E, UTD Members, EPRI, OEM, Industry Alliances

GTI Energy Waste Heat Effective Transfer in Brewery & Distillery Demonstration

Start Date: 11/30/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$48,664**
Total Project Cost: **$1,958,387**
Total SCG Cost: **$177,821**
Total Co-Funding: **$1,780,566**
Benefits:

The objective of this project is to demonstrate a cost-effective, modular, and unintrusive waste heat recovery solution that can be installed in various industrial applications to achieve a 15 to 25% recovery of heat from the brew kettle. This approach would save natural gas and lower 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 of modified tubing that provides excellent heat transfer in minimum space and pressure drop. The tubing surface features disrupt boundary layers, increasing gas mixing, average gas temperature, and higher overall heat transfer rates than its competitors.

Co-Funders: CEC, Tower and Campus Breweries, UTD Members

UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration

Start Date: 02/28/2021
End Date: 02/29/2024
Status: Active
2023 Funds Expended: **$137,500**
Total Project Cost: **$5,699,861**
Total SCG Cost: **$550,000**
Total Co-Funding: **$5,149,861**
Benefits:

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 between academia (University of California, Irvine, and Politecnico di Milano), the 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 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

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

UTD Controlled Mixing Burner for Process Heating (2.23.C)

The project aims to design, build, and test a laboratory prototype version of an innovative 0.5-1 million Btu/hr process heating burner for natural gas and alternate low-carbon fuels (LCFs). This approach will enable adopters of LCFs in process heating applications to use varying amounts of LCFs in their fuel streams, including up to 100% carbon-free fuels (CFFs) such as H2 and NH3. The project aims to demonstrate through laboratory testing that the flame size and shape, heat release profile, emissions, and turndown capability remain unchanged, irrespective of fuel carbon content. The team will test the prototype under different furnace temperatures, % carbon in the fuel, and other simulated operating conditions to assess the applicability of the technology to key end users as they seek to decarbonize operations. Key Performance Indicators for project success include achieving less than 25% change in flame length, NOx emissions, and peak heat release distance for 0 to 100% H2 or NH3 blended in natural gas. The burner should maintain a 4:1 turndown and less than 50 ppm CO with no stability, ignition, or flame-sensing issues. The burner's estimated cost and control complexity should be comparable to conventional burners. The project also aims to obtain an expression of interest from a major burner manufacturer to partner with them on the next stage of development/scale-up and support commercialization planning.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$305,000**
Total SCG Cost: **$8,600**
Total Co-Funding: **$296,400**
Benefits:

UTD Energy Source Options for Industrial Users - Phase 2 (2.20.E.2)

The objective of this project was to provide a robust, user-friendly analytical tool that can help decision-making and drive decarbonization and the 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 aimed to expand and simplify using 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 an industrial energy consumption data database 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. It 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: 06/30/2021
End Date: 04/05/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$165,000**
Total SCG Cost: **$2,581**
Total Co-Funding: **$162,419**
Benefits:

UTD Flex Fuel Gas Nozzle and Burner for Boilers (2.23.D)

The project aims to design and build a 500,000 Btu/h laboratory prototype version of the flex fuel nozzle, retrofit it to an existing commercial burner at GTI, and test its flame flexibility characteristics on natural gas and an analog for alternate low carbon fuels (LCFs) such as renewable energy-derived fuels and hydrogen under simulated boiler conditions. The goal is to demonstrate that wide variations in flame size and shape can be made through on-the-fly positioning of the nozzle components. The team will test the nozzle to assess the applicability of the technology to different boilers and select process heating burners to optimize performance with both natural gas and alternate LCFs. It will also develop designs for a 3-5 million Btu/h nozzle and burner. Key Performance Indicators (KPIs) for project success include confirmation through CFD modeling that flame length and girth can be changed by at least 2:1 by fuel nozzle adjustments, validation of CFD results demonstrating the same flame length and girth can be achieved with 300 – 1000 Btu/SCF fuel with no change in air pressure drop, and maintaining a 4:1 turndown and <50 ppm CO with no stability, ignition, and flame sensing issues. Incorporating the flex nozzle should not significantly increase the design and operation complexity of the burner, and the nozzle and associated adjustment drives should add less than 20% to the cost of the burner and controls. The project also aims to pursue a US patent application and obtain an expression of interest from a major burner manufacturer to partner with them on the next stage of development/scale-up and support commercialization planning.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$350,000**
Total SCG Cost: **$47,400**
Total Co-Funding: **$302,600**
Benefits:

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

UTD Gas Quality Sensor Validation Hydrogen Sensor - Phase 3 (2.14.0.3)

This project will broaden the capability of the gas quality sensor (GQS) 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: 06/30/2021
End Date: 02/28/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$85,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$70,000**
Benefits:

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 up to 40% hydrogen. 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 in coordination with Oak 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 for 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. In 2023, the team completed the assembly of the air-fuel skid for H2 operation. Job Safety Analysis (JSA) and Standard Operating Procedure (SOP) were updated to perform H2 testing and to ensure smooth and safe operation with hydrogen.

Co-Funders: UTD Members, ANL

Start Date: 06/30/2021
End Date: 02/28/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$340,000**
Total SCG Cost: **$84,000**
Total Co-Funding: **$256,000**
Benefits:

UTD Low Emission Efficient Burner for Ovens and Dryers - Phase 3 (2.20.A.3)

The project aims to design, build, and factory-test an innovative 3D-printed, UTD-patented burner at 3 MMBtu/h capacity for air heating applications such as ovens and dryers with natural gas (NG). Phase 3 will focus on installing a commercial prototype in a factory location. The technology has the potential to significantly reduce NOx and CO emissions, reduce blower requirements, and increase efficiency. Key Performance Indicators for Phase 3 success include demonstrating a high efficiency, stable ignition, and combustion characteristics, low NOx and CO emissions, high turndown, and stable, robust operation in crossflow air in service. The overall performance is a critical proof point to convince the manufacturing partner to take the next steps to offer a commercial product. Phase 3 will build on GTI's successful previous efforts in Phase 1 with Preheat to develop the design of a burner capable of operating efficiently and robustly for process air heating applications. Before installation at the factory host site in Phase 3, final burner testing may also be performed on the process air heater testing facility at GTI. Phase 2 is testing the performance of this innovative burner with H2-blended gas. In 2022 and 2023, an improved second prototype burner design was fabricated based on further computational fluid dynamics analysis. When tested on natural gas, it demonstrated operation at up to 6:1 turndown, very low CO emissions of below 10 ppm over the entire range of firing rates, robust ignition and stable flames, and superior NOx performance. The team completed performance testing of both prototype designs with < 9 ppm NOx (corr. to 3% O2) and < 10 ppm CO (corr. to 3% O2) emissions achieved.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$3,400**
Total Co-Funding: **$146,600**
Benefits:

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

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 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, Solaronics

Start Date: 08/30/2022
End Date: 08/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$21,400**
Total Co-Funding: **$158,600**
Benefits:

UTD Ribbon Burner Performance with Hydrogen-Blended Gases (2.22.B)

This project evaluates 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 integrate green hydrogen production, advanced waste heat, and water recovery combined with VOC mitigation and self-powered control.

Co-Funders: UTD Members

Start Date: 08/30/2022
End Date: 08/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$175,000**
Total SCG Cost: **$20,000**
Total Co-Funding: **$155,000**
Benefits:

UTD Small-Scale Natural Gas SMR Technology Optimization with Carbon Capture (2.23.G)

The project aims to perform preliminary design and development to optimize GTI Energy's small-scale steam methane reforming (SMR) technology, which can produce approximately 50 kg/day of hydrogen. The project will prepare a technology development plan for an efficient and affordable carbon capture (CC) technology suitable for subsequent experimental validation. It will also investigate the technical feasibility of identified options for modifying the design and operation of SMR to improve the economics of CC on a small scale. This effort fills a key technology and program gap for low-emissions transportation by evaluating options for carbon capture from small-scale SMR that would be ideal for distributed hydrogen production. Incorporating carbon capture will further reduce the carbon intensity of hydrogen produced on-site. While vehicle electrification has achieved a measure of success in personal light-duty vehicles, electrification of heavy-duty vehicles, such as semi-tractors and heavy-duty off-road vehicles, confronts barriers in onboard energy storage capacity and very large electrical power delivery rates, on the order of 1 MW. Hydrogen generation technology offers an alternative approach. Key Performance Indicators of success include demonstrating 20% energy savings (on a MJ/kg H2 produced basis) via a combination of SMR and carbon capture optimization. The project aims to achieve a minimum capture rate of 90-95% and a CO2 stream purity of 95% vol/vol.

Co-Funders: UTD Members, LCRI

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$140,000**
Total SCG Cost: **$5,200**
Total Co-Funding: **$134,800**
Benefits:

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

UTD Zero Emission Processes with Carbon Recovery - Phase 2 (2.21.C.2)

The project aims to leverage Phase 1 results to develop advanced process layouts, scientific data, mass and energy balances, CO2 capture integration configurations, and cost estimates for synthetic air combustion (SAC) processes. The goal is to prepare for submitting proposals to governmental agencies like DOE or CEC to receive large-scale funding for next-stage, scale-up technology development and demonstration efforts. Key performance indicators for success include additional validation of projections to achieve natural gas savings of 8-15%, CO2 reduction of up to 100% when integrated with carbon capture, elimination of NOx, delivered O2 at a cost lower than the cryogenic route, applicability to a wide range of industrial furnaces and boilers, and identification of the most promising process configurations to integrate carbon capture for leading industry applications. Phase 2 builds upon the recent SAC work completed under earlier UTD-funded research, which focused on limited ambient temperature SAC combustion with oxygen and CO2, and Phase 1 of UTD project 2.21.C, which tested SAC operation with synthetic air composed of oxygen, CO2, and H2O.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$160,000**
Total SCG Cost: **$5,200**
Total Co-Funding: **$100,000**
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. This process technology aims 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 using 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: 06/30/2021
End Date: 03/01/2024
Status: Active
2023 Funds Expended: **$0**
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

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. This work focused on performing 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 demonstrated 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, available for public tours.

Co-Funders: N/A

Start Date: 11/30/2021
End Date: 12/30/2023
Status: Completed
2023 Funds Expended: **$91,650**
Total Project Cost: **$110,250**
Total SCG Cost: **$110,250**
Total Co-Funding: **$0**
Benefits:

GTI Energy Advanced High Efficiency, Low-Capacity HVAC Systems

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

Start Date: 09/30/2017
End Date: 12/30/2023
Status: Completed
2023 Funds Expended: **$0**
Total Project Cost: **$900,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$750,000**
Benefits:

GTI Energy Hydrogen Blend Burner Design Analysis and Guidelines Research

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: N/A

Start Date: 08/31/2021
End Date: 01/31/2025
Status: Disallowed
2023 Funds Expended: **$210,000**
Total Project Cost: **$280,000**
Total SCG Cost: **$280,000**
Total Co-Funding: **$0**
Benefits:

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

GTI Energy Residential Gas Heat Pump Water Heater Field Demonstration

For this project, co-funded by the California Energy Commission (CEC), GTI Energy sought to advance the commercialization of a residential Gas-fired Heat Pump Water Heater (GHPWH) through a five-site field demonstration, extended-life laboratory testing and stakeholder outreach events. During 12 months of field and lab testing, GTI 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 consumption and greenhouse gas emission reductions of roughly 54% and 49%, respectively, compared to conventional water heaters. The team published a CEC final report.

Co-Funders: CEC

Start Date: 04/16/2017
End Date: 12/30/2023
Status: Completed
2023 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 aimed to deploy approximately 60 residential gas heat pump water heaters (GHPWH) to collect qualitative and quantitative data in regions representing diverse climates and housing characteristics. 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: 03/30/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$6,081,602**
Total SCG Cost: **$1,081,602**
Total Co-Funding: **$5,000,000**
Benefits:

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 justly, equitably, and cost-effectively. 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 in the gas system will greatly impact customers and 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 candidate communities' socioeconomic conditions data to evaluate different decommissioning approaches. The team will work directly with Long Beach and Santa Monica stakeholders in a series of workshops to understand natural gas customers' key needs and concerns. It will present specific recommendations for three decommissioning pilot projects and write a set of guidelines and criteria to inform the decommissioning of natural gas infrastructure in other areas. In 2022, the project team developed a set of decommissioning scenarios with their engineering teams and performed detailed engineering analyses to understand the impacts of decommissioning different Santa Monica system portions. In 2023, the project team met to review the project's final results. The project is pending completion upon the publication of the final CEC report.

Co-Funders: CEC

Start Date: 09/30/2021
End Date: 06/01/2024
Status: Completed
2023 Funds Expended: **$118,098**
Total Project Cost: **$1,091,358**
Total SCG Cost: **$125,000**
Total Co-Funding: **$966.358**
Benefits:

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

Lantec Development of Ultra Low NOx Forced Air Residential Furnace

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: SCAQMD

Start Date: 04/30/2019
End Date: 12/31/2024
Status: Disallowed
2023 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 issued a final project report in 2023 with the successful completion of the project. The research team will present their findings at the SoCalGas RD&D Q1 2024 research webinar.

Co-Funders: DOE, Samsung

Start Date: 09/30/2020
End Date: 06/01/2024
Status: Completed
2023 Funds Expended: **$400,000**
Total Project Cost: **$930,000**
Total SCG Cost: **$400,000**
Total Co-Funding: **$530,000**
Benefits:

ORNL Residential Hydrogen Blended Space Heater Development

SoCalGas RD&D participation in this project was discontinued due to CPUC's Res. G-3601.

Co-Funders: N/A

Start Date: 10/31/2021
End Date: 09/30/2024
Status: Disallowed
2023 Funds Expended: **$225,000**
Total Project Cost: **$600,000**
Total SCG Cost: **$600,000**
Total Co-Funding: **$0**
Benefits:

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

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, several burner configurations will be procured and deployed in water heaters for comparison. 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. In 2023, the research team completed its appliance testing suite and anticipates issuing a final report in 2024.

Co-Funders: AO Smith, Alzeta, American Catalytic

Start Date: 08/31/2020
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$55,000**
Total Project Cost: **$435,000**
Total SCG Cost: **$410,000**
Total Co-Funding: **$25,000**
Benefits:

UCI Low NOx Water Heater Retrofit for Hydrogen Blends Development

The project's objective was to take existing low NOx water heaters and improve the operational limits of hydrogen tolerance. The project's goals were to evaluate the modifications that would allow additional hydrogen to be added, to carry out the improvements, and to demonstrate the amount of additional hydrogen that could be blended and allow reliable operation. The team did laboratory testing to evaluate general observations, ignition, flashback, and efficiency. In addition, the team quantified 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. A journal publication was released on 3/3/2023.

Co-Funders: Rheem

Start Date: 09/30/2020
End Date: 05/30/2023
Status: Completed
2023 Funds Expended: **$85,000**
Total Project Cost: **$273,468**
Total SCG Cost: **$241,468**
Total Co-Funding: **$32,000**
Benefits:

UTD Accelerated Life Testing of ResCom Equipment Components with Hydrogen-Blended Gases (1.23.G)

This project aims to evaluate the performance of non-burner components in residential and commercial combustion devices with hydrogen-blended gas. The results will inform gas stakeholders about the potential issues of using hydrogen in gas networks. The key performance indicators of success are a report that lists the compatibility or degradation of each component when exposed to H2, a set of recommended strategies to address any problems identified by the report, and a publication in a peer-reviewed journal or conference proceedings that details the findings and methods of the project, and the compatibility problems that were or were not found. The project will also produce the following deliverables: component compatibility or degradation reports, problem mitigation strategies, and peer-reviewed publications of findings and methods. The primary target markets impacted by this project are standard gas equipment used in appliances, such as valves, regulators, tubing, etc., and residential, commercial, and industrial combustion equipment designed for natural gas.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
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

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. However, this UTD project will address key product development needs to enter the North American market successfully. 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 the reliability and performance of their new units 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.

Co-Funders: UTD Members, OEMs

Start Date: 06/30/2020
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$225,000**
Total SCG Cost: **$26,667**
Total Co-Funding: **$198,333**
Benefits:

UTD CleanO2 CarbinX Carbon Capture - Phase 2 (1.21.C.2)

The objective is to develop and test CleanO2's next-gen commercial carbon capture unit, CarbinX v. 4, focusing on condensing appliances. The aim is to achieve a carbon capture efficiency of ≥50% and a payback period of ≤5 years. Key Performance Indicators include compatibility with natural gas and propane condensing appliances, the effectiveness of the new cartridge design, and optimal waste heat recovery. The results will be published in a technical paper or conference presentation. Phase 2 of UTD 1.21.C will further validate the importance of distributed carbon capture technology within buildings, guiding the technology developer towards a product that can decarbonize a wider range of water heating appliances, including natural gas and propane-fired boilers. The primary markets for CleanO2's carbon capture technology are residential and commercial buildings, including multifamily homes, assisted living facilities, hotels, schools, offices, shopping malls, and commercial boilers with a capacity between 250 and 1,500 MBH. The technology aligns with UTD's goals to save consumers money and reduce GHG emissions. The current version reduces GHG emissions by 20%, with a target of 50% reduction for the next-gen v.4 unit and eventually 100% for future technology. The payback for the carbon capture unit based on average usage is approximately six years. With CleanO2's next-gen v. 4, rebates could potentially be multiple times that of the current technology iteration, significantly reducing the payback period.

Co-Funders: UTD Members, CleanO2

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$220,000**
Total SCG Cost: **$13,600**
Total Co-Funding: **$206,400**
Benefits:

UTD Combustion Technology for Emerging Low Carbon Manufactured Gases (1.23.E)

The objective of this project is to conduct a comprehensive evaluation of equipment that is already designed or being operated with manufactured gases in markets outside North America. The primary focus of this evaluation is on water heating and cooking applications, including performance and reliability tests. The goal is to identify key principles that can be applied to the types of natural gas-certified equipment typically sold in North America. In addition, a safety and technical review of emerging low-carbon manufactured gases used in various applications such as water heating, cooking, and space heating will also be conducted. These manufactured gases can include hydrogen blended with natural gas and emerging methane substitutes or hydrogen carriers such as ammonia, liquid-organic hydrogen carriers, and renewable hydrocarbons like bio-propane and rDME. Several Key Performance Indicators will gauge the success of the project. These include creating a list of appliances using manufactured gas across global markets and identifying the design modifications typically employed in these appliances so they can function with manufactured gases. The project will also involve testing appliances, developing performance data for appliances with hydrogen blended into natural gas, and identifying opportunities for technology and safety transfer to North America. This approach includes six water heaters and six ranges/cooktops. Lastly, a safety and technical review of emerging manufactured gas impacts beyond H2 will be conducted.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$225,000**
Total SCG Cost: **$35,280**
Total Co-Funding: **$189,720**
Benefits:

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

UTD Deep Energy Customized Affordable Retrofit of Building Envelope and Mechanicals - Phase 2 (1.22.E.2)

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$2,025,000**
Total SCG Cost: **$10,286**
Total Co-Funding: **$2,014,714**
Benefits:

The project aims to develop and test innovative mechanical equipment in GTI Energy's laboratory. This equipment will build upon the work under Phase 1, which focuses on developing and demonstrating innovative residential building envelope improvements, particularly deep energy retrofits and related equipment. The project will involve additional modeling and validation of the Hydronic Shell mechanical distribution system, testing Navien's new Hydro-furnace low-load single-family mechanical system retrofit, and assessing its fit with the Hydronic Shell. It will also involve developing an integrated gas-fired HVAC pod concept with space conditioning, ventilation, and potentially battery-electric storage to leverage the end-user benefits of the resilient gas distribution system. The overall goal is to integrate next-generation, high-efficiency, fuel-fired space conditioning equipment to show the continued use of fuel-fired equipment in Net Zero Buildings. Key performance indicators of success include demonstrating that a lab-tested pre-prototype of hydronic retrofit panel can maintain indoor comfort and provide efficient heating distribution for gas heat pumps (GHPs), achieving a +50% GHG reduction in at least two different integrated envelope + HVAC retrofits, submitting a modeling library item to EnergyPlus, assessing the fit of Navien's new Hydro-furnace with Hydronic Shell technology, and creating a conceptual design of a fuel-fired mechanical pod. Phase 2 of this "DECARB-EM" project leverages prime funding by NYSERDA in Phase 1, as well as potential prime financing from the U.S. DOE. UTD project 1.22.E also builds upon long-standing work by UTD under earlier project 1.11.M on residential retrofits through the US Department of Energy's Building America Research Program.

Co-Funders: UTD Members, DOE, Syracuse University, Hydronic Shell Technologies

UTD Emerging Distributed Methane Pyrolysis Technologies - Phase 2 (1.22.P.2)

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$170,000**
Total SCG Cost: **$12,673**
Total Co-Funding: **$157,327**
Benefits:

The objective of the project is to combine application/process with end-user demand modeling to classify a range of emerging distributed methane pyrolysis solutions as good, better, or best. The project team will achieve this through expanded outreach to the primary technology developers in this space, such as Modern Electron, and building on the Phase 1 effort to complete a survey of options for distributed methane pyrolysis technologies. This approach includes a techno-economic assessment (TEA) over various applications, treating the underlying conversion process, hydrogen end uses, and handling carbon outputs. Key performance indicators for Phase 2 project success include refining and executing the distributed methane pyrolysis application and process modeling plan, including scenarios in the Phase 1 TEA. Based on the process and building energy/industrial process modeling results for select applications/technologies, recommendations or follow-up proposals will be provided for UTD to advance specific technologies in good/better/best fits by end-use. The project team will complete a final TEA of distributed methane pyrolysis solutions, including at least five H2 end-use scenarios and five or more carbon output scenarios. Information and data will also be gathered regarding pilots and scale-up efforts of distributed methane pyrolysis technologies running in parallel. Over Phases 1 and 2, the project team will summarize data collected and modeling results to make recommendations to advance the technologies.

Co-Funders: UTD Members

- 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 aimed to scientifically determine the effect of cooking emissions on residential indoor air quality (IAQ) in real-world situations. This project collected field data to differentiate emissions from cooking processes from appliances by comparing direct-vent range hoods versus recirculating hoods. The team prepared a laboratory facility's residential kitchen ventilation test setup 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 cooking 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: 06/30/2020
End Date: 12/28/2023
Status: Completed
2023 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 > 1 for both cooling and heating, and publish results in a 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 regularly met with the National Research Council Canada staff and a leading GEHP OEM to collaborate on GEHP model development and share performance data. For Phase 1, the team is working to refine hourly performance curves for the OEM's GEHP VRF system using four completed field datasets. For Phase 2, the team has continued monitoring the system performance of the GEHP and AHU Integration Kit field site in Middletown, CT, since April 2023.

Co-Funders: UTD Members

Start Date: 08/30/2022
End Date: 08/30/2024
Status: Active
2023 Funds Expended: **$0**
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 was to advance the development of a cost-competitive, fuel-fired Thermal Heat Pump technology from HeatAmp of Sweden. The team optimized a cost-effective alpha prototype "burner/boiler" assembly and designed 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. After 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: 12/30/2021
End Date: 08/24/2023
Status: Completed
2023 Funds Expended: **$0**
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 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: 08/30/2022
End Date: 7/31/2025
Status: Active
2023 Funds Expended: **$0**
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 improved compatibility and performance changes. 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 research and development 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: 07/31/2022
End Date: 03/29/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$10,000**
Total Co-Funding: **$140,000**
Benefits:

UTD Hydrogen Flame Visibility and Colorants (1.23.J)

The project aims to evaluate and identify colorants for hydrogen-enriched gaseous fuel under various conditions. The objectives include establishing a matrix of hydrogen/methane mixtures to test visibility from 0% to 100% hydrogen and enhancing the safety of open-flame operation of hydrogen-enriched natural gas under four common lighting conditions with appropriate and safe gas colorants. Using gaseous colorants can allow the hydrogen/natural gas fuel to mimic natural gas flames, addressing safety concerns from gas end users regarding the appearance of hydrogen-enriched flames. Key Performance Indicators of success include assessing the flame visibility of hydrogen-enriched fuels from 0% up to 100% hydrogen addition and establishing a flame appearance map, conducting hydrogen combustion and visibility tests under at least four lighting conditions, and identifying at least two non-toxic and non-corrosive gaseous flame colorants that can be safely added into the gas transmission and storage infrastructure while enhancing hydrogen flame visibility. The project also aims to publish the results in a peer-reviewed journal or conference proceedings, demonstrate the colorant application with a manufacturing partner to develop the technology further, and evaluate on a conceptual basis how a colorant might be added to a gas distribution network.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$33,334**
Total Co-Funding: **$116,666**
Benefits:

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

UTD Impacts of Hydrogen-Blended Gas on Venting, Condensation, and Weatherized Equipment (1.23.H)

The project aims to assess how blending hydrogen at up to 30% and possibly higher in natural gas may impact the compliance of existing gas appliances with the National Fuel Gas Code, NFPA 54, and other key related global standards, guidelines, and building codes for flue gas venting, condensate management, and weatherized equipment. Key performance indicators for success include laboratory testing of at least three appliances or classes of appliances to identify the leading venting construction and design factors that impact good and bad combustion outcomes and flame characteristics. Factors may include vent diameter, height, length, input rate, and environment. The project also aims to develop vent tables similar to those in section 13 of NFPA 54/ANSI Z223.1 for the range of tested hydrogen blended gases and publish the results in a technical paper or a release of this project's Final Report. This project builds upon key Codes and Standards such as NFPA 54/ANSI Z223.1, the National Fuel Gas Code safety requirements for appliance installation and operation, fuel gas piping and venting systems in homes and other buildings, and applicable ASHRAE Standard requirements, forums, seminars, and research projects.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$25,333**
Total Co-Funding: **$134,800**
Benefits:

UTD Inherently Safe ResCom Combustion Systems for Hydrogen-Blended Gases (1.23.I)

The project aims to ensure customer gas appliances' safe, reliable, and efficient operation with H2-blended gas (5-50% H2 by volume). The project team will achieve this by developing and demonstrating inherently safe combustion systems for common gas appliances such as furnaces, water heaters, and ranges and identifying inexpensive options to retrofit typical existing appliances. This approach will assist gas utilities in demonstrating hydrogen blending levels well above 5% by volume and broadly deploy blended gas in their networks. Key performance indicators of success include practical, economical combustion system designs for new and retrofit applications that can either prevent flashbacks, detect flashbacks, or shut down the burner safely. The project team will demonstrate the technology in at least three common gas appliances in a laboratory setting. The team will publish the results in peer-reviewed journals or conference proceedings and file a provisional patent(s) application. The project also aims to obtain an expression of interest from a manufacturing partner to further develop and demonstrate the technology. This project will build on prior GTI Energy research under earlier UTD-funded research, UTD 1.20.H Phases 1-3, and other industry-funded projects to investigate the limitations of blending hydrogen with natural gas in typical North American appliances.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$175,000**
Total SCG Cost: **$29,474**
Total Co-Funding: **$145,526**
Benefits:

UTD Mitigating Methane Emissions from End Use Equipment - Phase 4 (1.18.F.4)

The project aims to investigate the impact of hydrogen in blends with natural gas on fugitive methane emissions from end-use equipment and to evolve the methodology for quantifying hydrogen slip. The project will identify the root sources of the emissions and assess potential mitigation strategies. Key performance indicators of success include quantified fugitive CH4/H2 emissions from typical residential/commercial appliances such as furnaces and water heaters, tested previously under Phases 1-3 but now have H2 blends up to 30%. The project will also quantify fugitive CH4/H2 emissions from typical industrial/large commercial system burners with H2 blends up to 50%. It will identify sources of emissions within equipment components or operations to aid in identifying and developing mitigation approaches or related best practices. The results, methodology, and emission factors for H2 blends for each system type will be published in a peer-reviewed journal or conference proceedings. This project builds on the work of Phases 1-3 of UTD 1.18.F in quantifying and identifying methane emissions in residential/commercial equipment. Phase 4 adds an analysis of the effect of hydrogen blending. In 2023, furnace steady state testing (top) and part load cycling test (bottom) showed seven part loads ranging from 40 -100% with a one-hour cool-down period between each cycle. Methane spikes can be seen at ignition and extinction of the burner and are sub-atmospheric during combustion, indicating complete combustion of the gas during steady-state operation.

Co-Funders: UTD Members

Start Date: 07/01/2023
End Date: 07/31/2025
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$20,000**
Total Co-Funding: **$180,000**
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 methane analyzers, instrumentation, control programs, and data acquisition issues. The team completed testing of the first furnace (two-stage 80% AFUE) and 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 for Phase 2 has been completed. 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: 07/31/2021
End Date: 12/31/2024
Status: Active
2023 Funds Expended: **$0**
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 was to find a technology to achieve a 5-15% edge over standard efficiency gas dryers. In this project, researchers investigated next-generation gas dryer technologies that 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, allowing 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 consistently showed 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. An external air-to-air heat exchanger was purchased and installed on the dryers to determine the potential boost from heat recovery. Testing the dryer in the environmental chamber demonstrated a 10%- 11% boost to the dryer's efficiency.

Co-Funders: UTD Members

Start Date: 06/30/2018
End Date: 02/27/2023
Status: Completed
2023 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 investigate next-generation gas dryer technologies that 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 consistently showed 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. 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: 06/30/2020
End Date: 07/30/2024
Status: Active
2023 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 Gas Absorption Heat Pump Water Heater - Phase 5 (1.11.H.5)

This project builds upon a gas-fired heat pump water heater (GHPWH) developed and supported in conjunction with UTD Project 1.11.H, scaling up the same absorption heat pump technology by an eight-fold factor. This project aims to aid the development of next-generation GHPWH by eliminating a major cost hurdle for some installations and enhancing the reliability and efficiency of diagnostics. One effort was to reduce the installation cost/barrier of the condensate drain by developing a proprietary method of neutralizing, collecting, and disposing of combustion condensate where access to a sanitary sewer drain is otherwise cost-prohibitive and improving the onboard diagnostics by exploring the use of Enhanced Solution Level Control which can enhance system reliability and long-term performance. Using the experience of 12 demonstrations of Phase 1 to 4 GHPWH pre-commercial prototypes, GTI and SMTI have identified typical conditions and root causes of poor efficiency and product failure. In July 2021, it was announced that UTD member Enbridge had invested CAN $4,000,000 in the late-stage start-up SMTI, the developer of the technology advanced in this and other UTD projects. The project team is finalizing preparations for installing GAHP hybrid equipment in the laboratory and upgrading the thermal heat pump test station. Researchers are analyzing the testing results to recommend system design modifications, sizing considerations, and control updates.

Co-Funders: UTD Members, SMTI

Start Date: 06/30/2019
End Date: 06/30/2024
Status: Active
2023 Funds Expended: **$0**
Total Project Cost: **$170,000**
Total SCG Cost: **$42,491**
Total Co-Funding: **$127,509**
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 to improve the onboard diagnostics, enhancing 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 advanced technology 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 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. For Phase 6, an agreement with SMTI to produce a next-generation alpha prototype GHPWH was completed, with expectations that SMTI will deliver the updated unit in the fourth quarter of 2023.

Co-Funders: UTD Members

Start Date: 06/30/2020
End Date: 08/31/2024
Status: Active
2023 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 evaluated and optimized the performance of low-capacity gas absorption heat pumps (GAHPs). The units of interest in this project were the Robur K18 (60 MBH) and prototype versions of SMTI 40K (40 MBH) GAHPs. The team applied 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 commissioned the K18 in the third quarter of 2022. The team developed 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 help optimize controls, equipment sizing, and design guidelines.

Co-Funders: UTD Members, OEMs

Start Date: 06/30/2020
End Date: 03/23/2023
Status: Completed
2023 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)

This project aims 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 addresses 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:	08/30/2022
End Date:	08/30/2024
Status:	Active
2023 Funds Expended:	**$0**
Total Project Cost:	**$150,000**
Total SCG Cost:	**$10,000**
Total Co-Funding:	**$140,000**
Benefits:	

SoCalGas™