PG&E Gas Research and Development

2023 Annual Report

PG&E

Table of contents

Building a clean and resilient energy system for all 2

PG&E Gas R&D 6

2023 in review 8

Financial Highlights 9

Diversity. Equity. Inclusion. Belonging. 14

Process used to select Gas R&D projects 22

Structure of PG&E's Gas R&D portfolio 27

Operations and Maintenance 28

Reducing Methane Emissions 32

Decarbonizing the Gas System 36

Appendix 39

2023 Policy Drivers 40

Acronyms 42

2022 Summary of ongoing and completed projects 43

Operations and Maintenance 44

Reducing Methane Emissions 76

Decarbonizing the Gas System 86

BUILDING A CLEAN AND RESILIENT ENERGY SYSTEM FOR ALL

In 2022, PG&E articulated its True North Strategy, a 10-year enterprise plan focused on rebuilding trust, delivering excellent service, and architecting a decarbonized, safe, and reliable energy system.[1]

Our True North Strategy reflects a conviction that PG&E has a vital role to play in building a better future and in supporting California's transition to a cleaner and more climate-resilient future.

A critical piece of PG&E's True North Strategy is greening the gas supply and shifting away from fossil-based methane.

Customer Accounts

4.6 million

Natural Gas System

44,000 miles **distribution pipelines**

6,400 miles **transmission pipelines**

PG&E owns and operates one of the nation's largest natural gas systems, comprising 50,000 miles of combined transmission and distribution (T&D) pipeline that serve approximately 4.5 million customer accounts. **Today, methane**—a potent greenhouse gas (GHG)—**represents nearly 95%** of the 895,520 million cubic feet **of annual natural gas throughput** delivered by our system.

[1]pgecorp.com/assets/pgecorp/localized/en/sustainability/corporate-responsibility-sustainability/reports/2022/su05_our_true_north_strategy.html

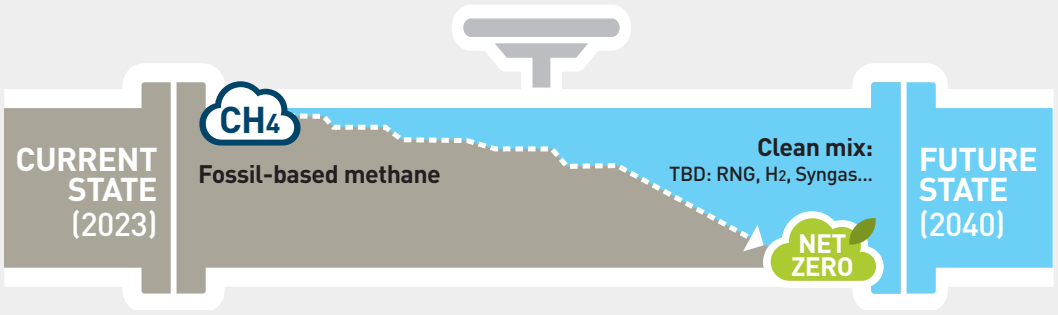


Figure 1: In the ongoing energy transition, PG&E envisions reducing the role of methane in its portfolio and increasing the amounts of clean renewable natural gas, syngas and hydrogen.

In alignment with California environmental policy, PG&E has committed to achieve a net-zero energy system by 2040—five years ahead of California's current carbon neutrality goal. Achieving this ambitious goal will be challenging. We need to adapt to expected reductions in demand for fossil-based natural gas while integrating cleaner fuels—renewable natural gas (RNG), synthesis gas, and "green" hydrogen—into our gas system and continuing to provide our customers with safe, reliable, and affordable service.

PG&E has already made great strides toward this goal.

Between 2021 and 2023, we began accepting RNG from 36 dairies across our service territory. By the end of 2024, we anticipate growing that number to 48. In late 2023, PG&E launched an initiative to purchase California-produced RNG for its natural gas customers, **the first step in a plan to procure RNG to serve 15% of its residential and commercial demand by 2030**.

In June 2022, PG&E submitted its annual emissions data to the California Public Utilities Commission (CPUC). Using 2015 emissions levels as a baseline value, the data demonstrated that PG&E had achieved **more than 24%** emissions reductions for reporting year (RY) 2021 and **32.4%** for RY 2022.

In April 2023—two years ahead of schedule—we formally announced that we had achieved our 2025 target of reducing pipeline emissions by 20%.

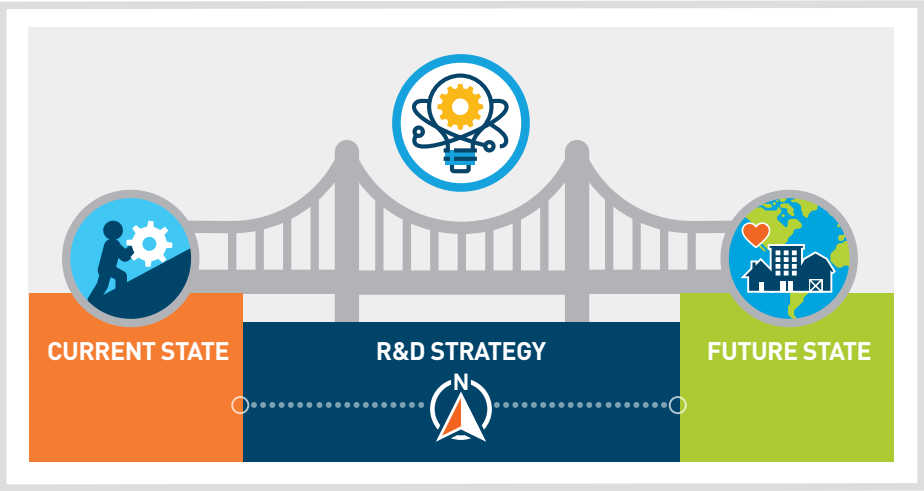
PG&E's Gas Operations and Engineering teams took a comprehensive approach to reducing emissions from the natural gas system, including:[2]

- Enhancing the leak survey program that now assesses more than 42,000 miles of natural gas distribution pipeline every three years versus the previous every-five-years rotation.
- Enacting the PG&E Super Emitter Program, which applies enhanced leak detection technologies and utilizes an accelerated repair schedule for the largest emissions findings.
- Modifying standard natural gas release or "venting" practices used to prepare transmission pipelines for maintenance, repair, or replacement projects.
- Replacing more than 100 pneumatic controllers at compressor stations and natural gas storage facilities.
- Introducing quarterly leak surveys at compressor stations and natural gas storage facilities.

[2]pgecurrents.com/articles/3704-pg-e-reduces-emissions-gas-pipelines-20

PG&E Gas R&D

To bridge the gap between where we are today and the ambitious future that we envision requires research and development (R&D). Our nation's natural gas systems were designed for a world powered centrally by fossil fuels in which supply and demand evolved predictably over time.



Today's utility operating environment is changing rapidly and less predictably, placing increasing strain on systems that were designed for a fundamentally different world.

In response to these challenges, PG&E initiated its Gas R&D team. Composed of energy industry professionals and engineers, **Gas R&D seeks to future-proof the gas system for the migration to green fuels, reduce emissions, and increase the efficiency of pipeline operations and maintenance activities**.

Since 2013, the Gas R&D team has focused on the development and deployment of breakthrough technologies and processes to improve gas system performance as measured in public and worker safety, customer satisfaction, cost effectiveness, environmental impact, regulatory compliance, and communication.

To optimize its efforts, Gas R&D leverages collaborative networks and research consortia such as the Pipeline Research Council International (PRCI), PRCI's Emerging Fuels Institute (EFI), NYSEARCH (a research suborganization with the Northeast Gas Association (NGA)), and GTI Energy and its two research subgroups, Operations Technology Development (OTD) and Utilization Technology Development (UTD). The Gas R&D team also participates in ad-hoc joint industry initiatives (JIP) with other gas utilities or pipeline operators.

Research Areas

In 2023, PG&E Gas R&D invested time, technical resources, and $1,159,675 in 171 projects across three main research areas: Operations and Maintenance (O&M), Reducing Methane Emissions, and Decarbonizing the Gas System.

Operations and Maintenance

We support R&D aimed at maintaining and increasing the safety and reliability of the gas system while reducing O&M costs. As electrification progresses, throughput in the natural gas system is anticipated to decline. At the same time, the costs associated with the safe and reliable maintenance of the system will not see a corresponding reduction. Efficiencies in these processes and advances in technology to reduce the time and manual labor needed to ensure system safety will enable PG&E to cost-effectively manage the gas system.

Relevant Areas of Interest: regulatory compliance, pipeline monitoring, well inspection and analysis, and geohazard risk management.

Reducing Methane Emissions

We support R&D that, if deployed widely, would reduce methane emissions from PG&E's gas system. PG&E has set ambitious goals for decreasing emissions over the next 25 years and has already seen significant progress, achieving its 2025 targets for reducing pipeline emissions in 2023. To continue building momentum, our team supports the development of novel technologies and processes that can advance our work further, faster, and more economically.

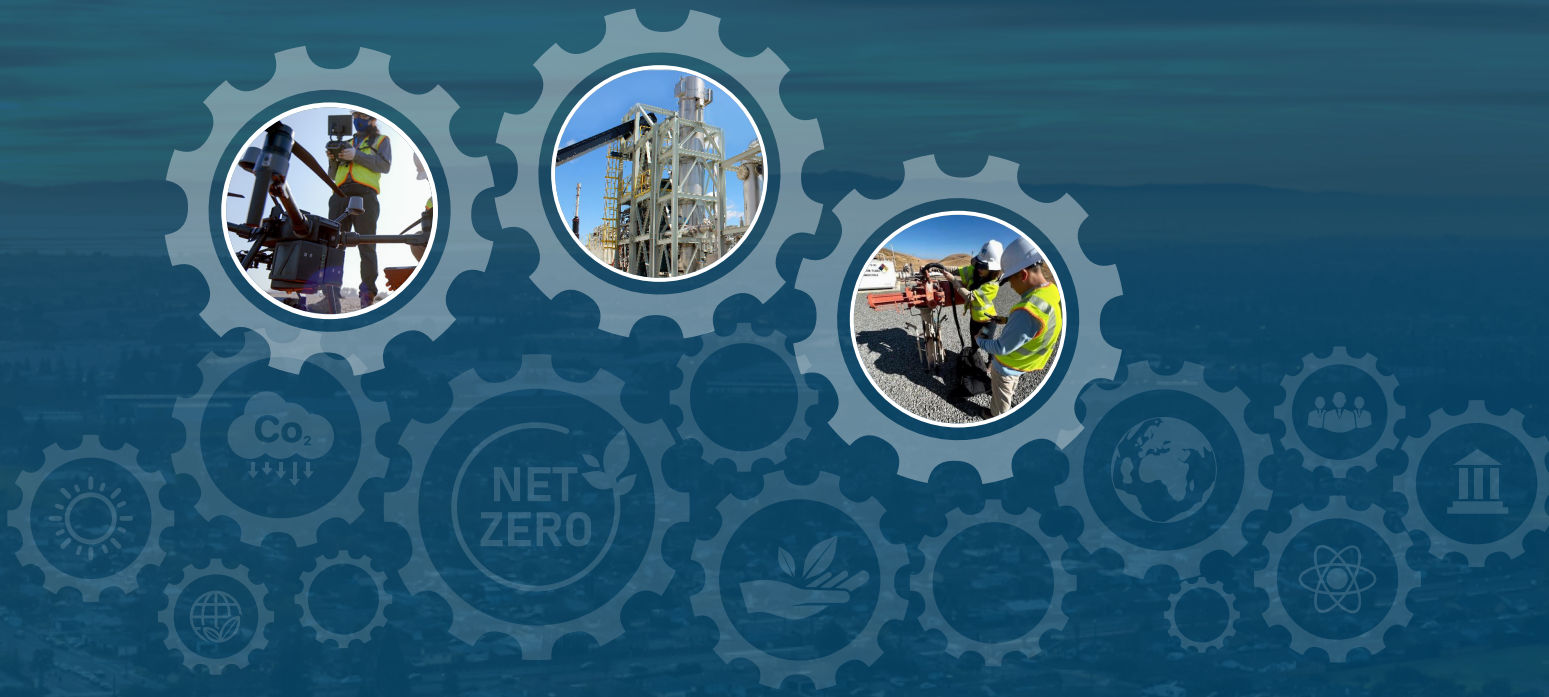
Relevant Areas of Interest: revision of emissions calculation methodologies, new and safer ways to repair meter set leaks, advanced leak detection for our transmission and distribution pipeline system, and continuous monitoring.

Decarbonizing the Gas System

We support R&D that develops or advances technologies that, if deployed widely, would decarbonize the gas system. Projects in this research area focus on greening the gas supply and shifting away from fossil-based methane.

Relevant Areas of Interest: researching the effect of hydrogen on the existing gas system and customer sites, exploring hydrogen blending in high-pressure natural gas transmission systems, obtaining RNG from both traditional and novel sources, and producing synthetic methane.

2023 IN REVIEW



Financial Highlights

2023 Funds Expended

In 2023, PG&E's Gas R&D group invested time, resources, and $1,159,675 across 171 projects falling in one of three research areas.

FUNDING CATEGORY	2023 ACTUALS
Operations and Maintenance	$173,955
Reducing Methane Emissions	$789,405
Decarbonization	$196,315
TOTAL	$1,159,675

In 2023, PG&E did not track administrative and project management time associated specifically with projects supported by Gas R&D. Beginning in 2024, the Gas R&D team will follow recent guidance from the CPUC's Energy Division to begin tracking administrative spending across the following **12 cost categories to increase transparency:**[3]

1. Investment Plan Development
2. Project Planning
3. Project Initiation
4. Post-Initiation Vendor Sourcing
5. Project Oversight & Governance
6. Stakeholder Communication, Engagement, and Outreach
7. Technology Implementation & Knowledge Transfer
8. Intellectual Property (IP) Coordination
9. Regulatory Support and Compliance
10. Internal Management Coordination
11. Program and Process Coordination and Improvement
12. Administrative Activities

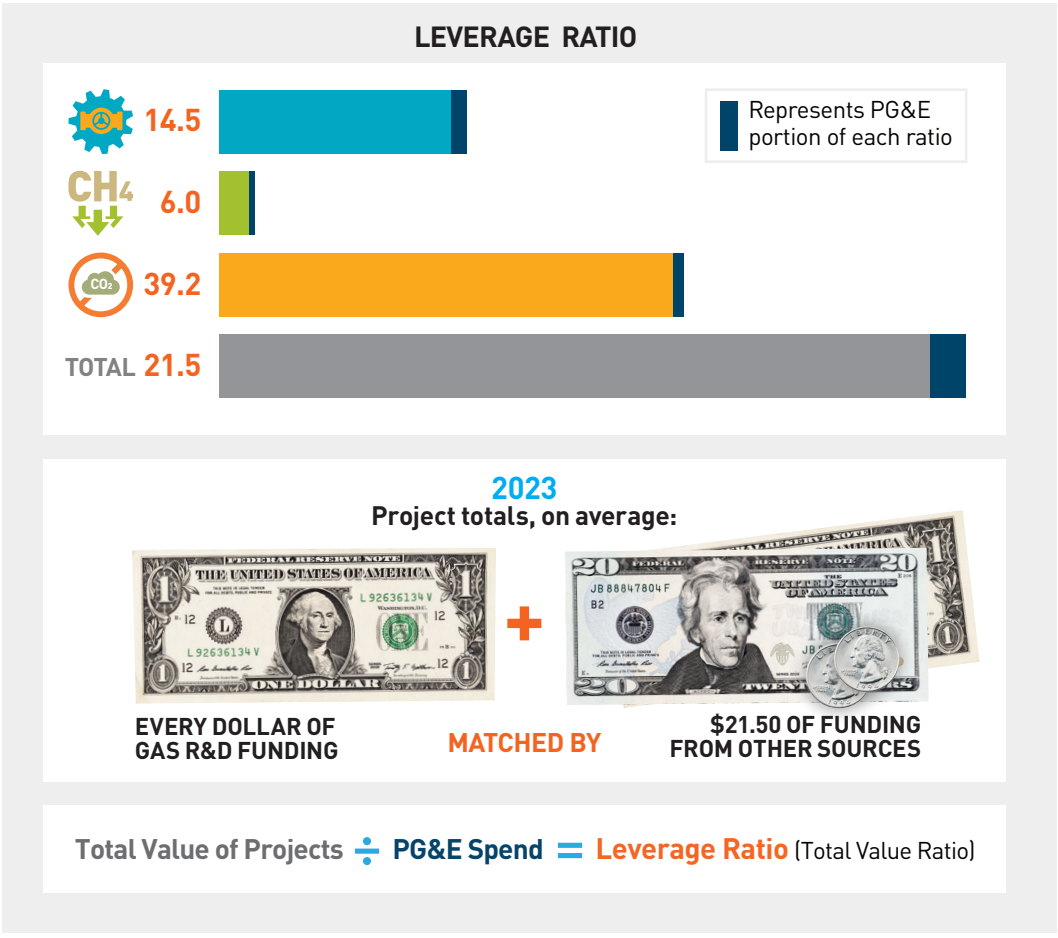
[3]Advice 6478-E Joint EPIC Administrator Advice Letter on Administrative Costs found at pge.com/tariffs/assets/pdf/adviceletter/ELEC_6478-E.pdf

2023 Leveraged Funding

Collectively, these 171 projects leveraged significant co-funding from private industry, the California Energy Commission (CEC), Pipeline and Hazardous Materials Safety Administration (PHMSA), the US Department of Energy (DOE), the National Science Foundation (NSF), national labs, and industry research consortia, including NYSEARCH/NGA, PRCI, EFI, GTI Energy, OTD, and UTD.

On a portfolio level, the total value of the projects supported by Gas R&D in 2023 equaled $148,661,377. The total value of PG&E's contribution to these projects is $6,193,240. Thus, on average, every dollar of Gas R&D funding expended on projects was matched by $20.50 of funding from other sources in 2023.

	2023 Actual Spend	PG&E Spend	Co-Funding	Total Value of Projects	Leverage Ratio
Operations and Maintenance	$173,955	$3,371,499	$45,625,238	$48,996,737	14.5
CH_4 Reducing CH_4 Emissions	$789,405	$1,178,336	$5,848,730	$7,027,066	6.0
CO_2 Decarbonizing the Gas System	$196,315	$2,363,405	$90,274,169	$92,637,574	39.2
TOTAL	**$1,159,675**	**$6,913,240**	**$141,748,137**	**$148,661,377**	21.5



Some of this leveraged funding included grant funding from a variety of agencies, including the CEC, PHMSA, DOE and NSF. In 2023, projects supported by **PG&E's Gas R&D received a total of $115,494,926 in such funding from public agencies**.

LEAD	RESEARCH AREA	PG&E FUNDING COMMITTED	FUNDING AWARDED	AGENCY
Brimstone Energy	Decarbonization	$ 50,000	$ 55,000,000	ARPA-E
UTD	Decarbonization	$ 40,000	$ 1,400,000	CEC
UTD	Decarbonization	$ 25,000	$ 2,000,000	CEC
UTD	Decarbonization	$ 26,100	$ 2,735,000	CEC
OTD	O&M Efficiency	$ 7,000	$ 1,056,000	CEC
OTD	O&M Efficiency	$ 12,554	$ 1,821,631	CEC
OTD	O&M Efficiency	$ 35,200	$ 1,738,436	CEC
Paulsson	O&M Efficiency	$ 0	$ 1,500,000	CEC
West Biofuels	Decarbonization	$ 0	$ 2,000,000	CEC
GTI	Decarbonization	$ 0	$ 3,999,971	CEC
GTI	Decarbonization	$ 50,000	$ 1,770,000	CEC
UCLA	Decarbonization	$ 0	$ 5,658,000	CEC
(TBD)	O&M Efficiency	$ 0	$ 1,582,117	CEC
UC San Diego-Scripps	O&M Efficiency	$ 0	$ 1,363,550	CEC
LLBL	O&M Efficiency	$ 440,000	$ 1,500,000	CEC
Eagle Rock Analytics, Inc	O&M Efficiency	$ 0	$ 1,000,704	CEC
UC Berkeley	O&M Efficiency	$ 0	$ 4,940,158	CEC
CEC Seismic	O&M Efficiency	$ 0	$ 3,485,255	CEC
UTD	Decarbonization	$ 120,000	$ 404,000	DOE-NREL
UTD	Decarbonization	$ 10,000	$ 2,599,733	DOE-NREL
UTD	Decarbonization	$ 300,000	$ 300,000	DOE-NREL
OTD	Decarbonization	$ 150,000	$ 10,000,000	DOE-NREL
GTI	Decarbonization	$ 37,500	$ 800,000	DOE-NREL
OTD	Cross Cutting	$ 30,000	$ 1,500,000	DOE-OFECM-NETL
UC Berkeley	Decarbonization	$ 0	$ 1,500,000	NSF
OTD	O&M	$ 350,000	$ 1,000,000	PHMSA
OTD	O&M	$ 0	$ 383,725	PHMSA
PHMSA	O&M	$ 0	$ 1,241,000	PHMSA
NYSEARCH	O&M	$ 49,610	$ 427,052	PHMSA
PRCI	O&M	$ 85,200	$ 788,594	PHMSA
	TOTAL	**$ 1,818,164**	**$ 115,494,926**	

Table 1: Grant funding to projects supported by PG&E's Gas R&D group in 2023.

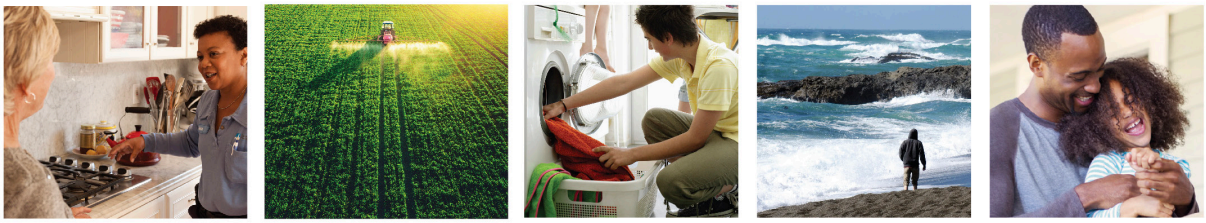
Of the 171 projects that PG&E's Gas R&D group supported in 2023, 140 of those projects were led by six research consortia: UTD, OTD, NYSEARCH/NGA, PRCI, EFI and GTI Energy.

For those projects supported by OTD and UTD, PG&E did not provide direct funding. Instead, PG&E paid annual dues and then determined how these dues were allocated across projects. For projects led by the other consortia and R&D groups, PG&E paid annual dues and/or paid additional funding in support of specific projects.

RESEARCH CONSORTIUM	2023 DUES
Colorado State University Methane Emissions Technology Center	$10,000
NYSEARCH/NGA	$72,250
OTD	$750,000
PRCI (general membership)	$159,569
PRCI (Emerging Fuels Institute membership)	$100,000
UTD	$350,000
TOTAL	**$1,441,819**

2023 Funding Recipients

- American Aerospace Technologies
- C-FER Technologies
- California Surveying and Drafting Supply
- Campos Engineering
- Det Norske Veritas (DNV)
- Eagle Rock Analytics, Inc.
- G4 Insights, Inc.
- GTI Energy
- National Renewable Energy Laboratory (NREL)
- Interstate Natural Gas Association of America
- Lawrence Berkeley National Laboratory
- Pacific Earthquake Engineering Research Center
- Paulsson
- Picarro, Inc.
- RMD
- SENSIT Technologies
- SKIPPER NDT
- SLB
- The Scripps Research Institute
- The University of Edinburgh
- ULC Technologies
- University of California
  - Berkeley
  - Irvine
  - Riverside
  - San Diego
- White River Technologies



Diversity. Equity. Inclusion. Belonging.

PG&E is committed to fostering a culture where diversity, equity, inclusion, and belonging (DEIB) are fundamental to our work. We also remain focused on representing the broad diversity of the communities we serve. The Gas R&D team takes part in many of PG&E's companywide initiatives and factors in the four DEIB principles when selecting projects and technologies to fund.

Such an approach is critical today as California makes bold strides toward carbon neutrality by 2045, in large part through widespread electrification of transportation, residential and commercial buildings, power generation, and industry.

In this environment, customer demand for fossil-based natural gas is projected to gradually decline. At these lower volumes, however, the cost to operate and maintain the gas system will not see a corresponding reduction. As a result, we can foresee a system supported more and more by those who do not have the resources to transition to electricity.

To ensure that the energy transition does not leave these customers behind, PG&E is actively seeking to evolve the gas system into an affordable, safe, and reliable net-zero energy delivery platform that helps California achieve its ambitious climate goals while avoiding or mitigating any adverse impacts—including rising energy costs and reduced reliability of energy supply—on environmental and social justice (ESJ) communities. PG&E has long had an ESJ policy[4] and in 2021 adopted a human rights policy.[5]

[4]pgecorp.com/assets/pgecorp/localized/en/sustainability/corporate-responsibility-sustainability/reports/2023/prosperity/energy-affordability-equity/pge_ej_policy.pdf

[5]assets.ctfassets.net/416ywc1laqmd/3KY8BncleqtnXQWhMkUVm0/bfdb19bae6375bf6b81dfcdd6dcc0280/Human-Rights-Statement.pdf

WHAT IS AN ENVIRONMENTAL AND SOCIAL JUSTICE COMMUNITY?

ENVIRONMENTAL and SOCIAL JUSTICE

To guide its ESJ efforts, PG&E has adopted the CPUC's definition of an ESJ community as one where residents are:[6]

- Predominantly **people of color** or low-income
- **Underrepresented** in the policy setting or decision-making process
- Subject to a disproportionate impact from one or more **environmental hazards**
- Likely to experience **disparate implementation of environmental regulations and socio-economic investments** in their communities

These communities may also include:

- **Disadvantaged Communities**[7]
- **All Tribal lands**
- Low-income households (defined as household incomes **below 80 percent** of the area median income)
- Low-income census tracts (defined as census tracts where aggregated household incomes are **less than 80 percent of area or state median income**)

In 2023: PG&E's Gas R&D group supported **25 research and development projects** located in environmental and social justice communities.

[6] www.cpuc.ca.gov/news-and-updates/newsroom/environmental-and-social-justice-action-plan
[7] oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

Supporting Projects that Matter

PG&E Gas R&D supports projects seeking to increase the efficiency and safety of pipeline operations and maintenance activities, reduce emissions, and future-proof the gas system for the migration to green fuels.

Recognizing the short-term, negative impacts that the energy transition may have on ESJ communities and people underrepresented in science, technology, engineering, and mathematics (STEM), we evaluate every project we consider for its potential to benefit these groups.

Examples of how we do this include:

- **Siting R&D projects** with no potential short- or long-term negative environmental impacts in ESJ communities.
- **Prioritizing projects** whose principal investigator or lead researchers are from an ESJ community or an underrepresented group.
- **Collaborating** with minority serving institutions.
- **Supporting technologies** that, if fully commercialized, could reduce emissions, improve air quality, and increase the reliability, safety, and affordability of energy in ESJ communities.

In addition to these targeted efforts, Gas R&D staff leverage many of PG&E's ongoing DEIB efforts.

Leading the Industry

For more than two decades, PG&E has led the industry in DEIB:

Transparency:

Since 2003: We have published our **workforce demographics**.

Diversity:

In 2017: PG&E Corporation became the **first company** in the Fortune 500 with a **LATINA CEO**.

Leadership:

Since 2006: DEIB principles have served as a foundation of our leadership development, onboarding and training.

18 CONSECUTIVE YEARS

Equality:

PG&E Corporation was the **first in our industry** to achieve **100% on the Human Rights Campaign's Corporate Equality Index.**

The Human Rights Campaign is the nation's largest civil rights organization working to achieve workplace equality for LGBTQ+ Americans.

EEOC CATEGORY	2021	2022	2023
Ethnic Minorities	**46.1%**	**47.5%**	**48.5%**
Officials and Managers	35.3%	36.7%	38.9%
Professionals	46.9%	48.1%	48.5%
Technicians	46.6%	48.5%	50.6%
Administrative Support Workers	66.6%	67.5%	68.8%
Craft Workers	36.4%	38.2%	39.4%
Operatives	43.9%	44.0%	45.7%
Laborers and Helpers	57.6%	58.4%	61.7%
Service Workers	32.9%	34.7%	36.2%

Figure 3: Ethnic minorities represented almost 50% of PG&E's workforce in 2023.[8]

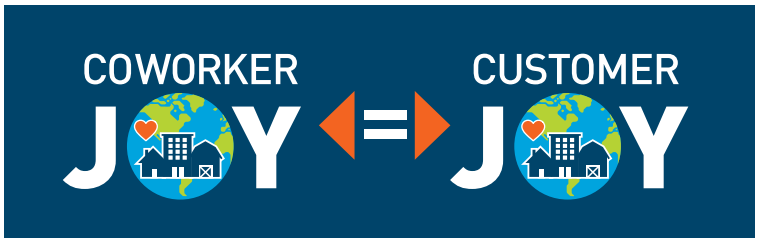
[8]https://www.pgecorp.com/assets/pgecorp/localized/en/sustainability/corporate-responsibility-sustainability/reports/2023/people/diversity/

Our Approach

PG&E's efforts to foster a DEIB culture and workforce are led by the Vice President, Chief Talent, Culture, and Inclusion Officer, with support from the senior leadership team.

The People and Compensation Committee of PG&E Corporation's Board of Directors reviews our DEIB practices and progress. This oversight helps ensure that our principles are embedded throughout the lifecycle of our talent management programs.

Key elements of our approach include engaging coworkers from day one, emphasizing the importance of DEIB through our onboarding and leadership development courses, mentoring, and targeted coworker development for diverse talent.



Coworker Experience

From day one at PG&E, we ground all coworkers in our commitment to and definitions of DEIB at new hire orientation.

In 2022, we added the term "belonging" to our approach to describe our values more fully:

Diversity is characterized by all the ways in which we are different. It's present in our job functions, work styles, experiences, and ideas. Diversity cultivates new perspectives and innovation, which enable us to better serve our customers, fellow coworkers, and shareholders.

Equity seeks to provide fair treatment, access, opportunity, and advancement for all people, while at the same time identifying and eliminating barriers that have prevented the full participation of some groups.

Inclusion is the process of leveraging the power of our coworkers' individual uniqueness to achieve our business strategies and goals, be better corporate citizens, and lead the industry.

Belonging means coworkers feel seen for their unique contributions, connected to coworkers and leaders, supported in their daily work and professional growth, and proud of our purpose, virtues, and stands.

Employee Networks

PG&E's Employee Networks date back five decades and, today, consist of Employee Resource Groups (ERGs) and Engineering Network Groups (ENGs) that help promote our business objectives and support a culture of DEIB by:

Supporting an environment of inclusion and belonging that values, recognizes, and acknowledges diversity in our workforce.

Promoting positive relationships with the hometowns and customers we serve.

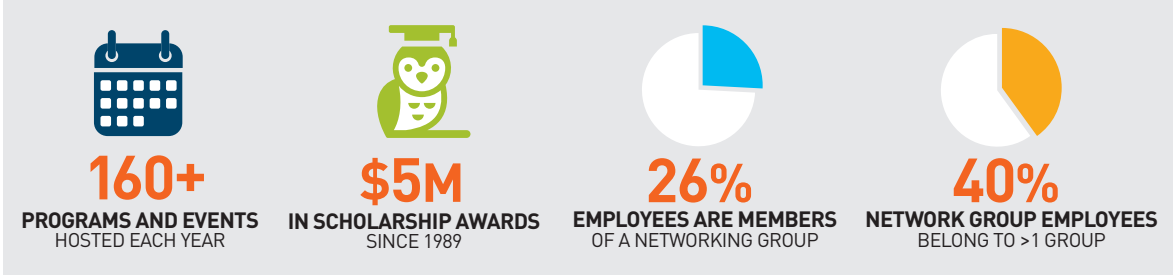
These networks help create an environment where every coworker can feel welcome and contribute to our overall business success. They assist in welcoming and mentoring new and existing coworkers, provide professional and personal development workshops, host social networking events, help recruit our future workforce, and offer community support through volunteerism, scholarships, customer education, and an environment for collaboration.

ERG and ENG members come from every level and job function and participate across 27 chapters throughout our service area.

Forty percent of all ERG and ENG members belong to more than one group, providing opportunities for allyship among the different groups and communities represented. Nearly half of PG&E's officers are executive sponsors, each of whom serves as an advisor and mentor providing strategic guidance to align strategy and action plans to the needs of the business.

Each year, our ERGs and ENGs support community organizations through charitable contributions and volunteerism. While these groups began as grassroots organizations, they've evolved into groups that create awareness and educate our workforce about culture and experiences. In turn, they also serve as ambassadors for our DEIB efforts at PG&E.

PG&E EMPLOYEE NETWORKS:



2022 DEIB Milestones

Enhanced our hiring process by engaging ENGs to help recruit and retain STEM talent at national conferences and educational institutions.

PG&E recruiters focused on potential employees from:

SWE Society of Women Engineers
SHPE Leading Hispanics in STEM
NSBE National Society of Black Engineers

Deployed a new bias awareness program. **TBD.**

HUMAN RIGHTS CAMPAIGN FOUNDATION
BEST PLACES TO WORK for LGBTQ+ Equality
2022
100% CORPORATE EQUALITY INDEX

LATINA Style MAGAZINE

PG&E Latino ERG recognized with an **honorable mention** for **ERG of the year**

Continued open and transparent dialogues on DEIB led by our **Strategic Allies Leading Transparency Task Force.**

In response to the civil unrest in the summer of 2020, this team of committed and engaged coworkers came together to facilitate discussions on topics such as racism, privilege, civil unrest, protests, how to disagree better not less and equity.

OUR ERGS AND ENGS AWARDED >150 scholarships = NEARLY $260,000

Examples include:

PG&E Black
$1,000–$5,000 scholarships
Given for STEM, business, environmental or energy-related emphasis.

PG&E Latino
$1,000–$2,000 scholarships
All majors eligible.

PG&E MEENA
$1,000–$3,000 scholarships
Given to students majoring in business or a STEM field.

PG&E PrideNetwork
$6,000 scholarships
Supports lesbian, gay, bisexual, queer and ally employees in achieving their full potential.

PG&E Samahan
$1,000–$2,000 scholarships
Promotes social and emotional aspects of Filipino-American culture and heritage.

PG&E Women's Network
$1,500–$4,500 scholarships
Promotes, develops and celebrates the community of women working at PG&E.

Forbes 2022 THE BEST EMPLOYERS FOR DIVERSITY
POWERED BY STATISTA

To determine the rankings, Statista surveyed more than 45,000 Americans working for businesses with at least 1,000 employees. Participants were asked to anonymously rate their organizations based on criteria such as age, gender, ethnicity, disability, and LGBTQ+ equality, as well as general diversity.[9]

DEI BEST PLACE TO WORK FOR DISABILITY INCLUSION 2022
100% DISABILITY EQUALITY INDEX

PG&E scored 100% for 8 straight years

This index is compiled by Disability:IN and the American Association of People with Disabilities.

PG&E National Society of Black Engineers ENG president recognized with the **"Above and Beyond" Honorable Mention**

seramount ERG IMPACT AWARDS

Juneteenth

Added as a **paid company holiday**

Celebrated 10 HERITAGE AND CELEBRATION MONTHS reflecting the many cultures and populations of our workforce

This included Generations at Work, our most inclusive month covering the many generations that work at PG&E. To celebrate, ERGs held virtual events, highlighted members of their communities, and published articles to build awareness. Examples of heritages celebrated include Black, Arab-American, Asian American, Pacific Islander, Pride, Latino, and Filipino-American.

[9]https://www.forbes.com/lists/best-employers-diversity

PROCESS USED TO SELECT GAS R&D PROJECTS

To select the projects and technologies that receive R&D funding, the Gas R&D team has conducted and continues to conduct a variety of activities.

In November 2022, PG&E reorganized its electric and gas R&D efforts and began work on its *R&D Strategy Report*.[10] As a part of this process, PG&E's R&D team worked closely with company operations staff to conduct a gap analysis.

Together, they identified 70 technology gaps—including 32 directly related to gas R&D—that stand in the way of PG&E achieving its objectives for its energy system.

Based on these findings, Gas R&D organized its efforts into three main research categories—O&M, Reducing Methane Emissions, and Decarbonizing the Gas System—each of which addresses a portion of the 32 gas-related technology gaps.

[10]https://www.pge.com/content/dam/pge/docs/about/pge-systems/PGE-RD-Strategy-Report.pdf

These high-level categories and associated technology gaps serve as the framework that the Gas R&D team uses when identifying potential projects to support, evaluating them, and making final selections.

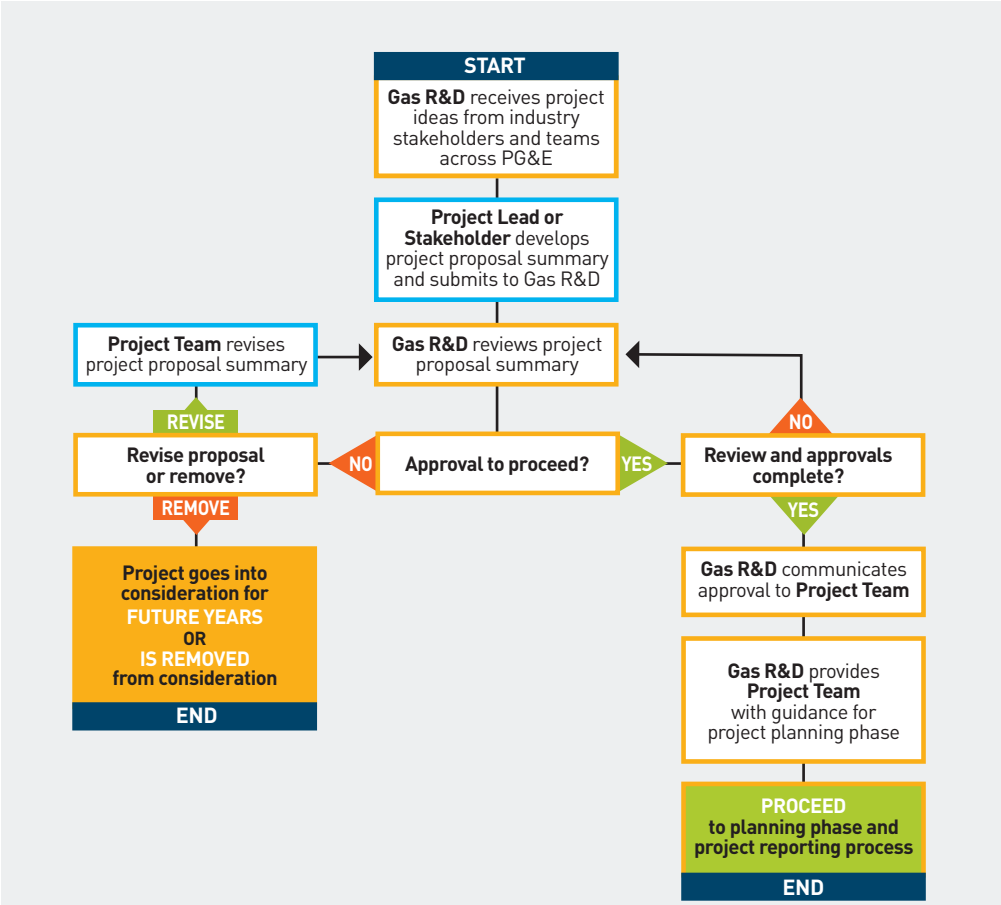


Figure 4: High-level process flow diagram for PG&E's Gas R&D project selection process.

Prior to initiating new projects, the Gas R&D team leads an ideation effort to define and select ideal projects for its portfolio (Figure 4). The Gas R&D team first assesses strategic and industry-related opportunities and gaps. Then, the team develops a plan for ideation in coordination with "top-down" guidance, which includes direction to prioritize projects that address identified technology gaps and contribute to the achievement of California energy polices and achieving our True North Strategy.

Gas-related technology gaps

Operations and Maintenance

- Crack Assessment and Monitoring for Small Pipes
- Material Properties Verification for Existing Pipe
- Toughness Assessments for Existing Pipe
- Crack Assessment Technologies
- Well Inspection and Monitoring
- Corrosion Inspections
- Manual Customer Shutoffs
- Accuracy of Well-Life Estimation
- Geohazard Risk Assessment
- Accuracy of Pipeline Locating Technologies
- Meter Set Corrosion Inspections
- Distribution Saddle Leak Repairs
- Plastic Insert Detection

Reducing Methane Emissions

- Revised Emission Calculation Methodologies
- Transmission Pipeline Blowdown Methane Emissions
- Meter Set Leak Repairs
- T&D Leak Detection
- Reducing False Positive on Leak Detection Surveys
- Above Ground Leak Detection and Monitoring

Decarbonizing the Gas System

- Costly and Unstandardized Interconnection Skids
- Uncertainty about Risks and Impacts from Trace RNG Chemicals
- Hydrogen Embrittlement
- Safety Risks of Hydrogen Blend Leaks
- Metering Accuracy with Hydrogen Mixtures
- Optimal Decarbonization Pathway
- Compatibility of Customer Applications with Mixed Gas
- Uncertainty of Storage Facility Performance for Hydrogen Blends
- Limited RNG Capacity from Traditional Sources
- Woody Biomass as an Energy Source
- Gas Appliance Combustion Emissions
- Lack of Operational Data for Hydrogen Effects on Gas System
- Need to Develop Cost-Effective and Safe Deblending Technologies

Table 2: PG&E's R&D teams worked closely with company operations staff to conduct a gap analysis. Together, they identified 70 technology gaps—including 32 directly related to gas R&D (above)—that stand in the way of PG&E achieving its objectives for its energy system.

Next, the Gas R&D team informally reaches out to internal and external stakeholders to gather project ideas in line with the overall strategy. Throughout the year, vendors, industry collaborators, and research consortia periodically submit projects for consideration. The team then collectively defines, assesses, and selects project ideas to advance. As part of this assessment, the Gas R&D team may conduct benchmarking, industry outreach, and vetting with internal/external entities.

Once the Gas R&D team has tentatively identified the projects it wishes to support, it asks project teams to develop a project proposal summary that will be used to review and approve the project before advancing it to the planning phase. This summary includes the development of initial scope, schedule, and budget estimates.

The summary goes through multiple rounds of review, each of which results in one of three decisions: approved to move to next round of review, refine and bring back for further review, or defer for potential future consideration.

Once all reviews and approvals are complete, Gas R&D staff communicate the approval to the project team.

STRUCTURE OF PG&E'S GAS R&D PORTFOLIO

PG&E's Gas R&D team supports innovative projects and technologies across three main research areas: Operations and Maintenance, Reducing Methane Emissions, and Decarbonizing the Gas System.

Operations and Maintenance

In this research category, the Gas R&D team funds projects that develop or advance technologies that, if deployed widely, would maintain and/or increase the safety and reliability of PG&E's existing gas system while reducing O&M costs and improving affordability for all customers—including those from ESJ communities.

Both the scope and scale of Gas R&D's O&M programs—which entail ongoing work across the full extent of PG&E's 50,000-mile pipeline network—require substantial investments of time and resources every year.

These efforts take a variety of forms—from routine, periodic leak inspections to emergency actions following natural disasters—and employ a wide array of technologies, ranging from drone and aerial surveys to in-line and nondestructive inspection technologies. While PG&E continually seeks and deploys state-of-the-art solutions to enhance the efficacy and efficiency of these programs, the changing dynamics of its natural gas system in the face of accelerating electrification and decarbonization make this pursuit more imperative than ever.

Relevant Technology Gaps

- Crack Assessment and Monitoring for Small Pipes
- Material Properties Verification for Existing Pipe
- Toughness Assessments for Existing Pipe
- Crack Assessment Technologies
- Well Inspection and Monitoring
- Corrosion Inspections
- Manual Customer Shutoffs
- Accuracy of Well-Life Estimation
- Geohazard Risk Assessment
- Accuracy of Pipeline Locating Technologies
- Meter Set Corrosion Inspections
- Distribution Saddle Leak Repairs
- Plastic Insert Detection

Figure 5: Identifying novel solutions—like drone technology—to maximize the efficiency of these ongoing maintenance and repair activities will be critical to providing affordable service in the years ahead.

Given the broad scope of PG&E's inspection, maintenance, and repair efforts, there are numerous avenues through which novel technologies and solutions could make a meaningful impact on company operations. Generally, Gas R&D seeks solutions that could help automate, optimize, and better target existing processes based on a more comprehensive and real-time understanding of conditions across the system. These types of capabilities could enable a more targeted approach to maintenance efforts that enhances the ability to proactively address developing issues and efficiently direct resources based on risk level or other factors without the need for as frequent system-wide inspections.

While PG&E will continue to make all necessary investments to ensure the safe and reliable delivery of energy across its system, **innovative approaches can help to ensure that those investments do not place an undue burden on our customers.**

Gas throughput expected to **decline with increased electrification**

Ongoing investments in safety and reliability may create rate pressures for fewer remaining customers

Increased O&M efficiencies can enable PG&E to **reduce rate pressure over time**

Gas R&D's efforts in this area are broadly focused on three areas:

Compliance with New Regulations: Requirements for the PHMSA Mega Rule require that PG&E expand the scope of many existing inspection and monitoring processes and deploy entirely new processes across many of our assets.

Crack assessment and monitoring

More **accurate, efficient and cost-effective** solutions for inspecting small diameter pipes

Toughness verification

Verify toughness of existing pipes via non-destructive methods that are cost-effective, accurate and repeatable

Storage Wells: High resolution in-line technologies are incredibly costly (up to $3M per well for in-line methods). The current process requires that operations be shut down and tubing pulled out to complete the inspection. Gas R&D seeks to reduce the installation and real-time monitoring costs of continuous monitoring solutions, while ensuring high quality, ongoing data transmission.

Well inspection and monitoring

Cost-effective and highly accurate solutions for **periodic inspection and/or continuous monitoring**

Accuracy of well-life estimations

Improved understanding of the critical determinants of well longevity and the ability to model their evolution over time for more accurate well-life estimations

Geohazard Risk Management: The industry's ability to accurately understand, predict and model changing risk levels is insufficient to enable the consistent and proactive identification of emerging issues. Through projects in this area, Gas R&D seeks to provide better ongoing visibility into the integrity of assets subject to enhanced geohazard risk; enhance understanding of how developing geohazards may impact PG&E assets, including the ability to more accurately model these impacts; and increase the ability to optimize the deployment of geohazard monitoring resources.

Visibility into integrity of assets subject to geohazard risks

Enhanced ongoing visibility into assets subject to geohazard risks, ability to model potential geohazard impacts and optimize deployment of monitoring resources

Reducing Methane Emissions

PG&E has set ambitious goals for decreasing emissions over the next 25 years as part of our broader climate strategy. We have committed to reducing Scope 1 and 2 emissions from natural gas operations by 45% by 2030. In April 2023—**two years ahead of schedule**—we announced that we had achieved our 2025 target of reducing pipeline emissions by 20%.

Relevant Technology Gaps

Relevant Technology Gaps

Revised Emission Calculation Methodologies

Transmission Pipeline Blowdown Methane Emissions

Meter Set Leak Repairs

T&D Leak Detection

Reducing False Positive on Leak Detection Surveys

Above Ground Leak Detection and Monitoring

Definition	PG&E 2030 Goal/Initiative
SCOPE 1 EMISSIONS **Direct** emissions from PG&E's operations	Reduce Scope 1 & 2 emissions from natural gas operations **by 45%**
SCOPE 2 EMISSIONS **Indirect** emissions from facility electricity and electric line losses	
SCOPE 3 EMISSIONS Emissions resulting from **value chain activities** now owned or controlled by PG&E but that can be **indirectly** impacted through PG&E actions	• Reduce Scope 3 emissions from natural gas supply **by 20%** • Reduce cumulative carbon emissions **by 2.5MMT** by converting commercial and industrial (C&I) customers unable to electrify from dirtier fuels to natural gas • Deliver **15% RNG** in PG&E's core throughput • Operationalize hydrogen pilot by 2024 to inform safe levels of blending into the system **by 2030** • Pledge **$25M** towards sustainable uses for woody biomass with other partners
SCOPE 4 EMISSIONS An emerging term for categorizing emissions reductions enabled by a company. PG&E can make significant contribution by enabling these emission reductions in our service area	

Continuing to meet company targets for methane emissions reductions will require investment in equipment upgrades and highly effective leak detection and repair technologies. In this research category, Gas R&D funds projects that develop or advance technologies that, if deployed widely, would reduce scope 1 methane emissions from PG&E's gas system. **Gas R&D's efforts in this area are broadly focused on three areas:**

Revised Emissions Calculation Methodologies: The figures for the Transmission Measurement and Regulation (M&R) station leaks and emissions are not based on actual recorded emissions but instead on population-based emission factors. While efficient, this approach does not provide accurate emissions information. To address this challenge, the Gas R&D team supports projects that are developing more granular emission calculation methods and the ability to continuously and cost-effectively detect and quantify on-site emissions levels at frequent intervals at the component level.

Revised emission calculation methodologies

More granular emission calculation methods and the ability to detect and record on-site emissions levels at frequent intervals at the component-level.

Meter Set Leak Repair: The current meter set leak repair process is time-consuming and increases ergonomic exposure for workers completing the repairs. Technologies to shorten meter set repair times and ensure a high-quality seal without breaking down the meter set can help reduce emissions and ensure worker safety while completing repairs. Projects in this area seek to develop novel technologies that minimize repair times, reduce the need for follow-up service visits, maintain a high-quality seal that can handle pressure at 60 psi, and support subsequent parts replacements and repairs. Because visual atmospheric corrosion inspections of meter sets are costly and subjective, projects in this area also seek to develop technologies that can remotely monitor meter sets for corrosion and successfully detect corrosion, alert repair crews, and/or shut off the meter set if failure is imminent.

Meter set leak repairs

The current repair process for meter set leaks requires breaking down the meter set. The process is time intensive, cost prohibitive, and poses safety risks to coworkers performing repairs. **Innovative technologies to repair meter set leaks without breaking them down are vital** to ensuring coworker safety, reducing emissions, and reducing O&M costs.

Transmission and Distribution Leak Detection: The lack of cost-effective technologies to continuously monitor and quantify emissions from assets that intermittently bleed by design makes it difficult to estimate emissions. Continuous monitoring has the potential to improve emissions reporting from stations and storage facilities and maximize emissions reduction efforts by prioritizing the highest emitters for replacement.

Continuous monitoring

Continuous monitoring has the potential to improve emissions reporting of stations and storage facilities and maximize emissions reduction efforts by prioritizing the highest emitters for replacement.

Figure 6: PG&E uses a QLM camera mounted on a yellow pole to continuously monitor and take measurements of intermittent devices at M&R station to accurately represent their emissions and establish an accurate emissions factor.

Decarbonizing the Gas System

In this research category, the Gas R&D group funds projects that develop or advance technologies that, if deployed widely, would decarbonize the gas system.

Such projects include those that conduct foundational research that better informs the industry's understanding of the challenges and impacts of integrating cleaner fuels into existing pipelines and system assets, as well as into customer applications and end uses.

Greening the gas system is core to PG&E's True North Strategy, as well as supporting the achievement of broader decarbonization goals at state and federal levels; however, research continues about what this transition will look like at scale and how this transition will occur.

While it is widely accepted that hydrogen and other green alternatives will likely be important fuel sources in the future, there is little certainty across the broader utility industry about exactly how these emerging fuels will be utilized in the future and how existing infrastructure and customer end uses will need to adapt to accommodate the switch from natural gas and other fossil-based fuels. Foundational R&D and earlier stage research is needed. As a better understanding of cleaner alternative fuels emerges, their interaction with and impact on current system components and infrastructure and other operational considerations will help to inform the path towards greening the gas supply.

Relevant Technology Gaps

- Costly and Unstandardized Interconnection Skids
- Uncertainty about Risks and Impacts from Trace RNG Chemicals
- Hydrogen Embrittlement
- Safety Risks of Hydrogen Blend Leaks
- Metering Accuracy with Hydrogen Mixtures
- Optimal Decarbonization Pathway
- Compatibility of Customer Applications with Mixed Gas
- Uncertainty of Storage Facility Performance for Hydrogen Blends
- Limited RNG Capacity from Traditional Sources
- Woody Biomass as an Energy Source
- Gas Appliance Combustion Emissions
- Lack of Operational Data for Hydrogen Effects on Gas System
- Need to Develop Cost-Effective and Safe Deblending Technologies

To determine the optimal path to a net zero future, PG&E is seeking the help of the scientific community to deepen the industry's understanding of the economics, properties, and interaction effects of cleaner fuels.

Additionally, PG&E seeks avenues to extend this research beyond controlled laboratory settings to better inform the understanding of how hydrogen might affect existing gas infrastructure and operations under a wide range of real-world conditions.

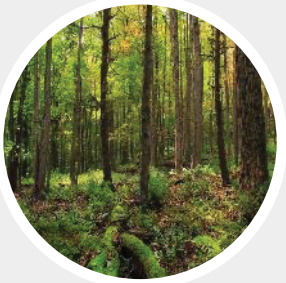
Developing this base of knowledge is critical to the ability to smoothly transition the gas system to green alternatives. Beyond foundational research, the Gas R&D team is also pursuing novel approaches and technologies that will help address known barriers to the introduction of cleaner fuels to the gas system. As the path forward becomes clearer over the coming years, PG&E anticipates that its R&D needs related to decarbonizing the gas system will shift away from foundational research and towards deployable technology necessary to effect the transition.

Gas R&D's efforts in this area are broadly focused on two areas:

Integrating Cleaner Fuels: In the transition to a net zero energy system by 2040, PG&E seeks to integrate clean fuels such as traditional RNG, non-traditional RNG, renewable hydrogen, and synthetic methane. Gas R&D seeks to support R&D and pilot projects exploring cost-effective interconnection, feedstock limitations, compatibility with existing infrastructure and processes, and novel fuel production processes.

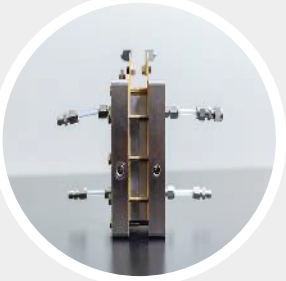
Traditional RNG

RNG created from **traditional organic sources:** livestock, landfills and wastewater treatment



Non-Traditional RNG

RNG created from **non-traditional organic sources:** woody biomass, food waste, etc.



Synthetic Methane

RNG created from **other sources:** power-to-methane, etc.

The Impact of Hydrogen: As hydrogen and other green alternatives become more widely accepted, the importance of studying how this emerging fuel will be utilized and how existing infrastructure and customer end uses must adapt becomes critical. Projects in this area will seek to understand how hydrogen will impact the existing gas system, customer end uses, and appliances.

Effects on existing system components and operations

1. Pipeline integrity
2. Storage well integrity
3. Safety characteristics
4. Metering accuracy

Effects on existing customer end uses and appliances

1. Compatibility with various customer end uses and appliances
2. Deblending at customer sites

APPENDIX

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 particulate matter **AB 617:** Pilot communities for air quality improvements
Methane Emissions	**SB 1371:** Mandates the CPUC to adopt rules and procedures to reduce methane emissions from commission-regulated pipeline facilities **SB 1383:** Reduce methane emissions from decomposition of organic wastes **CARB Oil and Gas Rules:** Requires new monitoring and repairs to reduce methane emissions **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 **PHMSA Notice of Proposed Rulemaking:** Mandates reductions in methane emissions from new and existing gas transmission pipelines, distribution pipelines, regulated gas gathering pipelines, underground natural gas storage facilities, and liquefied natural gas facilities

CATEGORY	REGULATIONS & POLICY DRIVERS
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:** 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
Additional Drivers	**Resolution G-3586:** Southern California Gas Company requests approval to record Research, Development, and Demonstration (RD&D) expenses to its Research, Development, and Demonstration Expense Account. • OP 3.b: SoCalGas shall demonstrate that any hydrogen programs and projects conducted by SoCalGas utilize clean renewable hydrogen, consistent with the definition given in Decision (D.) 22-12-057. • OP 5: All of Southern California Gas Company's new and future Research, Development, and Demonstration projects shall occur in the State of California.

Acronyms

ACRONYM	DEFINITION
AB	Assembly Bill
CARB	California Air Resources Board
CEC	California Energy Commission
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
DEIB	Diversity, equity, inclusion, and belonging
EFI	Emerging Fuels Institute
ENG	Engineering Network Group
EO	Executive Order
ERG	Employee Resource Group
ESJ	Environmental and Social Justice
GHG	Greenhouse Gas
IOU	Investor-Owned Utility
JIP	Joint Industry Project
LGBTQ	Lesbian, Gay, Bisexual, Transgender, and Queer
NGA	Northeast Gas Association
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
NYSEARCH	A research suborganization with the Northeast Gas Association
O&M	Operations and Maintenance
OIR	Order Institute Rulemaking
OTD	Operations Technology Development
PG&E	Pacific Gas and Electric Company
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRCI	Pipeline Research Council International
R&D	Research and Development
RNG	Renewable Natural Gas
SB	Senate Bill
STEM	Science, technology, engineering, and mathematics
UTD	Utilization Technology Development

2022 SUMMARY OF ONGOING AND COMPLETED PROJECTS

Operations and Maintenance

5.16.k Ph2 ORFEUS Obstacle Detection Technology for Horizontal Directional Drilling

The Project aims to produce a field-proven, market-ready obstacle location technology for horizontal directional drilling (HDD) applications. Optimized Radar to Find Every Utility in the Street (ORFEUS) is an effort to develop a safe, cost-effective, "look-ahead" obstacle detection system for HDD equipment. This project seeks to develop further the technology to bring forward a commercially viable product for identifying obstacles in and around the path of an HDD drill rig, thus reducing third-party damage to underground utilities. The ORFEUS technology incorporates a forward- and side-looking ground-penetrating radar within the HDD. This process will detect obstacles within the HDD path during the installation of new underground infrastructure. This technology could lower the risk of damaging substructures during the boring process. In 2023, the project team completed developing and debugging the data acquisition module and finalized the modifications of the ORFEUS detection algorithm and the angular sensor board. Calculating 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 technology enhancements incorporating the lessons learned from the field demonstrations are scheduled for a future project phase. The benefits of successful technology would provide an opportunity to reduce HDD damage that could affect the integrity of PG&E's pipelines, reduce safety concerns, and reduce the release of emissions into the atmosphere.

Co-Funders: OTD Members, PHMSA, SoCalGas

Start Date: 1/14/2021
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$3,500,000
Total PG&E Cost:	$350,000
Total Co-Funding:	$3,150,000

Benefits

5.17.m Ph2 Modify Pipeline Purging Program for Calculations of Methane Emissions Savings, Including Hydrogen

The objective of the Project is to update the pipeline purging software program to allow users to calculate methane emissions savings more efficiently by using various types of alternative purging processes and equipment (i.e., cross-compression) and hydrogen blending operations. The project team will create new algorithms, user interfaces, and software installation and will set up and provide beta and production versions of the software. The final deliverable will be a user manual. If the Project is successful, accurately capturing savings in the volume of gas loss could assist PG&E in making better financial decisions about which emission reduction projects to fund.

Co-Funders: OTD Members, SoCalGas

Start Date: 8/30/2023
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	$1,000
Total Project Cost:	$174,000
Total PG&E Cost:	$1,000
Total Co-Funding:	$173,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

5.18.a Ph3 Leak Repair of Meter Set Assemblies

The Project's objective was to expand on related work performed in phases 1 and 2 of the OTD 5.18.a project regarding leak seals for meter set joints. Meter set leaks are one of the top three sources of emissions in PG&E territory. Finding a quick solution to repair minor thread leaks is crucial to reducing emissions and improving safety. This Project focused on mitigating class C and D fugitive thread leaks, from 0.001 to ≤ 0.1 standard cubic feet per hour (scfh), on above-ground meter set assembly (MSA) piping at pressures of up to 60 pounds per square inch gauge (psig) upstream of the pressure regulator without the need for breaking down the meter set. Testing took place at the GTI Energy laboratory in Des Plaines, Illinois. Phase 3 of the project was proposed in Q2 2021. The final report was issued in November 2023. After exposure to various rounds of thermal cycling, salt-spray exposure, and ultraviolet radiation, the LLFA® Tape leak repair solution was effective on above-ground threaded fittings at 60 psig up to 1.0 scfh leak rate. A total of 27 leak repair samples were included in this evaluation. The project team found that achieving a successful leak repair depends on using the proper technique to install the wrap onto the leaking pipe.

Co-Funders: OTD Members

Start Date: 5/1/2021
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	**$0**
Total Project Cost:	**$140,000**
Total PG&E Cost:	**$28,000**
Total Co-Funding:	**$112,000**

Benefits

5.20.e Single Path Ultrasonic Meter Long-Term Performance

The objective of the Project was to conduct long-term performance and accuracy testing on single-path ultrasonic residential meters. The project team completed testing on three different types of smart meters with promising results that were delivered in the final report. Long-term performance and accuracy data of single-path ultrasonic meters will assist PG&E in making a business decision to utilize this new meter technology. These types of meters have advanced features such as remote shutoff, pressure monitoring, and system diagnostics and are desirable due to their compact size.

Co-Funders: OTD Members, SoCalGas

Start Date: 3/2/2020
End Date: 12/27/2023
Status: Completed

2023 Funds Expended:	**$0**
Total Project Cost:	**$140,000**
Total PG&E Cost:	**$20,000**
Total Co-Funding:	**$120,000**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

5.20.k Ph2 Addition of Low Power WAN (LPWAN) Communication Network

The Project seeks 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, capable of detecting and terminating gas flow in response to a hazardous incident such as a fire, flood, or gas leak inside a residential or commercial structure. This project is co-funded by the California Energy Commission (CEC) to improve the safety and integrity of natural gas infrastructure. The project team demonstrated and validated the technologies required for a smart shutoff system and identified gaps or barriers that must be addressed before commercialization. In 2021, the team created Phase 2 to better understand the deployment of a Low Power Wide Area Network (LPWAN) at scale after identifying knowledge gaps in the communication methodology. LPWAN was frequently used globally because of its communications reliability, simplicity of installation, and low costs. 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 on 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. PG&E 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 implementing 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, SoCalGas

Start Date: 11/1/2021
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$82,000**
Total PG&E Cost:	**$7,500**
Total Co-Funding:	**$74,500**

Benefits

5.20.k Smart Shutoff Technology for Commercial and Residential Buildings

The Project aims 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, capable of detecting and terminating gas flow in response to a hazardous incident such as a fire, flood, or gas leak inside a residential or commercial structure. This project is co-funded by the California Energy Commission (CEC) to improve the safety and integrity of natural gas infrastructure. The project team demonstrated and validated the technologies required for a smart shutoff system and identified gaps or barriers that must 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 on 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. PG&E 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 implementing 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, SoCalGas

Start Date: 8/4/2020
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$1,230,000**
Total PG&E Cost:	**$7,000**
Total Co-Funding:	**$1,223,000**

Benefits

5.21.a Meter Removal Tool, Commercialization Phase

The objective of the Project was to develop a wrenching tool to promote proper body ergonomics and reduce the risk of injury to field employees during wrenching activities. Over time, meter swivel nuts seize up and become difficult to loosen when removing and replacing meters. Also, the location and height of meter sets are not ideal for proper body ergonomics and increase the risk of injury to field employees during wrenching activities. Design began in the first quarter of 2021, with multiple design iterations resulting in a final design ready for field employee feedback. In June 2021, PG&E tested the design at the Center for Gas Safety and Innovation in Dublin, California. Overall, the team had reservations about the tool adequately addressing the problem—even if additional tool designs were perfectly designed. Chief among those concerns was the tendency of the entire meter to twist when pressure is applied to the swivel nut. The tool appeared to be used to "break" the rust from where the ridge on the swivel meets the swivel nut—based on how it attaches to those two parts. The team determined that the tool was too complicated for the task and that seized swivels were not a pressing enough issue to warrant continued project support. Based on these results, the team recommended that after this phase was completed in 2023, PG&E discontinue active involvement in the Project.

Co-Funders: OTD Members

Start Date: 1/1/2021
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$190,000
Total PG&E Cost:	$10,000
Total Co-Funding:	$180,000

Benefits

5.21.e Operational Demonstration and Evaluation of the CoSMiC Eye System

The Project sought to conduct a technical review and evaluate the CoSMiC-Eye Satellite-Based Right-of-Way Monitoring System. The system has been used successfully in Europe to monitor the areas surrounding pipelines and alert utilities when changes to terrain—such as new construction—are detected. The system was evaluated from August 2022 through February 2023 for its performance in a six-month field monitoring demonstration in National Fuel's service territory in upstate New York. This timeframe allowed for monitoring from summer into winter and included primarily rural areas with some built-up residential areas and numerous highway and road crossings. During the demonstration period, 81 potential threats were identified. National Fuel classified these threats into five categories: 1) construction works, 2) storage building/shed, 3) nothing relevant, 4) too far from the pipeline centerline, and 5) vegetation clearance. Follow-up continued with the publication of the final report. National Fuel and National Grid have proposed additional research and demonstration projects in their service territories.

Co-Funders: OTD Members

Start Date: 5/13/2021
End Date: 6/23/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$141,700
Total PG&E Cost:	$10,000
Total Co-Funding:	$131,700

Benefits

5.22.j Ph1 Design and Placement of Compact Service Regulators

This Project aims 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, which is based on the venting characteristics of standard internal relief valve regulators and not on vent-limiting regulators. The results from Phase 1 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 due to 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. PG&E can benefit from this research to improve safety, reduce cost, reduce 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

Start Date: 11/19/2021
End Date: 3/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$489,629
Total PG&E Cost:	$0
Total Co-Funding:	$489,629

Benefits

7.17.d Ph3 Soap Solution Comparison Study for Rate Estimation/Hazard Assessment

The Project aims to compare soap solutions to understand if solution additives may lead to relatively large variations in bubble sizes or formation rates. The project team has completed testing on several soap solutions varying the pressure, flow rate, and temperature, and the results for all four soap solutions selected will be provided in the final report. PG&E uses a soap test to assess if an above-ground leak should be categorized as hazardous or non-hazardous. Understanding how bubble size and formation rate might vary across soap solution products allows companies to assign the type of emergency response and mitigation needed to a given leak.

Co-Funders: OTD Members

Start Date: 8/18/2023
End Date: 8/1/2024
Status: Active

2023 Funds Expended:	$1,000
Total Project Cost:	$125,000
Total PG&E Cost:	$1,000
Total Co-Funding:	$124,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

7.23.o Methane Detection Technology—Regulation Equivalence Testing

The Project aims to develop a protocol to evaluate leak detection technologies against a common benchmark, highlighting functional differences and comparing effectiveness. Equivalence testing of various technologies will provide an understanding of detection effectiveness and performance comparisons despite equipment variations. The project team is developing the protocol to be agnostic across multiple detection technologies. The project team will review available technical documentation, including comparison studies and test data from previous projects, and provide it in the final report. If successful, the Project may assist PG&E in streamlining its evaluation and acceptance process and reducing the tools needed for regulated surveys.

Co-Funders: OTD Members

Start Date: 8/18/2023
End Date: 2/1/2025
Status: Active

2023 Funds Expended:	$1,000
Total Project Cost:	$200,000
Total PG&E Cost:	$1,000
Total Co-Funding:	$199,000

Benefits

7.24.c Ph1 Near Field Fixed Monitoring

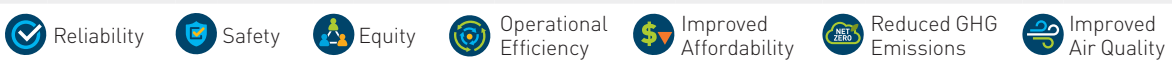
The objective of the Project is to evaluate the use of fixed methane monitors for leak detection near potential high-flow locations on above-ground equipment. Fixed methane monitors may aid in the early detection of potentially high-risk and high methane leaks. This evaluation may help operations reduce the need for daily monitoring or survey of the class and equipment of such assets. Additionally, incorporating fixed monitoring could allow fast detection of an unintentional release event, reduce operating risk, and improve safety. If successful, integrating continuous monitoring at PG&E could enable rapid detection of a major event and reduce overall operation costs at the wellheads in underground storage facilities.

Co-Funders: OTD Members

Start Date: 11/20/2023
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$73,000
Total PG&E Cost:	$36,500
Total Co-Funding:	$36,500

Benefits



8.20.j Aboveground Service Tee Identification and Mapping System

The Project aims 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 can 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 PG&E by reducing the potential of damage to its lines, thereby reducing damage to life, property, and community.

Co-Funders: OTD Members, White River Technologies

Start Date: 4/8/2021
End Date: 2/1/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$220,000
Total PG&E Cost:	$20,000
Total Co-Funding:	$200,000

Benefits

8.20.l Enhanced Locating Technologies for Underground Pipelines with Better Accuracy

The objective of the Project, 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 existing technology with an in-pipe mechanism to focus on congested areas and plastic materials. SoCalGas and PG&E are partners in the Project along with the CEC. SoCalGas focuses on transmission infrastructure, while PG&E focuses on distribution infrastructure 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 commercial electromagnetic locator tools following the potholing of three underground pipelines at pilot demonstration locations. The project team continued to examine the coordinated data of each locating technology for data accuracy. PG&E can use this research to add to the list of tools that identify steel assets without excavation, an approach that will improve affordability, reliability, and safety.

Co-Funders: OTD Members, White River Technologies, CEC

Start Date: 11/4/2020
End Date: 4/1/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$2,021,631
Total PG&E Cost:	$12,554
Total Co-Funding:	$2,009,077

Benefits

8.20.m 3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management

The objective of the Project, co-funded with the 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 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 PG&E. 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, lowering the data collection cost. PG & E can utilize this research to improve the three-dimensional geospatial accuracy of existing Geographic Information Systems data.

Co-Funders: OTD Members, CEC, SoCalGas

Start Date: 12/2/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$2,090,436
Total PG&E Cost:	$35,200
Total Co-Funding:	$2,055,236

Benefits

8.21.g GNSS Testing in an Urban Environment

The objective of the Project was to evaluate new Global Navigation Satellite System (GNSS) technologies available to help data collection in an urban canyon environment and to develop best practices for their implementation. The project team researched two solutions that showed promise for geolocating in urban canyons with less expense, shorter time, and fewer expertise requirements vs. more traditional surveying tools and techniques. The focus was on an inertial navigation system (INS), which is comprised of an inertial motion unit (IMU) and a global navigation satellite system (GNSS) receiver that uses sophisticated algorithms to use data from both to determine position, especially when the former is not able to determine position on its own fully. Results suggest higher-end INS can geolocate better in extreme urban canyon environments where a traditional GNSS receiver typically performs poorly; however, the precision and accuracy may not be good enough for survey-grade measurements. Costs are comparable between the INS tested and a traditional receiver. More expensive units with higher specs are available that may perform better but were not tested. Improving the accuracy and performance in the urban canyon will benefit PG&E when collecting GPS data on gas assets and increase our digital assets' work efficiency and reliability.

Co-Funders: OTD Members

Start Date: 7/30/2021
End Date: 7/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$175,000
Total PG&E Cost:	$10,000
Total Co-Funding:	$165,000

Benefits

An All-Optical Multi-Sensor Well Monitoring System to Secure Gas Storage Operations

The Project supported CEC PIR-19-001, developing and applying practical, all-optical reservoir surveying and monitoring technologies to improve California-based gas storage field operations. The work included designing, prototyping, laboratory testing, and building a downhole multi-sensor array during Phase 1/Year 1 (2020). During Phase 2/Year 2 (2021), PG&E deployed a multi-sensor array to an operational underground gas storage well at a depth of about 5,400 ft at its McDonald Island Underground Gas Storage Facility. The team recorded and field-processed data in real-time and on-demand in this phase. The team operated and monitored the all-optical monitoring system remotely. In Phase 3/Year 3 (2021-2023), the team completed data processing, data interpretation, results reporting, and all the remaining planned project field monitoring work during various operation events. It presented the final project results slide deck to PG&E. The next step is to complete the final project report by June 2024. With the successful completion of this work, PG&E will be able to continue real-time or on-demand well operation and integrity monitoring for many years ahead. This is expected to improve safety and operational efficiency while lowering costs. Specifically, this will allow PG&E to replace or complement some of the costly in-line inspection practices with a high risk of insertion mechanical damage and service interruption.

Co-Funders: CEC, Paulsson

Start Date: 7/29/2020
End Date: 12/31/2023
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$3,000,000
Total PG&E Cost:	$0
Total Co-Funding:	$3,000,000

Benefits

API-2-2 2022 Tech Transfer Fitness-for-Service Standard API 579-1

Regulatory bodies are much more likely to approve of innovative approaches to pipeline integrity if such innovations are written into consensus standards published by industry organizations such as the American Petroleum Institute (API) and the American Society of Mechanical Engineers (ASME). The Project aims to prepare the first two volumes of a collection of documents that will transfer Pipeline Research Council International (PRCI) technology (MAT-8 fracture model and SIA-1-2 stress intensity factor solutions) to the API 579-1/ASME FFS-1. This Project kicked off in July 2022 and delivered two final reports in July 2023. Report 1 documents the PRCI MAT-8 fracture model, a state-of-the-art approach for predicting burst pressure in pipe joints with longitudinal cracks and crack-like flaws. Report 2 describes the work product of PRCI Project SIA-1-2, which primarily consists of stress intensity factor solutions for cracks in pipe sleeve fillet welds. The project team found that both technologies are suitable for inclusion in the API/ASME fitness-for-service standard. This will benefit PG&E and other operators in safety and reliability improvement and cost reduction. A single avoidance of shutdown or slowdown of a facility can lead to savings ranging from 0.5 to 20 US$ million. There is a greater return on investment in new technologies once they have been incorporated into codes and standards that pertain to the pipeline industry.

Co-Funders: PRCI Members

Start Date: 7/16/2022
End Date: 6/21/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$30,000
Total PG&E Cost:	$0
Total Co-Funding:	$30,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

Development and Evaluation of a High-Resolution Historical Climate Dataset over California

The objective of the 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. PG&E 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. PG&E 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: UC San Diego-Scripps Institute, SoCalGas, CEC

Start Date: 1/19/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,363,550
Total PG&E Cost:	$0
Total Co-Funding:	$1,363,550

Benefits

EC-01-13 2021 ILI-Based Generic External Corrosion Growth Rate Distributions for Buried Pipelines

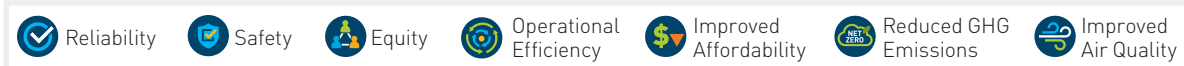
The objective of the Project was to provide the industry with generalized In-Line Inspection-based (ILI) corrosion growth rate distributions and associated causal factors. The growth rate distributions were based on actual data from successive ILI runs provided by Pipeline Research Council International members. The project team developed a probabilistic model for estimating external corrosion growth (ECG) rates via subsequent 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 (i.e., the impact of environment on corrosion), and 4) ILI results, if available. The report identified these parameters, with classifications assigned to each parameter. The project team delivered 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 each parameter's elements that can be classified. The report emphasized that these combinations are just guidelines; users can develop their own metrics. Pipeline operators could utilize project results to establish data-driven and justifiable ECG rates on pipelines, which cannot be calculated from historical and ILI run-to-run comparisons. PG&E 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 either new to the Transmission Integrity Management Program, only have only one ILI run, or that are difficult to inspect and currently assessed by External Corrosion Direct Assessment programs.

Co-Funders: PRCI Members

Start Date: 5/15/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$193,662
Total PG&E Cost:	$19,308
Total Co-Funding:	$174,354

Benefits



EC-02-11 2021 Database of All Burst Tests for Corrosion Cracking Dent and Interacting Defects

The objective of the Project was to develop and populate a database that includes 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 team developed a uniform burst test data collection format and supported future defect assessment and modeling efforts. Attributes for corrosion, stress corrosion cracking, 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 team completed data gathering, data entry, personnel training, and a burst test database demonstration with sponsors. The Project provided consistent and relevant data for future Pipeline Research Council International research in defect assessment and crack growth modeling and resulted in a database of burst and fatigue tests—with open access to members—that provides sponsors, including PG&E, cost savings opportunities on future research projects.

Co-Funders: PRCI Members

Start Date: 2/2/2022
End Date: 7/5/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$148,000
Total PG&E Cost:	$8,780
Total Co-Funding:	$139,220

Benefits

EC-2-10 2019 Development of a Comprehensive Metal-loss Assessment Criteria

This Project aims to develop Level 1 and Level 2 metal-loss assessment criteria that are easy to use and cover all pipe grades and construction eras. The metal-loss assessment criterion will indicate the risk of leak and rupture, reduce inspection data scatter, and eliminate maintenance that does not affect risk reduction. The Project integrates and builds on work completed in prior research, which developed a criterion for metal-loss assessment demonstrated in an independent evaluation to significantly reduce data spread and address bias in contrast to the American Society of Mechanical Engineers B31G and Modified B31G models. This criterion will allow for less scatter, conservatism, and other assessment models without compromising pipeline operational safety. In 2023, the project team completed the verification of coalescence criteria for adjacent and nested metal loss features. By the end of the year, the project team had finished developing the three key technology factors that will determine the success of the remaining work on the Project: 1) more accurate burst pressure prediction of multiple complex features than existing models, 2) coalescence criteria that can be used for the prediction of leaks versus ruptures, and 3) leak versus rupture prediction using the coalescence criteria. The next step is to complete all the related technical reports. Upon successful completion, this work will provide PG&E and other gas operators with a comprehensive and representative assessment of failure pressure in areas of corrosion damage, which will avoid being too conservative in the current practices. This, in turn, will result in effectiveness, efficiency, and cost reduction at no sacrifice of safety.

Co-Funders: PRCI Members

Start Date: 2/28/2019
End Date: 7/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,493,000
Total PG&E Cost:	$201,800
Total Co-Funding:	$1,291,200

Benefits

Electromagnetic and Optical Sensor Technologies for Natural Gas Storage Safety Monitoring

The Project will support CEC PIR-19-1, developing and demonstrating an integrated suite of novel, autonomous, and real-time natural gas wellbore integrity monitoring technologies based on distributed electromagnetic (EM) and fiber optic reflectometry methods. The approach combines novel guided-wave EM Time Domain Reflectometry (EM-TDR) with state-of-the-art Brillouin scattering-based Optical Time Domain Reflectometry (BO-TDR) methods for distributed monitoring of underground gas storage well borehole conditions over its entire length. The combination of EM-TDR and BO-TDR provides a multi-modal, multi-physics diagnosis of borehole health conditions by providing 1) EM signals from corrosion or stress-related borehole damages and 2) fiber optic strain and temperature signals from borehole operation, deformation, or leakage events. The project kicked off in July 2020, with field installation at PG&E's McDonald Island Underground Storage Facility completed in July 2021. In 2023, the project team successfully monitored several operation events, interpreting data via the installed fiber optic sensor systems. The team is on track to complete the remaining on-demand monitoring via the fiber optic sensor system by March 2024. Due to its low technology readiness level, the EM-TDR portion mainly focused on lab study and model development. Significant further development is needed after project completion. Upon completing this work by Q2 2024, PG&E can continue the non-invasive, minimally invasive, real-time, or on-demand monitoring of wellbore health. This will enhance the reliability and resiliency of underground gas storage, allow the identification of potential leakage risks, and support informed decision-making.

Co-Funders: CEC, LLBL, C-FER Technologies, Schlumberger

Start Date: 7/16/2020
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$2,280,000**
Total PG&E Cost:	**$440,000**
Total Co-Funding:	**$1,840,000**

Benefits

Fiber Optic Sensor Monitoring of Pipeline Strain under Geohazards

The Project supports Pipeline and Hazardous Materials Safety Administration (PHMSA) projects #6913G620P8000102 and #693JK32050007CAAP by using state-of-the-art distributed fiber optic sensing technologies to examine the feasibility of long-term monitoring of buried gas pipelines that are potentially vulnerable to ground deformation across faults and landslides related to PG&E's fault crossing mitigation project (R-1143) in Gilroy, California. The Project will develop and test materials and techniques for cost-effective, secure, and permanent attachment of sensors to pipelines. The researcher will work with domestic fiber-optic cable companies to manufacture a tightly coupled fiber-optic cable with a predicted lifetime of over 30 years that accurately measures strain, temperature, and acoustics on pipelines for long-term monitoring of pipeline structural performance when subjected to ground movements at fault crossing and landslide sites. In addition, the newly developed reliable, accurate, and economically viable direct strain monitoring tool for pipelines under geohazard conditions will provide full-scale field data to help calibrate the existing finite element analysis models for the first time in the industry. This will significantly improve the effectiveness and efficiency of geohazard assessment and mitigation. In 2023, the project team successfully tested and installed the systems at a PG&E field site. On-demand monitoring started in September 2023. The next step is to continue on-demand tracking and the development of related data analytics.

Co-Funders: PHMSA, OEM

Start Date: 8/11/2021
End Date: 12/30/2025
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$1,241,000**
Total PG&E Cost:	**$0**
Total Co-Funding:	**$1,241,000**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

Field Evaluation of Fiberoptic Sensing System of Pipeline at Fault Crossing

The Project sought to design, manufacture, install, and field-test a distributed fiber optic-based strain, temperature, and acoustic sensor system to measure and monitor pipelines. The new system—added to the current fault-crossing integrity management program tools at PG&E—measures and monitors strain, temperature, leak, soil strain, and movement. The system was field-tested at the Hayward Fault Crossing Distribution Integrity Management Program (DIMP) site in Union City, California, starting in October 2020. It was the first fiber optic sensing system for pipeline monitoring at PG&E. The primary focus of the Project included: 1) reliability and longevity of the direct fiberoptic cable attachment, 2) data processing, interpretation, correlation, and verification, 3) integration into the current practice, and 4) continuous on-demand monitoring every 6-12 months through the end of 2023. Monitoring pipeline integrity is considered a long-term, cost-effective strategy to reduce high-resolution inspection costs, e.g., by eliminating costly excavation while improving safety. In addition, the proposed fiber optic sensing system works as a new pipeline integrity and geohazard monitoring technology that can provide valuable, accurate, and complete profile field data unavailable in PG&E's current geohazard integrity management practice. In 2023, the project team completed the final on-demand monitoring and delivered the final project report. The experience and learning from this project have helped PG&E better plan and execute the fiber optic monitoring project at the Calaveras Fault-Crossing Mitigation Project (R-1143) site in Gilroy, California. PG&E will continue to employ the on-demand monitoring process as needed going forward.

Co-Funders: Paulsson

Start Date: 10/7/2020
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$30,000
Total Project Cost:	$60,000
Total PG&E Cost:	$50,000
Total Co-Funding:	$10,000

Benefits

Field Study of Skipper NDT 3D Mapping with D-1444 Project

In June 2022, Skipper NDT completed a crucial drone 3D mapping project for two parallel transmission pipelines at the Elkhorn Slough Site in Moss Landing, California. Drone 3D mapping was initiated in response to an urgent in-line inspection (ILI) Dig Project request and achieved the following results: 1) confirmed the pipeline location data, 2) identified discrepancies between the ILI mapping data and original GIS records, and 3) achieved significant cost savings in cofferdam construction. However, the 3D mapping of the pipeline on the west bank of Elkhorn Slough did not meet performance expectations. To address these issues and improve future operations, the Project set out two main objectives starting in October 2022: 1) to remap the west bank segment of the Elkhorn Slough pipeline using enhanced field practices and to identify reasons for the initial errors, and 2) to map a new pipeline segment at the Hollister site, comparing its accuracy against the new as-built records. Additionally, the project team collaborated with PG&E's Unmanned Aerial Vehicle Program to integrate Skipper NDT's mapping tool onto PG&E's drones for field deployment. By 2023, the team had successfully mapped the new Hollister pipeline segment, revealing a significant discrepancy in the as-built data's location accuracy, thereby demonstrating the superior accuracy of their mapping technique. This project has provided PG&E with a technologically and economically viable method for conducting 3D mappings of underground metallic pipelines. Furthermore, it has allowed safe, efficient, cost-effective surveys across water crossings and challenging terrains.

Co-Funders: SkipperNDT

Start Date: 7/1/2022
End Date: 8/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$130,000
Total PG&E Cost:	$60,000
Total Co-Funding:	$70,000

Benefits

Forced Resonance Imaging for Buried Pipeline Detection

The Project aimed to develop a subsurface gas pipeline 3D mapping technology with increased accuracy, focusing on locating plastic pipelines under various coverage and depth conditions. Until now, a viable solution to this challenge in the industry has not existed, which has resulted in excess excavation-related damage to the pipelines. The Bakhtar Radar (USAF EarthRadar), developed and verified under US Air Force Small Business Innovation Research programs, was modified to identify buried pipeline depth, dimensional details, and alignment. The tool is called the Bakhtar Buried Pipe Detector (BPD). BPD is expected to have the ability to automatically identify pipeline diameter, depth, type (metal or plastic), and alignment. Additionally, it will potentially screen and process field data, in real-time or near real-time, for further use, elevating the technology readiness level (TRL) to 7 or 8. In 2023, final field testing was completed with a probability of detection and characterization of about 25%. This indicates that further development is needed to give the industry a capable technology with a working prototype tool, especially when detecting plastic pipelines without tracer wires, which still lack a non-intrusive accurate locating solution under various coverage and depth conditions.

Co-Funders: CEC, OEM

Start Date: 6/30/2020
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$2,120,000
Total PG&E Cost:	$0
Total Co-Funding:	$2,120,000

Benefits

IM-1-06 2022 API-1163 Section 8—Level 1, 2 & 3 Research

This Project aimed to develop guidelines and procedures that utilities can use to implement the three levels of tool validation of the American Petroleum Institute (API) 1163 standard. This standard covers the qualification, selection, reporting, verification, validation, and use of in-line inspection (ILI) systems for onshore and offshore steel gas and hazardous liquid pipelines. The Project also outlined the complexity and cost increase associated with each level of validation. It developed 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 the statistical analysis outlined in the standard. Both were published in a report available to the public. The project team also held a webinar introducing the tool and statistical methods to project sponsors. An API 1163 committee reviewed the findings and determined to incorporate the results in future revisions of API 1163. 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. PG&E has reviewed the project's final report recommendations and is developing a plan for comparative testing of the new tool using existing methods. Once testing is completed, PG&E will evaluate implementation into its Transmission Integrity Management Program.

Co-Funders: PRCI Members

Start Date: 6/9/2022
End Date: 4/26/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$130,600
Total PG&E Cost:	$0
Total Co-Funding:	$130,600

Benefits

IM-1-08 2022 Pragmatic Application of MegaRule RIN 1—192.712 Toughness Values

The Pipeline and Hazardous Materials Safety Administration introduced the MegaRule RIN 1—192.712, which offers simplified guidelines for assessing the need for repairs on axial flaws detected by in-line inspections (ILI) based on Charpy energy values at 50°F. However, these guidelines do not adequately reflect the material toughness in various real-world conditions, leading to overly conservative assessments that require material toughness. To tackle this issue, this Project was launched in December 2022 to refine the application of MegaRule RIN 1—192.712. It proposed a tailored approach across three material categories: vintage base metal, Double Submerged Arc Welded (DSAW), and the Heat-Affected-Zone (HAZ) of Electric Resistance Weld (ERW) / Electric Fusion Weld (EFW), including some ERW fusion lines. The project delineated three analysis levels for each category based on available data: no data, some Charpy data, and both Charpy and traditional fracture mechanics test data. By 2023, a draft of the final project report was prepared and submitted for review. The forthcoming steps include completing this review process, making any necessary revisions, and obtaining final approval. This initiative aims to equip PG&E and other operators with scientifically grounded, practical guidelines for implementing the MegaRule requirements. These guidelines are designed to reduce inefficiencies and costs while maintaining safety standards.

Co-Funders: PRCI Members

Start Date: 12/12/2022
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$249,995
Total PG&E Cost:	$0
Total Co-Funding:	$249,995

Benefits

IM-3-03 2023 Comprehensive Review of SSWC Assessment

This Pipeline Research Council International (PRCI) Crack Management Strategic Research Priority (SRP) Project will perform a comprehensive review of previous work done in the industry and the current approaches to selective seam weld corrosion (SSWC) and look for a path for assessing the reported SSWC features. These new directions are formulated to overcome the inherent shortcomings in the current approaches. With the completion of this work, the PRCI Crack Management SRP will close the identified gaps related to how SSWC should be assessed via fracture mechanics models. The team will start by reviewing how the industry got to where it is, evaluating SSWC as a crack, and providing a path to gap closure. A critical evaluation of the current approaches should lead to understanding their limitations. The Project kicked off in June 2023. The team has completed Task 1 (Review of Past Analysis on SSWC Incidents) and Task 2 (Further Review and Analysis of SSWC Incidents). The next step is to complete Task 3 (New Direction) and the project by May 2024. Upon completion, the work will produce recommendations for assessing SSWC with these limitations in mind. The new directions identified in the Project would lead to significant improvements in managing SSWC, which should help PG&E and other operators make cost-effective decisions about how they approach SSWC, including satisfying regulatory requirements.

Co-Funders: PRCI Members

Start Date: 6/12/2023
End Date: 5/30/2024
Status: Active

2023 Funds Expended:	$1,920
Total Project Cost:	$100,000
Total PG&E Cost:	$1,920
Total Co-Funding:	$98,080

Benefits

INGAA JIP Recommended Practice Development for the Management of Landslide Hazards for Pipeline

The objective of the Project was to provide a high-level, concise framework for pipeline operators to utilize in managing geohazards, considering that no best practices or recommended procedures for geohazard data management currently exist. This set of documents includes a detailed recommended practice (RP) and a guide for implementing and executing a geohazard land movement management program. A secondary goal was to support potential rulemaking by the Pipeline and Hazardous Materials Safety Administration (PHMSA) related to geohazard management. The project team published an RP by the American Petroleum Institute (API) after reviewing various PHSMA and European datasets addressing gas and liquid incidents caused by Weather-Related Outside Forces and interviewed sponsors about their geohazard integrity management programs. In January 2023, the project team completed a high-level framework paper for geohazard management. In March 2023, they delivered to API RP 1187 a second paper on an RP for landslide integrity management. The two documents will aid PG&E and other operators with developing a geohazard management framework and landslide threat evaluation.

Co-Funders: INGAA, JIP Members

Start Date: 6/7/2022
End Date: 6/30/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$360,000
Total PG&E Cost:	$35,000
Total Co-Funding:	$325,000

Benefits

Internal Visual Inspection of Live Gas Services

In Q1 2022, the PG&E Gas R&D group and the Distribution Integrity Management Program Engineering (DIMP-E) engaged ULC Technologies to research, develop, and deploy an inspection system that could internally inspect live gas services from the riser to the gas main. The objective was to confirm fittings and transitions from plastic to metal pipe. Such confirmation typically requires excavation, which is costly and impacts customer property. Following excavation, the disturbed property may require restoration, increasing costs further. ULC Technologies designed a 7mm optical camera and stuffing box to facilitate camera insertion at the gas meter riser. During Q2 2022, the project team tested at four East Bay locations. The results were favorable: the stuffing box performed as designed, although the system could not produce an image of high enough quality for DIMP-E to approve its use. In addition, the team proposed adding a way to detect ferrous material to the system, which would enhance the system's capability to differentiate plastic from steel beyond just a visual image. In Q3 2022, ULC Technologies provided an improved system with a redesigned high-definition optical camera and an induction proximity sensor. Extensive lab testing during Q4 validated the system's ability to provide the required image quality, and the induction proximity sensor could send a definitive signal to the operator when a transition from plastic to steel was detected. In July 2023, DIMP-E approved the system for service line inspections. The system is expected to reduce the costs of gas service inspections, increasing affordability for all customers and reducing the cost impacts on customers where these inspections occur.

Co-Funders: None

Start Date: 3/1/2022
End Date: 7/25/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$34,170
Total PG&E Cost:	$34,170
Total Co-Funding:	$0

Benefits

M2016-002 Ph2 Odor Detection Threshold Study

The objective of the 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 understand each variable's effects better. The project team reviewed 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 odorants 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 PG&E 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, SoCalGas

Start Date: 10/1/2019
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,281,783
Total PG&E Cost:	$117,405
Total Co-Funding:	$1,164,378

Benefits

M2016-003 Ph. 2 Development and Testing of RFID for Coiled PE Pipe-Universal Locator Development

Since 2016 PG&E, NYSEACH and France's GRTgaz Research & Innovation Center for Energy (RICE) have been researching the development of coils of PE pipe equipped with RFID markers that enable detection of the pipe in the absence if a locating wire or a broken wire. The RFID 'macro-tags' would allow data (pipe inspection records, installation details) to be written to and then retrieved following installation. This project is co-funded by GRDF and NYSEARCH. Between Q4 2022 and Q3 2023 tests were conducted. Lab tests at RICE demonstrated detection accuracy between 10 cm and 15 cm. The accuracy of the detection was greatest when the macro-tag faces toward the ground surface. Water, nearby metallic objects or another macro-tags were found to affect accuracy by affecting signal quality and power. Integrity tests showed the pipe with installed macro-tags performed well during tensile strength tests but did not perform well during installation using HDD when macro-tags sheared off. Field testing did result in similar accuracy to the laboratory tests. Given the challenges, NYSEARCH members decided to end the current project and requested RICE determine what measures may be implemented to ensure the macro-tags do not shear off the pipe when using HDD. Additionally, the macro-tags as designed require a detector with greater power to detect them at great depths, which would require a hardware redesign. NYSEARCH also asked RICE to reconsider designing the macro-tags to be strictly detection related which could use existing detectors on the market. Development of this technology would increase locating accuracy, making locating more efficient and reducing operational costs. Additionally, locating these lines accurately reduces the risk of dig-ins, increasing safety.

Co-Funders: NYSEARCH Members, GRDF

Start Date: 9/3/2018
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$1,666,080
Total PG&E Cost:	$801,148
Total Co-Funding:	$864,932

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

M2016-006 Ph2 Energy Harvesting in Gas Industry Applications

The objective of the 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. The project team delivered the final report and concluded that many of the approaches, including thermo-electric, kinetic vibration, piezoelectric, and fuel cells, did not prove to be sufficiently mature enough to provide continuous, reliable power.

Co-Funders: NYSEARCH Members, SoCalGas

Start Date: 9/3/2018
End Date: 7/13/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$191,535
Total PG&E Cost:	$25,540
Total Co-Funding:	$165,995

Benefits

M2017-006 Ph2 Explorer Pipeline Cleaning Tool for Liquid with Flow

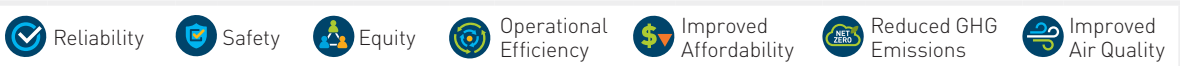
The objective of the Project was to develop and test the expansion of the 20/26 Explorer robot's capability to continuously inspect pipelines without needing to stop for liquid removal. The InvoDane 20/26 Explorer robot can inspect "difficult-to-inspect" pipes while remaining in service. Before this 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. The project team designed pre-commercial, liquid-capable drive tracks and magnet bars and tested them 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. After completing the submersion, pressure, and overall system-level tests, the modules advanced into the commercialization phase. These improvements in the Explorer robot fleet could allow PG&E 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: 6/1/2021
End Date: 7/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$1,305,170
Total PG&E Cost:	$80,000
Total Co-Funding:	$1,225,170

Benefits



M2018-009 Ph2 NJIT Advanced Terahertz (THz) Imaging & Spectroscopy for Non-Destructive Evaluation of Polyethylene Pipes

The objectives of the Project are to 1) 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 2) 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 help assess the quality of questionable BF joints and 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 than 'normal' BF joints. Sand defects showed 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. PG&E will utilize the knowledge gained to demonstrate and incorporate the THz technology into its existing processes and procedures.

Co-Funders: NYSEARCH Members

Start Date: 8/10/2020
End Date: 9/30/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$265,913
Total PG&E Cost:	$13,837
Total Co-Funding:	$252,076

Benefits

M2019-004 Ph2 Development of Mercaptan Sensor Systems with Non-Radioactive Ionizer

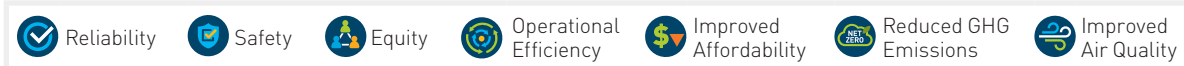
The Project aims to advance the sensor performance of a portable mercaptan sensor that can serve as an in-line quantification tool to replace sniffing checks and for use as a 'smart nose' in mobile applications to detect mercaptans accurately. The project team delivered and tested a pre-commercial prototype for PG&E, which requested further enhancement. A successful outcome for this project would result in a new, marketable technology that would allow PG&E, for the first time, to measure the concentrations of mercaptans at levels comparable to those of the human nose.

Co-Funders: NYSEARCH Members, PHMSA

Start Date: 9/21/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$923,147
Total PG&E Cost:	$49,610
Total Co-Funding:	$873,537

Benefits



M2019-009 Standard Library of PE Joint Samples with Embedded Defects for NDE Tool Validation

The Project sought to produce a polyethylene (PE) pipe butt-fusion (BF) sample library of joints with known defects. The gas industry will use the sample library to validate current and future non-destructive evaluation (NDE) technologies claiming to be capable of detecting PE butt fusion defects. NYSEARCH Members have invested considerable resources into NDE technology development through extensive testing with The Welding Institute. The sample library provides resources to validate any NDE tool purported to be capable of identifying defects that would impact the integrity of BF joints. The Phase-I work completed in 2022 successfully constructed a total of 41 butt-fusion joints with high- and medium-density PE pipes of two and eight-inch diameters, representing the range of fusion joint qualities that might be encountered, including no imperfections, fine particulate contamination, coarse particulate contamination, grease contamination, cold fusions, and planar lack-of-fusion flaws. Phase 2 work completed in 2023 produced two additional eight-inch diameter samples for detectable examples to apply to terahertz and microwave technology and two eight-inch diameter samples for aging PE pipe containing slow-crack growth. The team performed mechanical tests, computed tomography, and phased array ultrasonic testing on identical joints to make sure all the joints performed as expected per appropriate industry standards. This Project concluded in December 2023 when NYSEARCH received all samples. PG&E is benefiting from this library of defective PE butt-fusion joints since the defective pieces will be used to evaluate NDE technologies on other projects that PG&E is sponsoring in the future.

Co-Funders: NYSEASRCH Members

Start Date: 1/1/2020
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$990,420
Total PG&E Cost:	$48,465
Total Co-Funding:	$941,955

Benefits

M2019-010 Ph2 Eclipse Scientific Red/Green Light NDE Tool for PE Butt Fusion Joints

The Project aims to develop an automated non-destructive examination (NDE) tool 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 essential 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 faulty 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 were scanned and analyzed using an optimized projection-focused, phased-array technique designed for the inspection of medium-density-PE and high-density-PE BF joints. The results indicated that all common joint flaws can be 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 PG&E since any defect in the joint would be identified before placing the pipe into service. PG&E will utilize the knowledge gained in this project for possible in-house evaluations when a prototype is available.

Co-Funders: NYSEARCH Members

Start Date: 7/25/2022
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$442,000
Total PG&E Cost:	$77,000
Total Co-Funding:	$365,000

Benefits

M2020-004 Multi-Technology Test Program of NDE for PE Pipe Joints

The Project sought to define and prepare a program to effectively test, evaluate, and validate any non-destructive examination (NDE) technology that can assist in assessing plastic pipe joints. The Project responded to the needs of the industry, which lacks a solid test program to verify polyethylene (PE) Joint NDE performance capabilities. Industry regulatory groups also encourage gas companies to bring adequate NDE technology into standard operational routines. The project tasks include 1) development and structure of an NDE validation program, 2) preparation of the NDE inspection location, and 3) final preparation review for NDE validation testing. In 2023, the project team completed all remaining tasks and produced a validation process flow chart. The industry has pursued a capable NDE method for inspecting plastic pipe joints for quite some time. Several NDE technology providers have claimed to have capable tools, but the industry could not confirm their claims. This program and subsequent test project(s) will provide the context and test structure to evaluate and validate NDE technology providers' technologies/tools. PG&E will be able to avoid internal development efforts by adopting this program to effectively evaluate and qualify the interested NDE tools and develop the related field procedure.

Co-Funders: NYSEARCH Members

Start Date: 1/1/2021
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$92,745
Total PG&E Cost:	$7,275
Total Co-Funding:	$85,470

Benefits

M2021-004 Electromagnetic Time Domain Reflectometry (EM-TDR) for Pipeline Integrity

The objective of the 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 buried and aboveground pipes with known defects. The team analyzes test results and compares them to a database of the actual pipe defects. The results will be used to complete numerical simulations for a second field trial in early 2024. This study provides information on the ability to obtain more data on difficult-to-access pipeline portions 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. PG&E 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: 10/1/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$339,000
Total PG&E Cost:	$28,850
Total Co-Funding:	$310,150

Benefits

M2021-005 Odor Detection Study for Blended Hydrogen

The Project aims to determine if introducing hydrogen to natural gas blends changes the perception of natural gas odorants. Federal regulations require odorant injection into natural gas to provide consumers with the first line of defense to detect natural gas leaks. As utilities transition to new fuels such as hydrogen, more data and information must be collected 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 testing one odorant and odorant blend. The project scope calls for testing a second odorant commonly used by the gas industry. This last test and the final report are scheduled to be completed in Q1 2024. PG&E 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, Jeong, SoCalGas

Start Date: 9/21/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$294,755
Total PG&E Cost:	$21,835
Total Co-Funding:	$272,920

Benefits

M2021-006 Ph2 Explorer Wireless Range Extender

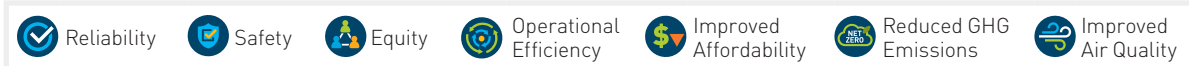
The objective of the Project was to build upon initial research to take the Explorer Wireless Range Extender through the technology readiness levels to commercialize the existing Explorer In-Line inspection robot with an expanded wireless communication range while deployed in the gas pipeline. To date, 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 into Explorer 20/26 and a report detailing the tests carried out, analyzed field testing results, and recommendations for the next steps. PG&E 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, OEM

Start Date: 5/16/2022
End Date: 11/9/2023
Status: Completed

2023 Funds Expended:	$50,508
Total Project Cost:	$542,400
Total PG&E Cost:	$59,675
Total Co-Funding:	$482,725

Benefits



M2021-006 Ph3 Explorer Wireless Range Extender

The Project focuses on field testing technology to extend the range of the wireless communication system on Explorer robots. The proposed scope calls for two field deployments. The first would be carried out at a NYSEARCH Test Bed (Johnson City, NY), and the second in a pipeline operated by a funding company. The project is organized into three tasks: Task 1—Deploying Explorer 20-inch tool in Open Pipeline at the NYSEARCH Test Bed to verify the reliable and robust operation of the entire system; Task 2—System Updates, the lessons learned from the field deployment in Task 1 are implemented on the system by adopting necessary changes in the design and functionality of the system; Task 3—Testing in a Real Pipeline will involve the deployment of Explorer 20/26 in a real pipeline (preferably not in operation) to initiate and operate the system as part of a commercial endeavor, incorporating multiple Remote Earth Modules (REMs) for comprehensive performance assessment. The Project kicked off in November 2023 and is targeted for completion by Q3 2024. Having achieved the following goals: 1) developed a full range of Explorer platforms, 2) developed a suite of sensors able to detect corrosion defects, cracks, and mechanical damage, and 3) developed a system to provide additional power to the robot via energy harvesting methods, the Project now focuses on extending the range of the wireless system used on the robots. This is the last known barrier to long-range operations, significantly higher operational efficiencies, reduced inspection costs, and lower-risk inspections. The final project deliverables are a report and a field-ready prototype for commercialization.

Co-Funders: NYSEARCH Members

Start Date: 11/1/2023
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$194,388
Total PG&E Cost:	$23,565
Total Co-Funding:	$170,823

Benefits

M2021-009 High-Resolution MFL for Explorer Series of Robotic Platforms—Feasibility Study

The objectives of the 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, a feasibility analysis report, and recommendations for the next steps. Improving the sensor capabilities of the Explorer family of robotic platforms will benefit the PG&E In-line Inspection program because smaller sensors will enable higher spatial and circumferential resolution and detectability of more minor defects with higher resolution. As a result, operators will have higher confidence levels in obtained measurements.

Co-Funders: NYSEARCH Members, PHMSA

Start Date: 4/30/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$215,084
Total PG&E Cost:	$23,900
Total Co-Funding:	$191,184

Benefits

M2021-011 Extending Energy Harvesting to Other Explorer Sizes—A Feasibility Study

The objective of the 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 precisely 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 the next steps. In 2023, the project resumed work and began an analysis of the power consumption and tow force of the robots in various pipe sizes and conditions. This project, if successful, will expand the inspection capabilities of the Explorer robotic tools and enable the PG&E in-line inspection program to collect more data and conduct longer inspections.

Co-Funders: NYSEARCH Members

Start Date: 4/30/2021
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$193,948
Total PG&E Cost:	$19,395
Total Co-Funding:	$174,553

Benefits

M2022-001 UTTO vLocate®—Gas Pipeline RTK Mapper & Virtual Locating Device

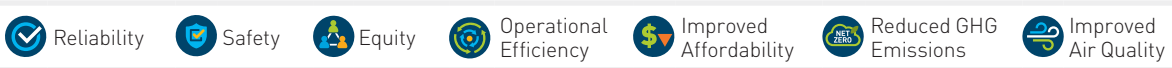
The objective of the Project was to develop and evaluate UTTO's RTK vLocate® and Mapping tool so that it may be used in the natural gas industry as a high-accuracy, asset-capture device for accurately locating and mapping buried assets. PG&E proposed this project to NYSEARCH members following initial testing in-house. The project successfully enhanced the system with 1) the ability to search and select a public or private RTK network manually; 2) the development of a custom list of asset type identifiers and classifications for facility asset types that can be assigned during the mapping process and their attribute data stored with any captured points; and 3) hardware development of a laser alignment accessory to enable sub-meter precise positioning and mapping. NYSEARCH members proposed additional enhancements during testing that are being considered as part of a potential future project phase. Once the manufacturer implements the upgrades, the handheld tool can be a beneficial low-cost addition to the PG&E asset locating and mapping toolbox, providing a fallback for relocating difficult-to-locate assets (e.g., plastic pipe with tracer wire degradation).

Co-Funders: NYSEARCH Members

Start Date: 8/22/2022
End Date: 7/24/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$185,180
Total PG&E Cost:	$30,860
Total Co-Funding:	$154,320

Benefits



MAT-1-8 2023 Post-Heating and Interpass Control as an Alternative to Delayed Nondestructive Examination

The Project will define weld procedure parameters that may be used to ensure sufficient hydrogen effusion and mitigate the risk of hydrogen cracking for Shielded Metal Arc Welding (SMAW) in-service fillet weld (Phase I) and SMAW girth weld production/tie-in (Phase II) procedures. The produced guidance will cover demonstrated weld time to peak hydrogen, the time after which hydrogen cracking should not commence, and general information on which parameters are most effective in controlling inspection delay time. Users can compare their welding procedure to the developed guidance and identify minimum recommended inspection delay times or post-heating and develop recommended welding procedure parameters that may be used to reduce inspection delay time while ensuring that hydrogen cracks do not enter service. This, in turn, will increase efficiency by reducing costs and improving safety for SMAW weld procedures. After the project kickoff in June 2023, the team identified pipe, sleeve, welding parameters, and weld geometries to encompass applications of interest to Pipeline Research Council International members. The team also identified electrodes of interest, developed electrode handling recommendations, and completed hydrogen effusion testing. The next steps are to conduct hydrogen diffusion modeling and complete the project by June 2024. The weld inspection delay of 12 to 48 hours can be eliminated or reduced upon project completion. This will benefit PG&E and other operators by improving field operation efficiency (reducing cost and increasing safety) for SMAW weld procedures.

Co-Funders: PRCI Members

Start Date: 6/8/2023
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	**$9,426**
Total Project Cost:	**$224,200**
Total PG&E Cost:	**$20,000**
Total Co-Funding:	**$204,200**

Benefits

MAT-7-2 2023 Hard Spot Susceptibility Review—Pipe Manufacturers, Pipe Type, Vintage

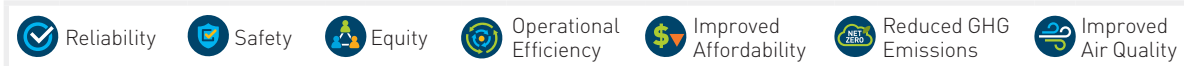
The PRCI Crack Management Strategic Research Priority (SRP) Project aims to develop guidelines to support operators who need to assess when an in-line inspection (ILI) survey for detection of hard spots should be performed. Additionally, as the industry pursues the energy transition, hydrogen-induced cracking (HIC) and hydrogen-assisted cracking (HAC) will become more paramount as they relate to hard spots in vintage steel. The specific guidelines to be developed will be required to align with the American Petroleum Institute Recommended Practice 1176, Assessment and Management of Cracking in Pipelines. This 12-month project began in April 2023, with the project team completing compilation of hard spot cooling rates and hard spots per mile by pipe manufacturers from ILI data. The team initiated the development of a prioritization scheme and the next step is to complete the a decision and prioritization process. The project is expected to be completed in Q2 2024 with the issuing of the final report. PG&E and other operators will be able to reference the guideline to determine whether a hard spot ILI assessment is required. By understanding where the hard spot threats are most likely to be and targeting ILI activities at those locations, PG&E and the industry will more rapidly identify hard spots and implement mitigation strategies in more efficiently and effectively.

Co-Funders: PRCI Members

Start Date: 4/8/2023
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	**$1,048**
Total Project Cost:	**$150,000**
Total PG&E Cost:	**$2,820**
Total Co-Funding:	**$147,180**

Benefits



MAT-7-2A 2023 New Multi-Year Project: Hard Spot Detection

This three-phase Project seeks to develop improved pipe material hard spot detection/sizing in response to the National Transportation Safety Board (NTSB) report NTSB/PIR-22/02 re: Danville, Kentucky. The Project builds on the Pipeline Research Council International (PRCI) MAT-7-2 Hard Spot Susceptibility Review project results. Phase 1 will focus on building a more robust framework for hard spot management through gap analysis. Phase 2 will focus on evaluating the performance of currently commercialized hard spot in-line inspection (ILI) tools and identifying the areas for improvement associated with both the tools and analysis. Phase III will run a machine learning model of inputs reviewed in phases I and II to enhance operator guidance. After the kick-off in September 2023, the project team prepared the test pipe samples for a non-destructive exam (NDE) at the PRCI Technology Development Center in mid-December. The next step is to complete the NDE and start the ILI test string build. Upon successful completion, this work will provide PG&E and other operators with integrity management tools for hard spots. The work will also be instrumental in preparing operators for the likely upcoming Pipeline and Hazardous Materials Safety Administration advisory bulletin regarding hard spots. In addition, the work will help future hydrogen projects as hydrogen is a significant contributor to hard spot incidents.

Co-Funders: PRCI Members

Start Date: 9/11/2023
End Date: 2/28/2025
Status: Active

2023 Funds Expended:	$10,000
Total Project Cost:	$848,391
Total PG&E Cost:	$25,614
Total Co-Funding:	$822,777

Benefits

MD-5-03 2022 Development of Guidance Document for Performing ECA in Accordance with Megarule 192.712 (c)

This Pipeline Research Council International (PRCI) Mechanical Damage Strategic Research Priority Project seeks to provide pipeline operators with a set of clear guidelines for performing engineering critical assessment (ECA) on mechanical damage features of various types, as allowed and per CFR 192.712(C). The work focuses on 1) defining critical strain values using various approaches (Ductile Failure Damage Indicator, Strain Limit Damage, American Society of Mechanical Engineers B31.8, and others); 2) defining methods for accommodating secondary features, including girth welds, seam welds, metal loss (as reported by in-line inspection, corrosion, (Gas Metal Arc) GMAs, etc.; 3) defining various methods available for estimating fatigue life both as a screening method and detailed analysis where detailed pressure data is available; 4) simplifying Kmax calculations as described in American Petroleum Institute recommended practice 1183 to utilizeto utilize Spectrum Severity Indicator (SSI) or cyclic index values instead of detailed mean stress and pressure ranges; and 5) defining a process for estimating remaining fatigue life for dents with metal loss features assuming metal loss as cracks in scenarios where metal loss cannot be positively ruled out to be a gouge. The Project kicked off in July 2022. In 2023, the project team iterated on the final report before its approval in December. The successful completion of this work provided PG&E and other operators with a set of clear guidelines for performing ECA on mechanical damage features of various types, per CFR 192.712(C), which will 1) help potentially avoid numerous unnecessary digs that would need to be performed if using the prescriptive guidance as provided in CFR 192 and 2) lead to safety, reliability, efficiency, and cost reduction benefits.

Co-Funders: PRCI Members

Start Date: 6/7/2022
End Date: 12/1/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$180,000
Total PG&E Cost:	$2,698
Total Co-Funding:	$177,302

Benefits

NDE-2-15 2023 SSWC Identification, Sizing, and Measuring Grooving Ratio in the Ditch

The Project's primary goal is to develop in-the-ditch evaluation methods and tools necessary to identify 1) external selective seam weld corrosion (SSWC) versus other defects, such as lack of fusion or seam trim; 2) measure external SSWC depth and length; and 3) to outline pros and cons for each method. Relevant seam types are double-submerged arc welding (DSAW), spiral submerged arc welding (SSAW), electric fusion welding (EFW), and electric resistance welding (ERW). The Project kicked off in October 2023 and is actively conducting various non-destructive examination (NDE) methods of characterizing field samples. The next step is to verify NDE data by destructive testing of some of the samples. Upon successful completion, this project will provide PG&E and other operators guidelines for positive identification of SSWC and proper measuring equipment and techniques for "in the ditch." Examples include 1) guidelines for measuring grooving ratio following the guidance in EC-2-12, 2) SSWC interaction rules, 3) SSWC morphology for different seam types in liquid and gas pipelines, and 4) guidelines for choosing the appropriate assessment model (notch versus crack) using results of IM-3-03 based on the morphology found in the ditch. These guidelines will improve the cost-effective assessment and mitigation of SSWC anomalies.

Co-Funders: PRCI Members

Start Date: 10/16/2023
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$8,946**
Total Project Cost:	**$325,000**
Total PG&E Cost:	**$20,000**
Total Co-Funding:	**$305,000**

Benefits

NDE-3-6 2022 Review and Evaluation of Pipe Stress Inspection Techniques for Onshore Pipelines

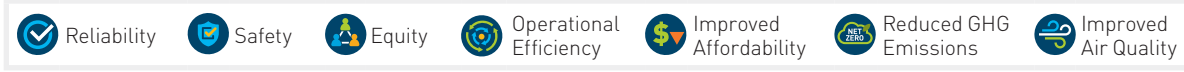
The Project will provide a comprehensive review, an operation manual, and a guideline document for all the known pipeline stress/strain detection technologies, including in-line inspection (ILI) technologies, in-the-ditch stress detection, and above-ground screening/estimation. The final goal is to understand better available technologies and their viable deployment in the field. This will complement the current mainstream inspection practices that mainly rely on anomaly geometry-based detection/characterization and have a low probability of detection/characterization or inaccurate sizing for crack-like challenging anomalies, resulting in unnecessary costly ILI or excavation. The Project kicked off in Q3 2022. The revised draft of the Literature Review Report is expected for final review/approval in early February 2024. The remaining lab and field tasks are on track for completion by October 2024, with targeted final project completion by December 2024. Upon successful completion, this work will also deliver an analysis report on the characteristics and applicability of different stress-detection technologies and original macro stress test raw data obtained from various equipment under different working conditions at the field sites at PipeChina, an overseas Chinese pipeline operator. These documents will allow PG&E and other operators to understand the field's design focus, parameter requirements, and use of the detection equipment guide. Based on the testing methodology and shared parameters/data from this project, PG&E, and other operators will be able to compare indicators of existing equipment and optimize or further improve the equipment, leading to significant cost benefits.

Co-Funders: PRCI Members

Start Date: 11/8/2022
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$8,429**
Total Project Cost:	**$237,000**
Total PG&E Cost:	**$20,000**
Total Co-Funding:	**$217,000**

Benefits



NDE-4-12 Ph2 2019 Continuous Improvement of ILI Capabilities

The American Petroleum Institute and Association of Oil Pipe Lines's R&D Work Group and Pipeline Research Council International (PRCI) are undertaking a Joint Industry Project to develop pull test strings and protocols to validate and test the performance specifications published for various crack in-line inspection (ILI) tools. As part of the PRCI Crack Management Strategic Research Priority Program, this project continuously leverages three well-known engineering firms' existing expertise in ILI crack technologies, deep knowledge of crack defects and their growth mechanisms, laboratory capabilities, and experience performing metallurgical analysis and defect characterization. In 2023, the project team completed most ILI tool pull testing work at the PRCI Technology Development Center in Houston, Texas, ILI data analysis, Non-Destructive Examination (NDE) flow profile characterization, and ILI-NDE data alignment. Due to difficulties in matching and comparing ILI and NDE data, some pipe body defect fabrication is on hold, and the team expects additional work and meetings between ILI and NDE firms. The next step is to analyze the ILI data and solve the ILI-NDE data alignment issue. The project completion timeline is likely delayed to December 2024. Once completed, this work will help PG&E and other operators identify and address the underlying physics-based reasons why cracks are hard to detect, identify, and size. It will support PG&E in conducting fair, unbiased, and accurate assessments of the current commercial ILI crack detection capabilities, thus ensuring sound and defendable decisions regarding cost-effective crack management.

Co-Funders: PRCI Members

Start Date: 12/12/2019
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,287,010
Total PG&E Cost:	$21,740
Total Co-Funding:	$1,265,270

Benefits

NDE-4-13 2020 Selective Seam Weld Corrosion Detection with In-line Inspection Technologies

The objective of the 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 can better detect SSWC. The Project will provide pipeline operators with up-to-date knowledge about ILI capabilities to detect SSWC and differentiate it from coincidental corrosion interacting with the long seam weld. This knowledge will help them make informed decisions about managing pipelines with SSWC or corrosion. In 2022, the vendor completed acid etching to create test samples with SSWC and corrosion. They delivered documentation that addresses raised edges of electrical-discharge-machined notches and adjacent corrosion. PG&E can use these results and identified tools to more accurately detect SSWC in its pipelines, improving safety and reliability.

Co-Funders: PRCI Members

Start Date: 7/27/2020
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$811,500
Total PG&E Cost:	$39,137
Total Co-Funding:	$772,363

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

NDE-4-13A 2023 Seam Weld Corrosion Detection with ILI Technologies

The Project aims to provide users with the knowledge of current in-line inspection (ILI) capability to detect selective seam weld corrosion (SSWC) and differentiate it from coincidental corrosion that interacts with the long seam weld. A second targeted result is a step change in ILI capabilities for detecting, identifying, and characterizing SSWC. This Project is an expansion of Pipeline Research Council International (PRCI) NDE 4–13—Selective Seam Weld Corrosion Detection with In-line Inspection Technologies, allowing the team to analyze more data, observe a larger sample, and ultimately understand how well ILI technology can differentiate SSWC from coincidental corrosion that interacts with the long seam weld. ILI technology will focus on the latest generation of circumferential magnetic flux leakage inspection tools with a higher density of sensors, as well as ultrasonic crack detection and electromagnetic acoustic transducer crack detection tools to detect any cracks that can develop at the tip of the "V" notch associated with SSWC. After kick-off in July 2023, project execution was rolled to NDE-4-13 by adding three more ILI vendors and four more ILI tools into the ILI pull testing and the subsequent data analytics. 4 of 7 ILI vendors have been provided feedback and one more vendor data has been received for analysis. The next step is to continue the study with seven ILI vendors. Upon successful completion, this work will inform decision-making around pipeline management at PG&E and other operators with benefit from the knowledge of shared operator and ILI provider experiences and the current ILI capability in SSWC detection and characterization.

Co-Funders: PRCI Members

Start Date: 8/2/2023
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$10,000
Total Project Cost:	$275,412
Total PG&E Cost:	$10,000
Total Co-Funding:	$265,412

Benefits

Open Solutions for Historical Climate Data for California

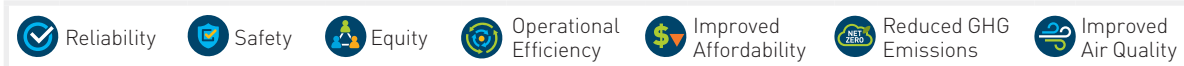
PG&E has been working with Eagle Rock Analytics since 2020 to produce a data assimilation platform that serves as a central location for weather-related data of interest to natural gas stakeholders. Project work continues along the two main focuses: 1) assessing climate implications for reliability planning for fossil gas and 2) producing hourly quality-controlled versions of hourly weather data. For Focus 1, the project team organized, facilitated, and analyzed working group discussions with gas and other energy industry stakeholders to understand and better serve their specific weather data needs and concerns. For Focus 2, the project team has produced a series of quality-controlled weather datasets, including those required by related Electric Program Investment Charge grants, developed protocols for quality assurance/quality control (QA/QC) and data formatting, identified best practices and metadata standards, and analyzed available hourly data by variable and data source. Converting QA/QC processes to be entirely cloud-based is underway. The Project supports research efforts under California's Fifth Climate Change Assessment. The design and implementation of this work will ensure that historical climate data relevant to natural gas sector planning can be continuously updated and maintained at a low cost to ratepayers.

Co-Funders: Eagle Rock Analytics, Inc., CEC

Start Date: 9/27/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,000,704
Total PG&E Cost:	$0
Total Co-Funding:	$1,000,704

Benefits



Performance-Based Earthquake Engineering Assessment Tool

PG&E's Gas R&D, Transmission Integrity Management Program, and Geosciences Department participated in this research project's technical advisory committee (TAC) meetings. The objective was to develop a seismic risk assessment software, OpenSRA, for gas transmission lines and storage wells. OpenSRA has the following features: 1) free open-source software that may be accessed from a public website supported by the Pacific Earthquake Engineering Research Center; 2) analyses of scenarios performed locally on a user's desktop computer, ensuring inputs and results remain confidential; 3) site-specific analyses allowing the user to input information about specific earthquake hazards and specific systems; 4) risk forecasting using past earthquakes and estimated ground motions such as estimated ground motions, fault displacement, landslides, and liquefaction; and 5) a graphical user interface for input and analysis output that enables the user to visualize scenario results. The new seismic risk assessment tool will result in more reliable risk estimates, thereby enabling PG&E to assess seismic risk and direct mitigation efforts more fully to the most vulnerable components, enabling prioritization of implementing appropriate mitigation efforts. Remediation and risk-based construction can increase safety by reducing vulnerabilities in the highest-risk areas, lowering costs, and minimizing gas releases by preventing failures. Resources for mitigation, operation, and maintenance programs will be efficiently and effectively disbursed. The research was completed in Q1 2023.

Co-Funders: CEC, UC Berkeley, UC Berkeley Pacific Earthquake Engineering Research Center, UC San Diego, Lawrence Berkeley National Laboratory

Start Date: 1/30/2020
End Date: 3/30/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$4,940,158
Total PG&E Cost:	$0
Total Co-Funding:	$4,940,158

Benefits

Real-Time Kinematic (RTK) Base Stations & Trimble's Pivot Virtual Reference Station Network Solution

The objective of the Project was to bring Trimble's Virtual Reference Station (VRS) Network solution in-house and online for increased operating precision and efficiencies. The Trimble Pivot VRSNet software provides real-time kinetic (RTK) correction data to PG&E's GPS devices by leveraging its network of base stations to offer high-accuracy GPS data in real-time. Land Surveying & Engineering Support (LS&ES) has managed the RTK VRS network in-house since 2023 to allow PG&E to maintain and control its geospatial data backbone for future mapping projects or any other application that utilizes GPS. The Project provides a unified backend framework for all lines of business to leverage common GIS data and support a more robust governance model like One PG&E.

Co-Funders: CSDS (Trimble)

Start Date: 7/1/2021
End Date: 9/29/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$266,225
Total PG&E Cost:	$266,225
Total Co-Funding:	$0

Benefits

ROW-3-1 2018 Airborne Automated Threat Detection System

The primary objective of the Project was to validate the performance of a remote sensing system capable of automated multi-threat surveillance, monitoring, and rapid reporting operating on a long-range, long-endurance, medium-altitude unmanned aircraft capable of patrolling hundreds of miles of pipeline right-of-way per flight. The unmanned aircraft system test program was evaluated at test sites in Pendleton, Oregon, Woodbine, New Jersey, and San Joaquin Valley, California, using American Aerospace sensors, unmanned aircraft, test facilities, and equipment. The Project included four flight campaigns that 1) generated data from multiple sensors over staged and opportunistic targets, 2) tested multiple algorithms, and 3) measured key performance parameters on aerial patrol. In what is believed to be an industry first, the project team attempted to develop industry-wide aerial patrol performance guidance—including key performance indicators—for sensor-based imminent threat detection sensitivity, reliability, robustness, and accuracy, in alignment with industry standards for existing operator leak detection programs. PG&E has been using drones for limited inspections. It can now use an automated threat detection system on board a medium-altitude, long-endurance, unmanned aircraft capable of flying beyond the visual line of sight for routine patrol and surveillance and as a risk reduction solution for gas transmission pipeline rights-of-way. Unmanned systems will increase operational efficiency, reduce operating costs, and reduce rate pressures on customers.

Co-Funders: PRCI Members, American Aerospace Technologies

Start Date: 5/1/2019
End Date: 10/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$315,000
Total PG&E Cost:	$4,999
Total Co-Funding:	$310,001

Benefits

Seismic Risk Assessment and Management of Natural Gas Pipelines & Storage Facilities

In 2019, PG&E began providing expertise and input to the project research team. The objective was to reduce the risks posed by earthquakes and landslides to PG&E's natural gas pipelines and storage facilities. The Project developed an open-source application using state-of-the-art seismic hazard assessments and Bayesian network models to quantify the earthquake ground motion, fault displacement hazard, landslide, and liquefaction risks for natural gas storage and pipeline infrastructure. The operational concept of the software platform allows users to 1) conduct risk assessment at different levels of complexity and sophistication, depending on the needs and objectives of the analysis; 2) use the platform as a decision support system for gas infrastructure proactive risk management, tracking, and use of leading risk indicators; and 3) develop or upload new models and data if desired. The Project also provided a step-by-step guide and examples of how to run various analyses and use different risk management features of the software. The software will allow PG&E to understand the risks better and implement mitigation measures, increasing safety. Additionally, it will enable the allocation of appropriate resources more efficiently and effectively, reducing operating costs and reducing rate pressures on customers. The Project was completed in Q4 2023.

Co-Funders: CEC, UCLA

Start Date: 1/16/2020
End Date: 5/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$3,485,255
Total PG&E Cost:	$0
Total Co-Funding:	$3,485,255

Benefits

Steel Thermal Compression Sleeves for Pipeline Repair

This PG&E internal Project is to evaluate a promising thermal compression sleeve repair product developed based on the Type-A repair product that has been used for various other applications in the industry for decades. Integrity inspections are a top priority for gas transmission engineering. This technology could reduce PG&E's mitigation costs and durations and improve the safety of the gas transmission system. The project team began work in early 2023 and completed all related product testing and evaluation, field crew preliminary training, and internal field procedure development by the end of the year. Field deployment is expected in 2024. Based on the successful completion of this work, PG&E now has an in-service method for repairing cracks or other crack-like planar defects in pipeline seam welds, which will significantly reduce the related repair costs at no sacrifice of safety and reliability.

Co-Funders: None

Start Date: 3/22/2023
End Date: 11/30/2023
Status: Completed

2023 Funds Expended:	$23,963
Total Project Cost:	$23,963
Total PG&E Cost:	$23,963
Total Co-Funding:	$0

Benefits

US-4-04 2022 Advancement of Through-Tubing Case Inspection for Underground Storage Wells

The Project aims to advance sensor technology in through-tubing inspection tools, increasing their ability to detect, measure, and characterize metal loss features. The project team will work with 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 reliability-based casing integrity assessment framework. Tool performance evaluation for several logging tests is ongoing. Before 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. PG&E is planning to perform a field demonstration of this technology in 2024. Additionally, PG&E will utilize the results to manage well integrity as outlined in each field's Storage Risk Management Plan.

Co-Funders: PRCI Members, PHMSA

Start Date: 9/30/2021
End Date: 6/30/2025
Status: Active

2023 Funds Expended:	$16,715
Total Project Cost:	$1,576,998
Total PG&E Cost:	$85,200
Total Co-Funding:	$1,491,798

Benefits

Reducing Methane Emissions

1.14.g Ph6 RMD Support for NFPA Standard Development

The Project aims to create a comprehensive program for achieving full customer adoption of cost-effective, reliable, accurate, and readily available residential remote methane detectors (RMD). The program will include technology development and evaluation, codes and standards development, stakeholder engagement, and economic and market analysis. The Project kicked off in 2014 and has had six subsequent phases, which should likely be completed in 2024. Post-project steps include performing ventilation tests to verify proper exhaust of gases, testing devices at 10% and 25% lower explosive limits to ensure they are in correct working order, and initiating exposure lab tests. Odorant alone may not be enough for customers to report leaks. An in-home alert system would provide a proactive approach to gas leak detection and improve safety.

Co-Funders: OTD Members, SoCalGas

Start Date: 7/1/2021
End Date: 8/1/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$48,000
Total PG&E Cost:	$4,000
Total Co-Funding:	$44,000

Benefits

5.19.f Ph2 Purging Gas Pipes into Service w/o Venting Gas

The Project aims to develop an alternative method to purge gas pipes into service with minimal to no gas released into the atmosphere. There is an industry need to commercialize a cost-effective vacuum purging system to mitigate methane emissions from traditional purging practices. A vacuum purging system could enhance public safety and reduce unaccounted gas losses. Phase 1 of the project was completed in Fall 2020. The vacuum purging method was validated through a market needs assessment, and a commercial partner was identified for production. Phase 2 began in 2021 when GTI Energy developed an enhanced vacuum system and validated it on main and service pipelines. The vacuum system can be used to commission new or repaired pipes without venting natural gas into the atmosphere as the vacuum compressor removes the remaining air or inert gas from within the pipeline. Once the proper vacuum level is reached, natural gas can be introduced into the pipe without venting or mixing air and natural gas. Upon completion of the project, GTI Energy plans to conduct field trial demonstrations and begin commercial production of the technical solution.

Co-Funders: OTD Members, SoCalGas

Start Date: 11/20/2020
End Date: 8/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$175,000
Total PG&E Cost:	$17,500
Total Co-Funding:	$157,500

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

5.23.c Best Purging Practices for Minimizing Methane Emissions

The Project sought to establish better purging practices for eliminating or avoiding methane emissions during pipeline construction, commissioning, and maintenance. While venting gas is the most efficient method for blowing down a pipeline, it is hazardous to the environment and can pose safety risks to the public. Best practices must be identified to conduct successful purging operations and reduce or eliminate methane emissions related to purging. This project kicked off in 2022 at the GTI Energy testing facility in Des Plaines, Illinois. The deliverable included a comprehensive literature survey identifying various methods to reduce or eliminate methane emissions due to purging and blowdowns. In 2023, the project team released the final report that included operational recommendations and guidance to determine the best practices associated with each method. Cross compression, pipeline drawdown, flaring, and vacuum purging were identified as the major alternatives to venting. PG&E is already piloting many of these technologies, and the project results encourage further expansion of these efforts.

Co-Funders: OTD Members, PHMSA

Start Date: 1/1/2023
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$491,577
Total PG&E Cost:	$0
Total Co-Funding:	$491,577

Benefits

7.16.a Ph3 Leak Repair Prioritization

The Project team is further exploring the development of leak rate estimation algorithms developed in Phases 1 and 2, which began in 2016 and were initially focused solely on prioritization of leak repair. Phase 3 advances these estimation algorithms by combining the collected data with advanced modeling and a detailed estimation equation developed by the University of Texas-Arlington (UT-Arlington). This phase of work focuses on non-hazardous leaks (e.g., Grade 2 or 3) that pose minimal safety hazards. The project results are valuable to the industry as survey crews need an easily deployable method or instrument to quantify leak rates. If leak rates could be quantified, more significant leaks could be prioritized for repair to maximize methane leak mitigation. The deliverable includes a final report combining existing methods with new insights from UT-Arlington's estimation equations and advanced modeling techniques. The report will include revised emission rate conversion charts based on soil type and borehole/pavement testing findings. Unfortunately, during the project update in Q4 2023, GTI Energy determined that developing the model as a practical tool for leak rate estimation is not attainable. Rather than proceed with the fieldwork, GTI Energy recommends concluding this project. The project team will hold a closeout meeting in 2024.

Co-Funders: OTD Members, SoCalGas

Start Date: 2/28/2022
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$150,000
Total PG&E Cost:	$1,000
Total Co-Funding:	$149,000

Benefits

7.19.b Ph2 Advanced Leak Detection Technology for Grading Leak

New methane detectors regularly enter the market. Keeping up with the latest and best technologies is essential to optimize leak detection, decrease emissions, and enhance safety. This Project aimed to more accurately define the repeatability and certainty of the open path laser spectroscopy (OPLS) leak grading methodology. GTI Energy set out to determine if existing leak grading criteria could and should be altered to accommodate new technologies such as RKI Instrument's OPLS leak detection method. The deliverable included a final report with an in-depth comparison of grading protocols for open-path survey tools and pump-based instruments and an open-path sensor-specific leak classification procedure. Phase 2 of the project was kicked off in 2023. The project team conducted field testing across PG&E territory. It issued the final report in Q4 2023, with the main takeaway being that the two leak detection methods cannot use the same grading approach. Unfortunately, the sample size was small, with most leaks under 1 standard cubic foot per hour. As a result, the results were inconclusive.

Co-Funders: OTD Members, SoCalGas

Start Date: 1/14/2022
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$160,000
Total PG&E Cost:	$22,857
Total Co-Funding:	$137,143

Benefits

7.19.e Ph2 Developing a Framework for Company-Specific Emission Factor

The Project sought to develop refined company-specific commercial and industrial natural gas customer meter emission factors. The results would support PG&E's use of company-specific emission factors developed through the bubble classification bins for commercial and industrial meter sets. The main deliverable of this project was to be a "decision tree" or a pre-screening method to quickly estimate the size of a leak on commercial and industrial meters to allow companies to identify and prioritize repairs for the larger emitters. Each year, the US Environmental Protection Agency (EPA) produces an estimate of greenhouse gas emissions from the US called the Annual Greenhouse Gas Inventory (GHGI), with a specific section detailing GHG emissions from "natural gas systems." The estimates highlight emissions from specific categories of assets across all segments of the natural gas value chain. The EPA used emission factors from two previous OTD/GTI Energy studies to justify recent changes to the emission factor used in the GHGI for commercial and industrial meters. The Project was proposed in 2021. A final report was issued in Q4 2024. Unfortunately, the main takeaway was that while GTI Energy implemented a set of steps/framework to establish a company-specific emission factor based on prior data and newly collected data, the updating process revealed potential difficulties that must be overcome during future testing.

Co-Funders: OTD Members, SoCalGas

Start Date: 8/15/2021
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$170,000
Total PG&E Cost:	$17,000
Total Co-Funding:	$153,000

Benefits

7.20.f Ph1 Characterizing Methane from Purging Activities

The objective of the Project is to develop a method to quantify the volume of natural gas emitted during the commissioning of a pipeline. With increasing pressure on operators to measure, report, and reduce methane emissions, developing a method to quantify emissions released during purging is crucial. GTI Energy validated this method in preparation for field studies. It is envisioned that the knowledge gained from this project could be applied to emergency blowdowns later. The Project began in 2020 and is scheduled to be completed in Q3 2024. The project team has created a test rig; the next step will be to conduct field testing. The deliverable of this project is a final report documenting the test data and results with a means to quantify volumetric quantities of methane emissions produced during a pipeline purge.

Co-Funders: OTD Members

Start Date: 4/1/2020
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	$5,889
Total Project Cost:	$100,000
Total PG&E Cost:	$20,000
Total Co-Funding:	$80,000

Benefits

7.20.l Methane Mitigation Using Linear Recovery Motor Compressor

The Project seeks to design, build, and test a high-pressure linear motor leak recovery compressor for cost-effective recovery of methane leaks within the natural gas value chain's transmission, storage, gathering, and processing sectors. Such a tool would reduce methane emissions from PG&E compressor stations. The project team designed and is building the compressor using a proven linear motor architecture. The linear motor compressor enables multiple compression stages to be integrated into a single moving part, allowing the compressor to function under a broad range of operating conditions and reach the high discharge pressures required for gas recovery without the cost and complexity of traditional multi-stage compressors. The Project will validate the technology's effectiveness in various relevant environments to identify the wide-ranging applications for its use. The Project began in 2020 and, due to delays, will probably be completed in 2025. In Q4 2023, the GTI Energy team continued to finalize outstanding design items that are holding up the final fabrication and assembly of the leak recovery compressor.

Co-Funders: OTD Members, DOE, SoCalGas

Start Date: 11/4/2020
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,917,000
Total PG&E Cost:	$30,000
Total Co-Funding:	$1,887,000

Benefits

7.21.b Advanced Tools for Methane Emissions Estimation

The Project sought to develop an advanced tool to estimate emission rates by incorporating spatial methane concentration measurements. This tool is crucial to reducing methane emissions because leak grading relies only on concentration measurements rather than leak rate quantification. The proposed approach intended to use air dispersion physics models and deep learning algorithms to enhance estimation and prediction accuracy. This project kicked off in 2021 and was intended to be completed in 2023. Unfortunately, the GTI Energy team encountered multiple challenges, including blockers in the implementation related to the applicability of small leaks and a sparse number of sensors, a limited understanding of the roles and significance of some parameters, and a limited knowledge of the strategy for using mobile data versus static measurement. Because of this, the Project is on pause and may close out in 2024.

Co-Funders: OTD Members

Start Date: 1/1/2021
End Date: 8/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$140,000
Total PG&E Cost:	$14,000
Total Co-Funding:	$126,000

Benefits

7.21.f Establishing an Auditor Training Program for Differentiated Gas

The objective of the Project is to publish a white paper outlining a technical framework to certify Responsible Natural Gas with guidelines on how to report the environmental attributes of a gas product that are important to utilities. Currently, gas suppliers and certifying organizations lack a standardized method for reporting and quantifying greenhouse gas—including methane emissions—natural resources, and other Environmental and Social Governance factors. The California Air Resources Board has started estimating the out-of-state methane emissions associated with California's natural gas supply. The American Gas Association and the Edison Electric Institute are promoting a system of reporting estimates of upstream methane emissions based on the protocol developed by M.J. Bradley and Associates. PG&E and other OTD Members want to incorporate Responsible Natural Gas into their business plans. Utilities have the unique need to integrate methane emissions along with upstream gas suppliers and reconcile the various methods to assess emissions. During the state-of-the-art assessment, the Project was rescoped in response to white papers published by Highwood Emissions Management, Rocky Mountain Institute, and Resources for the Future, which achieved most of the deliverables initially planned for this project. The new deliverable will require the project team to create training materials and establish an auditor training program to assess methane emissions for all segments of the gas value chain based on the protocols developed under GTI Energy's Differentiated Gas Initiative. Benefits include improved emissions quantification along the value chain, resulting in enhanced identification of sources and corresponding mitigation measures.

Co-Funders: OTD Members

Start Date: 1/1/2021
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$207,000
Total PG&E Cost:	$16,000
Total Co-Funding:	$191,000

Benefits

CPS-17-04A 2021 Improved GHG Fugitives Leak Detection

The Project seeks to identify isolation valves in the PG&E system that exhibit large leaks. Since multiple valves are typically manifolded to a single vent, it can be challenging for operators to determine which valve requires replacement or repair. Through-valve gas leakage from natural gas compressor unit suction and discharge isolation valves is a significant source of methane emissions in natural gas transmission and storage. Addressing this critical source of methane leaks will substantially 1) improve the ability to contain greenhouse gas emissions, 2) demonstrate a proactive response, and 3) contribute to PG&E's reduction target commitments. At the test facility (owned by SoCalGas), the project team tested multiple technologies that signal through-valve leakage when pressurized, including three thermal imaging infrared cameras and three acoustic measurement devices. Field tests delivered promising results at pressures up to 400 pounds per square inch for two forward-looking infrared cameras and three acoustic measurement devices. The contractor is working on a final report summarizing the results. A no-cost time extension has been issued.

Co-Funders: PRCI Members, OTD Members, SoCalGas

Start Date: 11/8/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$120,000
Total PG&E Cost:	$10,000
Total Co-Funding:	$110,000

Benefits

Evaluating Emissions from Transmission M&R Stations

The Project will collect emissions data from transmission Metering and Regulating (M&R) stations using Sensit Fix Point Laser methane detectors. Transmission M&R stations represent the top three emitters in PG&E's territory. The California Public Utilities Commission and the California Air Resources Board have mandated that California utilities reduce emissions by 20% by 2025 and 30% by 2040. The current method and structure for reporting and calculating emissions uses a population-based emission factor. This approach is problematic because it fails to show the impact of the methane reduction strategies implemented by PG&E to lower emissions in the reported data. To accurately show emissions reductions in the data, it's necessary to develop measurement-based emission factors instead of population-based ones. The Project began in 2017 and collected data from 12 stations. The project team will continue to gather significant emissions data until they can confidently propose a new emission factor.

Co-Funders: none

Start Date: 8/21/2017
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	$32,149
Total Project Cost:	$117,100
Total PG&E Cost:	$117,100
Total Co-Funding:	$0

Benefits

M2014-001 Ph3 JPL Methane Detector and Control System for sUAS Technology

The Project seeks to advance the use of Small Unmanned Aircraft Systems technology for leak surveys. The technology is already established for accuracy in methane detection capability and ground emission location. Additionally, it will work to develop methane emission quantification. Phase 3 was intended to improve methane's ground localization and a quantification algorithm that has been underway since 2020. Drone testing at all three proposed locations, including within PG&E territory, was completed in 2023. The Jet Propulsion Laboratory is creating a final report to provide a thorough data analysis and takeaways from the project.

Co-Funders: NYSEARCH Members, JPL, SoCalGas

Start Date: 11/3/2020
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	$24,069
Total Project Cost:	$338,140
Total PG&E Cost:	$67,630
Total Co-Funding:	$270,510

Benefits

M2017-004 Ph3 Methane Oxidation Catalysts to Replace Flaring

The Project seeks to develop materials that oxidize hydrocarbons at low temperatures via a catalytic process. If a proof-of-concept device could be procured, it could eventually be scaled up to replace flaring units. This is important to PG&E as it could be deployed in cities and on sites where flaring is not permitted, but abatement of relatively small volumes of natural gas is needed. In Phase 1, Stanford University improved the activity of palladium (Pd) catalysts by ten times relative to commercial Pd-based catalysts and explored the influence of water on combustion rates. In Phase 2, the Stanford team tested the results under realistic conditions and designed a lab prototype to show proof-of-concept of the champion catalyst system's performance. Phase 3 is focused on large-scale feasibility, cost/benefit analysis, unit fabrication, and performance verification. NYSEARCH, the Questor team, and the Stanford professor who pioneered this research will present a status report in March 2024 that will update the oxidizer prototype design.

Co-Funders: NYSEARCH Members

Start Date: 1/1/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$9,595
Total Project Cost:	$238,122
Total PG&E Cost:	$39,155
Total Co-Funding:	$198,967

Benefits

M2018-001 Ph3 Reducing Methane Emissions at Threaded Connections

Threaded connections from meter set assemblies and Metering and Regulating stations account for 45% of distribution system emissions in California. In 2017, the California Public Utilities Commission, as part of SB1371, derived a list of best practices for California operators to review and revise pipe fitting specifications and potentially roll out a pipe fitting replacement program. The Project evaluated measures such as using better sealants and tightening National Pipe Taper conformance standards. In Phase 3, the team performed cyclic leak testing on NPT and Aeronautical National Pipe Taperjoints under severe testing conditions. In 2023, the project team completed and shared the final report containing the main takeaway: original thread dimensions and the original applied torque may be a variable in the root cause of leaks.

Co-Funders: NYSEARCH Members

Start Date: 4/28/2021
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$14,334
Total Project Cost:	$129,735
Total PG&E Cost:	$11,450
Total Co-Funding:	$118,285

Benefits

M2020-006 Standardization of NYSEARCH Methane Emissions Validation Process

The objective of the Project is to identify, apply, and test a methodology or set of methods that enable a gas distribution operator to validate the accuracy of measuring, locating, and quantifying the methane emissions rate from non-hazardous natural gas infrastructure leaks. Non-hazardous leak indications (Grade 3) are given a lower priority from a safety perspective and can be monitored rather than scheduled for repair. By adding a process for validating methane emissions, gas company operators and their constituents can prioritize the environmental impact of Grade 3 leaks. Once this work is completed, this methodology can be standardized.

Co-Funders: NYSEARCH Members, SoCalGas

Start Date: 6/30/2020
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$2,193
Total Project Cost:	$71,820
Total PG&E Cost:	$9,265
Total Co-Funding:	$62,555

Benefits

M2020-009 Development of a Decision-Making Algorithm for Detection and Quantification of Leaks

The Project worked to develop a gas migration algorithm that incorporates collected gas concentration data and predicts underground leak behavior in near-real time. Predicting the underground migration of leaks is difficult, as there isn't a commercial tool to measure flow rate remotely. Ranking leak flow rates using existing leak detection technologies and knowing the surrounding atmospheric conditions may be possible. The project team conducted initial field tests at Metals and Engineering Corporation (METEC) in July 2021 and developed model algorithms using data generated from the METEC test. Additional live field testing was completed at PG&E in 2022. The final report was issued in Q1 2023. The analytic method DImensionless Number Approach (DINA) was developed as part of this project. DINA can quantify and localize underground pipeline leaks. The DINA algorithm can accurately determine leak rates and locations for the range tested. Field applications of DINA in PG&E territory were successful for leak rates between 14.6 g-CH4/hour and 82.0 g-CH4/hr. DINA could not identify very low leak rates (< 9 g-CH4/hour). Placing natural gas detectors around the location of the highest surface methane concentration was an effective way to deploy and determine the leak rates of the pipeline when it was tested in the field. Although DINA needs to be combined with wireless natural gas detectors, it is flexible enough to integrate different detectors or instruments as long as surface methane concentrations are provided.

Co-Funders: NYSEARCH Members, SoCalGas

Start Date: 6/15/2021
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$16,364
Total Project Cost:	$225,633
Total PG&E Cost:	$41,025
Total Co-Funding:	$184,608

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

M2021-002 Ph2 sUAS Inspection for Submerged Pipes

Phase 1 of the Project, which focused on submerged pipe applications, tested multiple small, unmanned aircraft systems, barge, and submersible drone configurations. Separately, the Project evaluated and tested a variety of sensors. After assessing, the team either declined the sensors for failing to meet measurement standards or approved them for additional integration into designated spots on specific drone models. The team conducted initial tests in controlled laboratory settings and the field to refine the drones' maneuverability and flight patterns. Phase 2 involved the enhancement of remotely operated platforms and sensors. In this phase, the team also improved field surveys and inspection processes. The goal was to enable adaptation for two primary purposes. First, for internal use within a gas company, specifically focusing on its interests. Second, for commercial service providers that conduct leak surveys and pipeline integrity inspections.

Co-Funders: NYSEARCH Members

Start Date: 1/31/2022
End Date: 6/30/2023
Status: Completed

2023 Funds Expended:	**$13,776**
Total Project Cost:	**$224,500**
Total PG&E Cost:	**$37,000**
Total Co-Funding:	**$187,500**

Benefits

MATR-3-15A Assessment of Temp Repair Methods to Reduce Blowdowns

Non-metallic repairs, such as composite systems and clamps with elastomer seals, may degrade over the life of the pipeline. As pipelines age, evaluating the available repair options and those currently installed is important to ensure continued service. The Project aimed to explore the degradation associated with non-metallic repairs. Specifically, it provides practical guidance on assessing, limiting, or extending their service life. This will help operators plan for replacement through a permanent in-service repair or justify their continued use without arbitrary replacement. This project concluded in 2023 with the delivery of the final report.

Co-Funders: PRCI Members, SoCalGas

Start Date: 4/5/2022
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	**$4,669**
Total Project Cost:	**$250,000**
Total PG&E Cost:	**$7,782**
Total Co-Funding:	**$242,218**

Benefits

METEC Industry Advisory Board (IAB) 2023 Basic Membership

The Project focused on procuring PG&E's annual membership to the Industry Advisory Board (IAB). An IAB annual membership enables active membership in The Methane Emissions Technology Evaluation Center (METEC). This unique facility simulates accurate methane emission sources from various natural gas facility operations. With a basic IAB membership, PG&E can participate in IAB meetings, vote, provide guidance and baseline support to the METEC facility, and review ongoing research at METEC, including through early access to internal research results funded by membership fees. The deliverables include regular briefings on recent research results, including research performed by Colorado State University and other groups, and updates on various emissions-related topics.

Co-Funders: METEC IAB Members

Start Date: 1/1/2023
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	**$10,000**
Total Project Cost:	**$10,000**
Total PG&E Cost:	**$10,000**
Total Co-Funding:	**$0**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

PG&E Internal—Schlumberger Valve IQ Testing

The objective of the Project was to test Schlumberger's solution to monitoring compressor emissions. Currently, compressor emissions represent 44% of transmission compressor station emissions. This estimate is based on an annual measurement, which may not represent actual emissions at the station. This monitoring system showed the potential to accurately represent compressor emissions and better understand how to reduce emissions in this category. This Project was completed in 2023 when the Schlumberger Valve IQ system was tested at PG&E's Gerber compressor station. All valves were deemed healthy by the Schlumberger system, with no significant valve leakage. The Project was closed out. The sensor was not relocated to another station as there was no feasible way to validate the emissions data.

Co-Funders: Schlumberger Valve IQ

Start Date: 7/1/2021
End Date: 5/9/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$15,000
Total PG&E Cost:	$15,000
Total Co-Funding:	$0

Benefits

Picarro Support—Strategic Objectives 2023

The Project helped PG&E reduce emissions, improve customer safety, and optimize emissions reporting and surveys. This project began in January 2023 and concluded in December. Picarro's first task was to analyze the leak indication search area (LISA) prioritization process to enable PG&E to improve response time for riskier tiers and allow more time for the less risky tiers. Secondly, Picarro improved the LISA generation process to reduce the "no leak found" or "false positive" indications. This helped PG&E save time and resources. The third pain point Picarro addressed was integrating immediate response triggers for emission drives. This required updating the software to include immediate response notifications/triggers for emission drives in PG&E's Super Emitter Program. This helped improve safety. Additionally, Picarro developed the Methane Emission Dashboard, which helps simplify and streamline the annual methane emission reporting process involving heavy data collection and complex calculations. This data-driven Dashboard provides real-time visibility to executives and helps them support strategic decisions and program adjustments. Lastly, Picarro continued to support PG&E in reducing the Super Emitter threshold. Picarro's technology was deployed in December 2023.

Co-Funders: Picarro

Start Date: 1/1/2023
End Date: 12/7/2023
Status: Completed

2023 Funds Expended:	$462,500
Total Project Cost:	$462,500
Total PG&E Cost:	$462,500
Total Co-Funding:	$0

Benefits

T-786 Ph2 Classifying Methane Emissions at Regulator Stations

Methane emissions at transmission metering and regulating (M&R) stations are currently calculated using a population-based emission factor. This method prevents utilities from demonstrating the progress of methane mitigation efforts. A new measurement-based approach is necessary to demonstrate emission reduction. Phase 2 of this Project aims to build on data collected in Phase 1. During Phase 1, NYSEARCH developed a ranking tool and framework to classify emissions from transmission M&R stations. Phase 2 will work to complete a test protocol allowing operators across the country to conduct emission measurements at their M&R stations. This data will be compared to values from the ranking tool developed in Phase 1. Using measured data and data from the tool will refine results and help operators determine which stations have a higher potential for fugitive emissions. After pilot visits are completed, the project team will analyze the data and issue a final test protocol. The Project is expected to close out in September 2024, with the delivery of a final report outlining the work completed and project results.

Co-Funders: NYSEARCH Members, SoCalGas

Start Date: 6/3/2023
End Date: 9/4/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$171,420
Total PG&E Cost:	$14,205
Total Co-Funding:	$157,215

Benefits

T-796 LDC Validation of Satelytics' Aerial System for Methane Detection & Emission Quantification

The objective of the Project is to test Satelytics' aerial methane detection and emission quantification technology, including initial evaluation of its probability of detection (PoD) performance. Satelytics has adapted mid-infrared spectroscopy and satellite-captured imagery in near-Earth orbit, collecting methane detection emissions with associated GPS coordinates. Three field tests using Satelytics' leak survey techniques, which include controlled methane releases, will be conducted in 2024. Once complete, the project team will provide a final report summarizing the overall field test results and statistically calculating a perspective on PoD. If successful, PG&E will have another leak detection technology in its inventory to perform leak surveys efficiently and improve the overall operational confidence of the pipeline system.

Co-Funders: NYSEARCH Members

Start Date: 8/10/2023
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	**$112,955**
Total Project Cost:	**$649,497**
Total PG&E Cost:	**$112,955**
Total Co-Funding:	**$536,542**

Benefits

T-797 LDC Validation of Bridger Photonics' Aerial System for Methane Detection & Emission Quantification

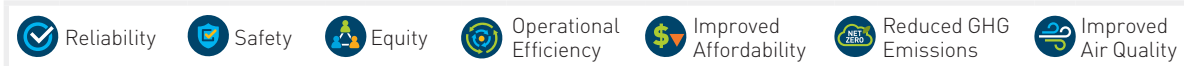
The objective of the Project is to test Bridger Photonics' aerial methane detection and emission quantification technology, including initial evaluation of its probability of detection (PoD) performance. The project team will conduct three field tests using Bridger Photonics leak survey techniques, which include controlled methane releases, in 2024. Once the tests are completed, the project team will provide a final report summarizing the overall field test results and statistically calculating a perspective on PoD. If successful, PG&E will have another leak detection technology in its inventory to perform leak surveys efficiently and improve the overall operational confidence of the pipeline system.

Co-Funders: NYSEARCH Members

Start Date: 7/26/2023
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	**$80,912**
Total Project Cost:	**$445,022**
Total PG&E Cost:	**$80,912**
Total Co-Funding:	**$364,110**

Benefits



Decarbonizing the Gas System

1.11.H Ph6—Residential Gas Heat Pump Water Heater

The Project builds 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 significant 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 GHP-WH 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 GHP-WH. SMTI delivered the updated unit in the fourth quarter of 203. Researchers completed the Phase 6 test plans and fabricated prototypes of the additional features being developed in Phase 6.

Co-Funders: UTD Members

Start Date: 11/1/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$200,000
Total PG&E Cost:	$10,000
Total Co-Funding:	$190,000

Benefits

1.16.H Ph3—EnergyPlus Models for Advanced Heating Systems

EnergyPlus is the US Department of Energy's (DOE) flagship whole-building energy simulation engine. It is commonly used by itself or on the back end of other building energy simulation software. It permits the simultaneous simulation of a whole building's energy consumption and interaction with the surrounding environment. Before the start of this project, EnergyPlus had limited ability to simulate advanced condensing furnaces; no models existed for gas heat pumps, and only limited functionality existed for modeling combined space and water heating systems (combis). While the popularity and importance of EnergyPlus has grown dramatically within the energy efficiency community, decision-makers considering the best heating, ventilation, and air conditioning (HVAC) options for a building or in policy development had minimal options for comparing state-of-the-art gas appliances to their electric counterparts. The project's primary objective was to provide decision-makers with accurate and reliable simulation tools for gas heating systems and to enable fair comparison with competing technologies. Success for this project meant demonstrating the competitiveness of gas in future residential and commercial buildings. Phases 1 and 2 of this Project focused on developing performance curves and models for condensing furnaces, gas absorption heat pumps, and tankless-based combis. Phase 3 of this project, described in the final report, focused on disseminating findings from prior phases as updates to EnergyPlus and expanding commercial HVAC modeling and building energy model validation using real-world Zero Net Energy homes in California.

Co-Funders: UTD Members

Start Date: 7/1/2020
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$220,000
Total PG&E Cost:	$30,000
Total Co-Funding:	$190,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.16.H Ph4—EnergyPlus Model for Gas Heating Systems

The Project aims to provide decision-makers with accurate and reliable modeling simulation tools for gas heating systems to enable fair comparison with competing technologies. An important goal for the gas industry is to allow the adoption of gas heating systems comparable with or better than high-efficiency electric alternatives. To achieve this, it is essential to provide reliable information regarding their potential benefits (e.g., cost and energy savings). Phase 4 of the Project will focus on adding data on emerging gas heat pumps and hybrid gas-electric systems, which will build on the work accomplished in Phases 1-3, where the project team added data on advanced furnaces, tankless combined space/water heaters, and gas absorption heat pumps into the EnergyPlus model. This project will add performance data from advanced gas heating systems into EnergyPlus, thus increasing the visibility of gas options and allowing regulators and building developers. Those designing heating, ventilation, and air conditioning systems to model them and fully understand their operation and benefits.

Co-Funders: UTD Members

Start Date: 6/1/2022
End Date: 1/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$150,000
Total PG&E Cost:	$10,000
Total Co-Funding:	$140,000

Benefits

1.18.F Ph2—Mitigate Methane Emissions in ResCom End Use

The Project will quantify methane emissions from at least six critical residential appliances that were not tested in Phase 1 of the project. The goals are 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. The project team tested residential appliances, including cooking ranges and tank water heaters, 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 collected total hydrocarbon emissions data for steady-state and part-load tests to generate a complete picture of the emission profile for typical furnace operation. The team has started data analysis for the final report after completing the experimental phase for Phase 2. The team will quantify the methane emissions profiles for the four furnaces at various part-load conditions to generate emission factors. Differences in emissions will be correlated to operational differences to understand how the team can mitigate emissions in equipment design and operation.

Co-Funders: UTD Members

Start Date: 8/1/2020
End Date: 2/28/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$145,000
Total PG&E Cost:	$25,000
Total Co-Funding:	$120,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.18.H Economical High-Efficiency Residential Gas Absorption Heat Pumps

The objective of the Project is to design, fabricate, and evaluate in laboratory settings a complete working "alpha" prototype unit that adds cost-effective cooling with low-global-warming-potential (low-GWP) refrigerant to the upcoming 40k British thermal units per hour version of the low-cost gas absorption heat pump (GAHP) product developed in UTD project 1.18.H with Stone Mountain Technologies Inc (SMTI). The GAHP uses an economical single-effect, ammonia/water absorption cycle. GTI Energy has estimated an annual fuel utilization efficiency of 140%. Still, the current unit only provides whole-house heating and domestic hot water. If successful, this effort will add a low-GWP vapor compression module to provide air conditioning, reaching a seasonal energy efficiency rating of 12.0 and heat recovery for water heating using SMTI's advanced hydronic air handler. The Project will likely evaluate the performance of low-GWP refrigerants, including R-32.

Co-Funders: UTD Members

Start Date: 7/1/2023
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$7,100
Total Project Cost:	$267,000
Total PG&E Cost:	$7,100
Total Co-Funding:	$259,900

Benefits

1.19.B Ph2—Gas-Fired Warewasher

The Project seeks 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 10 parts per million nitrogen oxides). 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: 7/1/2020
End Date: 3/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$175,000
Total PG&E Cost:	$13,988
Total Co-Funding:	$161,012

Benefits

1.19.B Ph3—Gas-Fired Warewasher Door Machine Demonstration

The Project seeks 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 warewasher doors have begun. Research on the conveyor warewasher is currently focusing on heat-exchanger modeling and design.

Co-Funders: UTD Members

Start Date: 11/1/2021
End Date: 3/30/2024
Status: Active

2023 Funds Expended:	$1,625
Total Project Cost:	$145,000
Total PG&E Cost:	$2,000
Total Co-Funding:	$143,000

Benefits

1.20.B—Boostheat Thermal Compression-Based Gas Heat Pump

The objective of the 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 (BH) has recently established an innovative and new business model in Europe. However, this UTD project will address critical 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 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 critical technical challenges and consolidated staff under a single roof. In early 2022, the company indicated that the reliability and performance of its 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: 7/1/2020
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$225,000
Total PG&E Cost:	$16,236
Total Co-Funding:	$208,764

Benefits

1.20.G—High-Efficiency Combi System Integrating PV and Self-Power

The Project aimed to develop and demonstrate a hybrid residential combined heating, ventilation, air conditioning, and water heating (combi) system in the laboratory. The Project used off-the-shelf appliances and novel controls to integrate gas and electric systems with micro-cogeneration, energy storage, and renewable energy systems. This approach reduced operating costs and greenhouse gas emissions by up to 50% and achieved a coefficient of performance of up to 1.5. This approach will improve energy resilience and help retain a high-efficiency role for natural gas and liquefied petroleum gas in the residential forced-air market. It also prepares the industry for nascent gas heat pump technology that will require solutions for system integration. In 2022, a residential nanogrid testbed achieved key performance markers. The team presented results from this Project at the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2022 Winter Conference and the World Gas Conference 2022 in Daegu, Korea, in May 2022. The team presented a paper in July at the Purdue 2022 Compressor Engineering, Refrigeration & Air Conditioning conference. The team will submit additional documents resulting from this research at the ASHRAE 2023 Winter Conference. In 2023, the project team formalized a Project Test Plan with Enginuity; secured an Enginuity E-ONE micro-CHP (combined heat and power) system along with automated electric and thermal load banks in order to perform simulated use testing of E-ONE; and completed modeling of nanogrid systems to understand control options and quantify cost/emission reduction benefits. The team will install the E-ONE in a nanogrid testbed and begin simulated use lab evaluations.

Co-Funders: UTD Members

Start Date: 7/1/2020
End Date: 2/29/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$550,000
Total PG&E Cost:	$16,502
Total Co-Funding:	$533,498

Benefits

1.20.H Ph2—Hydrogen-Blended Gas in ResCom Combustion Equipment

The Project supports the potential deployment of up to 30% hydrogen blends in natural gas supplied to commercial and residential buildings in North America. It focuses on assessing 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. 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 US and Canadian blocking stocks, and 3) identify safety, emissions, and efficiency benefits or concerns. The team completed a preliminary literature review on relevant test and certification methods and then developed a comprehensive test plan. 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. Preliminary results to date for this project were presented at a seminar at the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' Winter Conference in February 2023. In 2023, the team also completed the commissioning of the test stand for Phases 2 and 3 and initiated tests with hydrogen blends in a hearth and gas furnaces in Q3 2023.

Co-Funders: UTD Members

Start Date: 8/15/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$775
Total Project Cost:	$180,000
Total PG&E Cost:	$5,425
Total Co-Funding:	$174,575

Benefits

1.20.H Ph3—Hydrogen-Blended Gas in ResCom Combustion Equipment

The Project intends to support the potential deployment of up to 30% hydrogen-blended gas in North American buildings. The team will assess the performance, emissions, 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/or modified for standardized testing of furnaces and water heaters. 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, in particular with high interest from organizations in Latin America. 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.

Co-Funders: UTD Members

Start Date: 6/1/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$7,443
Total Project Cost:	$150,000
Total PG&E Cost:	$17,443
Total Co-Funding:	$132,557

Benefits

1.20.K Field Evaluation of Indoor Air Quality in Residential Buildings

The Project addressed the urgent issue of quantifying the effects on Indoor Air Quality (IAQ) of natural gas and electric cooking and collecting real-world scientific data. Emissions from residential cooking processes have become a contentious issue concerning IAQ in homes. The usefulness of the stove hood, types of appliances, tighter homes, and ventilation standards must be considered when addressing IAQ issues. Recent publications on residential IAQ have suggested that emissions from cooking can negatively affect a home's air quality. Specific emphasis is put on combustion emissions instead of emissions produced from food, whether cooked using electricity or gas. While the publications present conclusions about the safety of cooking with natural gas, reviewing these articles and several referenced sources has uncovered questionable methods and conclusions based on established research principles.

Co-Funders: UTD Members

Start Date: 11/1/2020
End Date: 12/28/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$335,000
Total PG&E Cost:	$17,920
Total Co-Funding:	$317,080

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.21.A HeatAmp Adsorption Thermal Heat Pump

The Project sought to advance the development of a cost-competitive, fuel-fired Thermal Heat Pump (THP) technology from the Swedish company HeatAmp by optimizing a cost-effective alpha prototype "burner/boiler" assembly and then designing a system for future evaluation in GTI Energy's laboratory. The HeatAmp THP has flexible installation configurations (integrated/split units, indoor/outdoor), and the sorption module is integrated into a hydronic buffer tank with a compact form factor. The unit draws in and upgrades ambient heat via an outdoor fan coil unit, achieving projected energy/emission reductions of >33% versus standard fuel-fired equipment. A sorption module that houses ammoniated salts drives the heat pump effect. The primary target is domestic hot water applications, with options for combined space/water heating ("combi") or pool heating functions. This technology has several potential advantages as a competitive addition to the residential-scale THP portfolio. The appliance uses a natural refrigerant with zero ozone depletion or global warming potential, suitable for all climate zones. Additionally, the sorption components are integrated into the tank, reducing thermal losses and safely isolating the NH3 charge. On projected performance, the US residential heating (gas/propane) market size is expected to hit 2,778 trillion British thermal units per year (TBtu/year) by 2040 (according to the BTO Market Calculator). With a target gas coefficient of performance of 1.30, the proposed triple-state sorption heat pump would have a technical potential savings of 833 TBtu/year. A payback period of 3-6 years is expected for milder climates, with even better paybacks expected in colder climates.

Co-Funders: UTD Members, Northwest Energy Efficiency Alliance

Start Date: 7/1/2021
End Date: 8/1/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$90,000
Total PG&E Cost:	$5,000
Total Co-Funding:	$85,000

Benefits

1.21.C—CleanO2 CARBiNX Carbon Capture

The Project seeks to evaluate the performance of a CleanO2 CARBiN-X v 4.0 carbon capture device in the laboratory to 1) validate claims of a carbon dioxide capture rate of four metric tons per year and cost savings of at least 30% for hot water heating and 2) 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 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: 7/13/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$13,000
Total Project Cost:	$150,000
Total PG&E Cost:	$13,000
Total Co-Funding:	$137,000

Benefits

1.21.E Gas Engine Heat Pump Modeling, Testing and Implementation

The Project aims to validate natural gas engine-driven heat pump (GEHP) performance for variable refrigerant flow (VRF) systems across a range of conditions and expand the market through three factors: 1) enhanced GEHP energy models using measured performance data; 2) validation of a new American National Standards Institute and Compressed Gas Association method of test for new GEHP performance metrics; and 3) techno-economic assessments on the best use of three new GEHP equipment options. The options include 1) Air Handler Unit Integration Kits (for VRF retrofits), 2) Yanmar Hydrobox and BME Sierra Air Water System (for hydronic unit integration), and 3) Aisin Hi-Power (for self-powered resiliency). This Project will validate the performance metrics needed to expand the US market for important high-efficiency gas technology for commercial buildings that can achieve heating and cooling gas coefficient of performance greater than 1. GEHP reduces peak electric demand through gas-fired cooling and levelized year-round gas demand with ultra-high-efficiency heating performance. Using cost-effective, high-efficiency gas technologies supports the direct use of natural gas in high-performance buildings and expands customers' competitive product offerings.

Co-Funders: UTD Members

Start Date: 7/1/2021
End Date: 2/28/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$320,000**
Total PG&E Cost:	**$5,000**
Total Co-Funding:	**$315,000**

Benefits

1.21.F Commercial Heat Pump Water Heater Field Performance Comparison

The Project compares the performance of a commercial gas and electric heat pump water heater technology in 1-2 field locations and in GTI Energy's laboratory using the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' standards to establish each technology's cost and energy-saving capability. The specific goals are: 1) to assess the performance of commercial gas and electric Heat Pump Water Heaters (HPWH) at GTI Energy and in the field and 2) to provide equitable comparative information between commercial heat pump technologies. Gas HPWH offers the gas industry a high-efficiency option for its Energy Efficiency gas incentive programs. At the same time, it allows customers to retain gas as an affordable, resilient, and reliable energy source. Gas HPWH can be deployed where the electric supply may be constrained, and supply and distribution upgrades may not be feasible within the end-user's timeframe. Propane-fired versions would provide an option for areas not served by gas infrastructure. Data evaluating the impact of deploying various HPWHs may also aid members in public dialogue regarding energy efficiency, options, and choices.

Co-Funders: UTD Members

Start Date: 9/1/2023
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$136,000**
Total PG&E Cost:	**$2,000**
Total Co-Funding:	**$134,000**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.21.H—CFS Burner Technology Carbon Reduction Including Hydrogen Blending

In this Project, the team sought to determine the potential decarbonization associated with 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 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. In 2023, the project team tested a tube burner. Based on the results of this project, flashback and flame appearance do not appear to be an issue for blends of natural gas and hydrogen, up to 30% for the burner types tested.

Co-Funders: UTD Members

Start Date: 7/1/2021
End Date: 6/30/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$150,000
Total PG&E Cost:	$5,000
Total Co-Funding:	$145,000

Benefits

1.21.H Ph2—CFS Burner Technology Carbon Reduction Including Hydrogen Blending

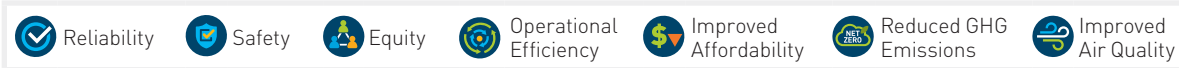
The Project seeks to determine the decarbonization potential of typical commercial food service (CFS) appliances when utilities blend up to 30% hydrogen with natural gas. Phase 2 will focus on full appliance testing and cooking performance impacts and build on the testing of standalone burners and controls in Phase 1. GTI Energy, 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 at 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: 6/30/2022
End Date: 1/30/2024
Status: Active

2023 Funds Expended:	$7,778
Total Project Cost:	$160,000
Total PG&E Cost:	$17,778
Total Co-Funding:	$142,222

Benefits



1.21.I—Ionic Liquid Absorption Heat Pump for Commercial Water Heating

The 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 in partnership with the University of Florida and leading original equipment manufacturers. The prototype will be performance-tested at loads (steady and dynamic) typical of commercial buildings with 100 gallons of storage and a nominal heating output of 145 thousand British thermal units per hour. The team finalized the design of the desorber, which included shifting the type of overall heat exchanger (HX) design. In addition to these desorber design exercises, the team continued to solicit and evaluate custom premix burner options in open-air testing from multiple burner manufacturing partners. Final simulations of the desorber design were performed to screen for potential hot spots and other issues. A package of drawings was prepared, bids were secured from local fabricators, and a fabricator was selected. The desorber setup and testing were completed. These tests yielded results that were used to calibrate parallel computational fluid dynamics (CFD) modeling and a general analytical approach to heat transfer estimation. Results from peanut oil were analyzed and extended to the ionic liquid. Finally, a Multiphysics CFD simulation was performed, where gas phase (flue gases) and shell-side fluid (peanut oil/ionic liquid) were combined for the first time. Using the data collected, the local heat transfer coefficients were estimated using standard non-dimensional analysis, yielding an estimated Nusselt number of 46.3 and HTC of 315 W/m2K, within a 5% error from experimental results. The research team completed testing of the desorber and is preparing to report full desorber test results.

Co-Funders: UTD Members

Start Date: 11/1/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$225,000**
Total PG&E Cost:	**$10,000**
Total Co-Funding:	**$215,000**

Benefits

1.22.A—Hydrogen Blending End-Use Performance and Safety Field Demonstration

The Project intends to demonstrate the safety, technical, and performance implications of blended hydrogen gas 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., heating ventilation and air conditioning, water heating, and 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, Nevada, 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: 6/30/2022
End Date: 7/31/2025
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$450,000**
Total PG&E Cost:	**$5,000**
Total Co-Funding:	**$445,000**

Benefits

1.22.B—Modern Electron Thermionics for Furnaces

The Project's objectives were to partner with the technology start-up Modern Electron (ME) to 1) define the techno-economic potential of residentially sized self-powered boilers and furnaces, using the preliminary product definition from ME and 2) identify product development improvements to the furnace application through proof-of-concept testing (as compared to baseline) with efficiency and emissions goals in mind. The Project kicked off in 2022 in partnership with ME, whose thermionic energy converter (TEC) technology, as applied to furnaces and boilers, was the subject of this Project and whose participation was essential for its execution. In late 2022, ME ceased developing the TEC technology for space heating applications, reorganized their company, and pivoted completely to commercializing a methane pyrolysis solution. The company became Modern Hydrogen through this transition, and GTI Energy's primary contact left the organization. For about nine months, the project team remained engaged with Modern Hydrogen to determine if interest in pursuing this project returned, but in Q3 of 2023, ultimately, they confirmed that they had no plans to do so. GTI Energy and UTD mutually agreed to terminate this project at that time.

Co-Funders: UTD Members

Start Date: 6/30/2022
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$175,000
Total PG&E Cost:	$7,500
Total Co-Funding:	$167,500

Benefits

1.22.C—Fuel-flexible Ultra-Low NOx Catalytic Burners for ResCom Appliances

The Project will pave the way for the adoption of hydrogen-blended gas and address the need for deep nitrogen oxide (NOx) reduction in domestic burners by developing and demonstrating a catalytic combustion gas burner for residential and commercial applications that can accommodate up to 50% hydrogen while achieving lower NOx emissions than the current state of the art. Whereas standard burners combust fuel with oxygen at high temperatures, catalytic burners use catalysts to trigger a chemical reaction between the fuel and oxygen without creating a flame. The lower temperature helps minimize NOx production while providing a steady heat output to the load. A literature review report of available burners was developed, and updates are being finalized. The review builds on previous studies and other research underway on catalytic burners. The project team has contacted multiple burner manufacturers to secure burners to conduct testing. Three catalytic burners have already been secured to conduct testing on various fuel blends. The project team is setting up the testing space in an industrial laboratory in order to conduct individual burner testing.

Co-Funders: UTD Members

Start Date: 6/30/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$17,100
Total Project Cost:	$150,000
Total PG&E Cost:	$17,100
Total Co-Funding:	$132,900

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.22.G—Safe Use of Hydrogen in Buildings

The 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. The Project also addresses barriers to the safe use of 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 (i.e., 40–100%) operation, 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: 7/31/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	**$3,824**
Total Project Cost:	**$150,000**
Total PG&E Cost:	**$8,824**
Total Co-Funding:	**$141,176**

Benefits

1.22.P Emerging Distributed Methane Pyrolysis Technologies

The Project aims to survey distributed methane pyrolysis technologies. Activities include a techno-economic assessment of various applications, such as the underlying conversion process, hydrogen end uses, handling of carbon outputs, and any potential contaminant or purity considerations. As part of this effort, the project team will perform in-depth technology reviews and interviews with five or more players who use distributed methane pyrolysis solutions (e.g., Modern Hydrogen). With this information and information gathered from literature and data collection, the team will complete a techno-economic analysis of distributed methane pyrolysis solutions, inclusive of a range of hydrogen end-use scenarios (e.g., boiler for space heating) and a range of carbon output scenarios (e.g., disposal). Given the goal of finishing this task within the current cycle and before entering Phase 2, the project team will proactively consider application/process modeling. This involves establishing a strategy by creating a preliminary system modeling plan. This plan will be utilized in a subsequent phase to integrate with end-user demand modeling and pinpoint various distributed methane pyrolysis solutions, categorizing them as good, better, and best. This study focuses on an emerging pathway for hydrogen production, methane pyrolysis (or "turquoise" hydrogen), which, given its advantages relative to other production pathways, allows for siting hydrogen generation much closer to the point of use and potentially much more cost-effectively.

Co-Funders: UTD Members

Start Date: 9/1/2023
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	**$15,000**
Total Project Cost:	**$60,000**
Total PG&E Cost:	**$15,000**
Total Co-Funding:	**$45,000**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.23.E Combustion Technology for Emerging Low Carbon Manufactured Gases

The objective of the Project is to conduct an experimental, technical, and safety evaluation of equipment that is designed or being operated with manufactured gases in non-North American markets, with a focus on water heating and cooking applications. Evaluations will include performance and reliability tests and identify fundamental principles to apply to the types of natural gas-certified equipment typically sold in North America. The project team will also conduct a safety and technical review of emerging low-carbon manufactured gases used in water heating, cooking, space heating, etc. In this investigation, utility members will be equipped with design specifications and performance data for appliances designed for markets already using hydrogen-rich manufactured gases. Utilities will be able to close the knowledge and design gap for the industry's shift from current natural gas (NG) to NG/hydrogen blends. Investigating other potential fuels outside NG/hydrogen blends will give utilities options for more carbon-neutral fuels. Other performance issues outside efficiency and emissions may not cover the specific needs of individual communities or industries. The Project can prepare utilities with additional fuel information for these niche markets within the North American market.

Co-Funders: UTD Members

Start Date: 7/1/2023
End Date: 6/30/2025
Status: Active

2023 Funds Expended:	$8,300
Total Project Cost:	$225,000
Total PG&E Cost:	$14,940
Total Co-Funding:	$210,060

Benefits

1.23.G Accelerated Life Testing of ResCom Equipment Components with Hydrogen-Blended Gases

The Project aims to assess the compatibility of commonly used non-burner components in residential/commercial (Res/Com) combustion appliances and equipment when subjected to hydrogen-blended gas. This assessment will help gas equipment and appliance manufacturers, gas utilities, standards-setting organizations, and other entities better understand the potential challenges of using hydrogen in natural gas distribution networks. Project deliverables include 1) a report listing component compatibility or degradation when exposed to hydrogen and 2) a recommendation of mitigation strategies for any problems identified. No fuel quality standards exist for hydrogen appliances, nor have existing appliances been tested with hydrogen. As a result, multiple projects at GTI Energy and other organizations are looking at the long-term durability of appliances and burners with hydrogen and investigating the compatibility of components upstream of the burner.

Co-Funders: UTD Members

Start Date: 7/1/2023
End Date: 6/30/2025
Status: Active

2023 Funds Expended:	$11,000
Total Project Cost:	$150,000
Total PG&E Cost:	$11,000
Total Co-Funding:	$139,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

1.23.I Inherently Safe ResCom Combustion Systems for Hydrogen-Blended Gases

The objective of the Project is to ensure the safe, reliable, and efficient operation of customer gas appliances with hydrogen-blended gas (5-50% hydrogen by volume) by 1) developing and demonstrating inherently safe combustion systems for common gas appliances (furnaces, water heaters, ranges, etc.) and 2) identifying inexpensive options to retrofit typical existing appliances (e.g., deployed in less than one hour at a cost of <$100). This will help gas utilities demonstrate hydrogen blending levels well above 5% by volume and broadly deploy blended gas in their networks. Hydrogen blending at a level of 5% by volume using green hydrogen will only result in an emission reduction of <2%. To achieve deep decarbonization, much higher levels of green hydrogen are needed (e.g., at 30% hydrogen, emission reduction is 13%). While early pilot projects with low blends help develop the necessary blending infrastructure, if gas utilities and their customers are to reach their decarbonization goals, higher blend levels will need to be deployed sooner rather than later. Higher blends of hydrogen are likely tolerable by most conventional gas appliances. However, in cases where 10–40% hydrogen creates combustion instabilities, these can be a nuisance or catastrophic. Accidents will also be complicated to predict. The solutions this Project seeks to explore could be easily implemented by appliance installers or technicians completing home inspections ahead of any pilots. A potential solution could be as simple as a gas orifice replacement to ensure that all appliances in customer homes will be safe with higher blends of hydrogen. The project kicked-off in Q3 2023 and began an initial literature and prior art review regarding flashback-resistant burner and air-fuel mixer designs. The team engaged with a simulation consulting firm to perform a portion of the analysis.

Co-Funders: UTD Members

Start Date: 7/1/2023
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$5,200**
Total Project Cost:	**$175,000**
Total PG&E Cost:	**$9,579**
Total Co-Funding:	**$165,421**

Benefits

1.23.J Hydrogen Flame Visibility and Colorants

The Project seeks to evaluate and identify colorants for hydrogen-enriched gaseous fuel at various conditions to 1) establish a matrix of hydrogen/methane mixtures to test visibility from 0% to 100% hydrogen and 2) enhance the safety of open flame operation of hydrogen-enriched natural gas at four common lighting conditions with appropriate and safe gas colorants. Gaseous colorants can allow the hydrogen/natural gas fuel to mimic natural gas flames. This will help gas utilities address the safety concerns of gas end users regarding the appearance of hydrogen-enriched flames. Blending renewable hydrogen into natural gas infrastructure is a practical solution for decreasing carbon emissions. However, one major challenge is to ensure safe operation and address end users' safety concerns regarding the performance deviation of hydrogen/natural gas mixtures from traditional natural gas flames. In 2023, the project kicked off: the Project Team identified a burner and created a CAD document to replicate the burner at GTI Energy.

Co-Funders: UTD Members

Start Date: 7/1/2023
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$7,100**
Total Project Cost:	**$150,000**
Total PG&E Cost:	**$11,833**
Total Co-Funding:	**$138,167**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

2.14.0 Ph3—CI—Gas Quality Sensor Validation Hydrogen Sensor

The objective of the Project is to continue to develop and demonstrate in actual field-operating conditions a practical, reliable, and low-cost gas-quality sensor (GQS) that can detect changes in gas quality (e.g., heating value, hydrocarbons, and carbon-dioxide concentrations) in real-time and provide this data to natural gas pipeline operators, local distribution companies, and end users of natural gas. Early project activities involved modifying software so that a new spectrometer could be integrated with the concentration-determining algorithms. The new spectrometer was capable of reading high wavelength data and, therefore, was expected to be able to collect carbon dioxide data directly. The software was modified to collect and process this data. Changes were needed to meet the requirements established by the demonstration site. The project team used a mobile hotspot to collect and transmit data during the demonstration period. Communications with the computer were carried out through an Ethernet cable using the available port on the enclosure. The project team transferred several beta prototype sensors back to CMR Group (CMR). One sensor was transferred to a U.S. engine company for validation testing. Two sensors were returned to CMR in France so they could be sent to companies carrying out validation testing in real-world conditions. Data from a demonstration test in Tulsa was retrieved, processed, and shared with CMR. The data showed more scatter than anticipated, which appeared to be a result of temperature variations during the demonstration period. Efforts were made to apply a temperature correction. Phase 3 efforts to investigate adding more capabilities to the GQS are currently underway. CMR will provide the latest version of its GQS unit to the project team for additional testing, including when measuring hydrogen content in gas streams. The project team is currently awaiting this delivery.

Co-Funders: UTD Members, CMR Group

Start Date: 7/1/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$75,000
Total PG&E Cost:	$5,000
Total Co-Funding:	$70,000

Benefits

2.16.A Ph3—Next Generation Infrared Burner—Field Test

The Project seeks to design, build, and field-test a prototype of a next-generation, high-response, higher-efficiency infrared burner. Key performance indicators and goals to measure and demonstrate the success of Phase 3 will be to show: 1) improved efficiency of at least 4% versus existing gas-fired units, 2) improved start-up times of <3 seconds through advanced materials, and 3) reliable burner operation at the host site for at least 100–200 hours. Burner manufacturer Solaronics has been offering the new technology to its customers. Still, only about 20% of Solaronics' customers have shown potential interest in the new metal foam burners since the technology is not entirely demonstrated and field-proven. Phase 3 will address this market penetration hurdle by putting a near-commercial prototype at a customer-host site for testing and demonstration. In doing so, Phase 3 will advance the introduction of another new high-performance commercial product that efficiently uses natural gas and, with its high-performance response, can compete and be successful in a product category that is dominated by electric units, which on a source-energy basis, may consume three times as much energy as the gas-fired ones.

Co-Funders: UTD Members

Start Date: 6/1/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$10,000
Total Project Cost:	$300,000
Total PG&E Cost:	$27,300
Total Co-Funding:	$272,700

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

2.16.A Ph4—Next Generation Infrared Burner

The Project aims to test and optimize the performance of the new gas-fired infrared (IR) burner that UTD is developing under previous project efforts (2.16.A) in partnership with Solaronics, Inc.—a leading gas-fired IR heater original equipment manufacturer (OEM) and a top metal foam material OEM. The goals are 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 parts per million (ppm) nitrogen oxides, < 30 ppm carbon monoxide). 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 will gather additional data.

Co-Funders: UTD Members

Start Date: 6/30/2022
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$180,000**
Total PG&E Cost:	**$10,000**
Total Co-Funding:	**$170,000**

Benefits

2.20.A—Low Emission Efficient Burner for Ovens and Dryers

The Project sought to advance the commercial introduction of a new burner to reduce emissions, energy use, 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 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 burner performance at the laboratory, 3) designing and integrating the assembly at the host site, and 4) evaluating prototype burner performance at different operating 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 reduced emissions by improving 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 for hydrogen operations is still undergoing, and the team expects it to lower emissions and improve turndown. The prototype testing simulates the host site test setup and demonstrates proof of concept. The prototype enables market demonstration while reducing integration risks with the host-site system.

Co-Funders: UTD Members

Start Date: 6/1/2020
End Date: 8/17/2023
Status: Completed

2023 Funds Expended:	**$0**
Total Project Cost:	**$400,000**
Total PG&E Cost:	**$12,622**
Total Co-Funding:	**$387,378**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

2.20.E—Energy Source Options for Industrial Users

The objective of the Project was to provide a robust, user-friendly analytical tool that can help decision-making that drives decarbonization and the achievement of local environmental targets. This approach supports reliable and cost-effective energy supply to the industrial and large commercial sectors. The final product was a roadmap for adopting natural gas and other energy options. The Project aimed to expand and simplify the use of a detailed techno-economic analysis developed in a previous phase. The analysis considered fuel-switching and electrification scenarios for industrial and large commercial end users. In 2021, the team analyzed a database of industrial energy consumption data for key end-use applications and used it to prioritize the industrial technologies based on geographical locations. In 2022, the project team transitioned the spreadsheet-based tool to an online platform. The team identified several GHG reduction pathways for process-heating segments and evaluated preliminary, including net-zero carbon alternative fuels, renewable energy options, energy efficiency improvements (waste-heat recovery), electrification, hybrid energy sources, and system optimization and control. The final product of the Project was a roadmap for adopting natural gas and other energy options.

Co-Funders: UTD Members

Start Date: 1/14/2020
End Date: 2/28/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$120,000
Total PG&E Cost:	$8,480
Total Co-Funding:	$111,520

Benefits

2.20.E Ph2—Energy Source Options for Industrial Users

The objective of the Project was to provide a robust, user-friendly analytical tool that could inform decision-making around decarbonization and the achievement of local environmental targets. This approach was expected to support reliable, cost-effective industrial and ample commercial energy supply. The Project also sought to expand and simplify the use of a detailed techno-economic analysis developed in a previous phase. The study considered fuel-switching and electrification scenarios for industrial and large commercial end users. In 2021, the team analyzed an industrial energy consumption 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 an online platform with various applications beyond boilers. The team identified several greenhouse gas reduction pathways for process-heating segments. It evaluated net-zero carbon alternative fuels, renewable energy options, energy efficiency improvements (waste-heat recovery), electrification, hybrid energy sources, and system optimization and control. In 2023, the team started working to expand the tool to include furnaces and ovens.

Co-Funders: UTD Members

Start Date: 7/1/2021
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$135,000
Total PG&E Cost:	$2,000
Total Co-Funding:	$133,000

Benefits

2.20.F—Next Generation NGV Driver Information System

The 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 US Department of Energy (DOE) that provides $1,000,000 in federal funds plus $1,000,000 of in-kind partner support. GTI Energy will model the thermodynamics of the vehicle tank(s), the critical 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 will enable the temperature data to be uploaded through the Controller Area Network system without requiring an expensive data acquisition unit.

Co-Funders: UTD Members

Start Date: 7/1/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$250,000**
Total PG&E Cost:	**$50,000**
Total Co-Funding:	**$200,000**

Benefits

2.20.G—Smart CNG Station—Field Demonstration

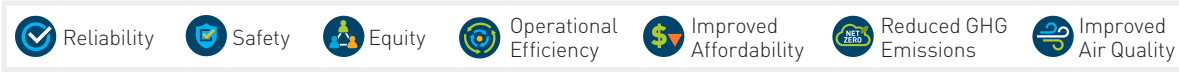
The Project seeks to develop a smart compressed natural gas (CNG) fueling station to increase usable, "onboard" CNG storage capacity by 10–25% and demonstrate it at five field locations. This improved fueling system will provide consistent "full-fills," resulting in lower capital costs for fuel storage on natural gas vehicles and reduced operating costs for filling. The Smart CNG station will communicate live gas properties between the vehicle and the pump so that the gas mass in the tank can be accurately predicted. This will result in the full capacity of the tank being utilized instead of a pressure limit artificially limiting the molecules of natural gas allowed into the tank. Part of PG&E's natural gas strategy is developing new potential end-uses for natural gas. One of the most promising is heavy-duty transportation, including trucking, as replacing gaseous/liquid fuels with battery electric is difficult, given the typical duty cycles. Anything that has the potential to significantly improve the customer's experience with heavy-duty natural gas trucks is critical to expanding it as a future end-use. Please see Phase 2 for an update.

Co-Funders: UTD Members, US Department of Energy

Start Date: 7/1/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$4,320,000**
Total PG&E Cost:	**$120,000**
Total Co-Funding:	**$4,200,000**

Benefits



2.20.G Ph2—Smart CNG Station—Field Demonstration

The Project aims to develop a smart compressed natural gas (CNG) fueling station system to enable "full fills" of CNG vehicles and demonstrate the system at five field locations. Heavy-duty CNG trucks often experience "under-filling" to 20–25%, as frequently cited by industry experts. The smart station will communicate live gas properties between the vehicle and the pump so that the gas mass in the tank can be accurately predicted. The outcome of Phase 2 is a commercial prototype of the smart dispenser hardware and the results of demonstrating this technology on CNG trucks. Researchers deployed 18 HEM data-acquisition systems (HEM DAS) onboard a local fleet of concrete mixers. This allows the project team to collect fueling and fuel consumption data onboard each vehicle to better understand how baseline dispensers operate and how much they truly underfill vehicles. The system is transmitting data about the fuel system to the cloud where investigators download and evaluate fills and driver filling practices. During 2023, the team continued actively testing the smart controller and algorithm using a commercial CNG dispenser and two target cylinders connected to HEM DAS. This will continue into 2024. The technology solution will provide consistent full-fills to CNG heavy-duty trucks. This should result in more minor fuel tank requirements, longer time between refueling, and more confidence in the trucks' range. CNG trucking can be a pathway for renewable natural gas to replace diesel fuel eventually, and this technology could reduce the capital cost differential between CNG and diesel trucks.

Co-Funders: UTD Members, US Department of Energy

Start Date: 7/1/2020
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$2,000,000
Total PG&E Cost:	$25,000
Total Co-Funding:	$1,975,000

Benefits

2.21.A—High Hydrogen Burner for Commercial and Industrial Applications

The Project sought to design, fabricate, and test an advanced fuel-flexible hydrogen and renewable natural gas 0.5 to 1 million British thermal units per hour (MMBH) burner in a commercial-scale furnace at GTI Energy's laboratory. The team partnered with two leading, large industrial end users and two national laboratories to ensure that the final prototype burner met the requirements of representative end users. GTI Energy 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 blends. The team used the funding to demonstrate a scaled-up burner with higher hydrogen blends (up to 60%) to evaluate and commercialize the technology with two leading end users in coordination with Oak Ridge National Laboratory and Argonne National Laboratory. The team then separately authorized and funded field testing of the prototype. In 2021, the project team evaluated the testing apparatus and instrumentation required for hydrogen testing. The research group ordered a flow meter, controls, and other equipment for high-hydrogen testing. In 2022, the project team conducted Computational Fluid Dynamics simulations for design evaluation. The project group also analyzed a burner design for higher hydrogen firing rates with all the design conditions and worked on the design of the gas mixing station. In 2023, the team completed the assembly of the air-fuel skid for hydrogen operation. The Job Safety Analysis and Standard Operating Procedure were updated to perform hydrogen testing and to ensure smooth and safe operation with hydrogen.

Co-Funders: UTD Members, ORNL, ANL

Start Date: 7/1/2021
End Date: 8/1/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$340,000
Total PG&E Cost:	$5,000
Total Co-Funding:	$335,000

Benefits

2.21.B—Energy Recovery from Brewing/Distilling

The Project aims to validate Waste Heat Effect Transfer (WHET) waste heat recovery technology at two microbreweries, providing robust and reliable operation where waste heat is available and water heating is needed. The WHET process will economically recover heat from brew kettles and use that heat for water heating. This approach will provide sufficient operational flexibility to match the facility's operating load variations. The Project will demonstrate the cost-benefits of the WHET technology by achieving a payback period of less than five years. The team will also prepare a technology transfer plan. This Project is leveraging $1.4 million in prime California Energy Commission (CEC) funding and supports CEC project objectives. More than 1,000 breweries and 100 distilleries in California can benefit from the WHET system and save up to 25% of their energy costs. Additionally, there is a potential to deploy the technology at the 30,000 commercial laundry facilities in the country, which consume roughly $800 million in electricity per year. A 20% energy savings would lower energy demand by $160 million annually.

Co-Funders: UTD Members, CEC

Start Date: 11/1/2021
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,670,000
Total PG&E Cost:	$40,000
Total Co-Funding:	$1,630,000

Benefits

2.21.C—Zero Emission Processes with Carbon Recovery

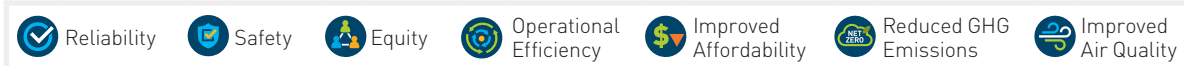
The Project developed a new synthetic air combustion (SAC) process to 1) improve industrial boiler or furnace efficiency when using natural gas, 2) lower carbon dioxide emissions, and 3) provide a means to capture or convert carbon dioxide into valuable products. The team conducted laboratory tests in industrial conditions, and the results helped compare calculated and experimental results when using SAC versus typical air-fired combustion. This process technology aimed to help create a lower-carbon future using natural gas in industrial boilers and furnaces. In 2021, the project team conducted synthetic air-combustion tests using artificial air containing oxygen and carbon dioxide at ambient temperature in a commercial burner. Results confirmed that burners run well on synthetic air. The team has conducted tests with preheated artificial air containing steam. In 2022, technicians modified the experimental furnace test platform to prepare for the next round of tests. Testing was carried out in the GTI Energy Industrial Combustion Laboratory. The project team found that SAC combustion improves furnace efficiency, eliminates nitrogen oxide emissions, and leaves thermal profiles, temperatures, and heat release patterns nearly unchanged. Another important observation is that carbon monoxide emissions are elevated to undesirable levels with SAC combustion under certain conditions. This issue can be resolved by using higher levels of excess oxygen. During 2023, the team worked to define the form and extent of layouts, mass and energy balances, and economics to be used to compare CO2 capture approaches before beginning detailed analyses for the selected CO2 capture approaches.

Co-Funders: UTD Members

Start Date: 11/1/2021
End Date: 11/8/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$150,000
Total PG&E Cost:	$3,000
Total Co-Funding:	$147,000

Benefits



2.21.F—CNG Locomotive Field Demonstration

The Project objective is to design, build, test, and operate a pre-production, compressed natural gas (CNG) hybrid line-haul locomotive to demonstrate the Cummins Westport ISX12N natural gas, near-zero-emission engine in rail service. In 2023, the project team continued to work on locomotive design and procurement of long-term components (CNG tanks, batteries, engines, alternators, and power electronics). The benefit will be a better understanding of the potential of CNG as a locomotive fuel. The project will demonstrate Tier-5-capable locomotive built with commercially available and reliable components, illustrate the use of near-zero-emission, on-road engines for use in off-road markets, open new markets such as rail and marine, quantify the benefits of multi-engine hybrid locomotives, reduce fuel consumption by 20% to 40%, and showcase the benefits of CNG and renewable natural gas use in rail application. These benefits include reducing fuel costs, reducing criteria pollutants, lowering greenhouse gas emissions, and collecting data to validate durability and reliability.

Co-Funders: UTD Members, US Department of Energy

Start Date: 7/1/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$5,199,733**
Total PG&E Cost:	**$10,000**
Total Co-Funding:	**$5,189,733**

Benefits

2.21.H—Hydrogen Fueling for Heavy-Duty Vehicles

The Project will facilitate the installation of public high-flow H35 hydrogen stations for heavy-duty vehicles, which will expand these vehicles' range and operation area. At a higher level, the Project will enable hydrogen to be a component in the future mix of renewable energy to power long-distance hauling. There is no national standard for high-flow hydrogen fueling of heavy-duty, long-haul trucks. An industry protocol for hydrogen fueling of light-duty vehicles (SAE J261) establishes the maximum flow rate and rate of pressure increase. Still, this protocol needs to be faster for heavy-duty trucks, which require at least ten times the amount of hydrogen during each fill, than for light-duty vehicles. In 2023, the team began construction of the time-fill test unit and completed the Hazard and Operability review. Operation of the test unit is expected to begin in early Q1 2024. The team will also assist NREL in validating the fueling protocol developed for high-flow fueling. The collaboration with the National Renewable Energy Laboratory will create a publicly available protocol for high-flow fueling of heavy-duty vehicles.

Co-Funders: UTD, UTD Members, NREL

Start Date: 7/1/2021
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$692,500**
Total PG&E Cost:	**$5,000**
Total Co-Funding:	**$687,500**

Benefits

2.22.B—Ribbon Burner with Hydrogen-Blended Gas

The Project aims to evaluate traditional ribbon burner 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. Based on test results and discussions with a leading manufacturer of ribbon burners, the ribbon burner geometry was modified to burn hydrogen. Prototypes of the modified burners were manufactured and shipped to the team for testing. Further testing and development will continue in an industrial research laboratory. The data and correlations obtained will serve as a basis for developing innovative decarbonization concepts that integrate green hydrogen production, advanced waste heat, water recovery, volatile organic compound mitigation, and self-powered control.

Co-Funders: UTD Members

Start Date: 6/30/2022
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$175,000**
Total PG&E Cost:	**$10,000**
Total Co-Funding:	**$165,000**

Benefits

2.22.G—Pre-Cooling for High-Flow Hydrogen Fueling

The Project will develop a chilling system to pre-cool hydrogen for high-flow fueling of heavy-duty trucks at 10,000 pound-force per square inch, or 70 MegaPascals. Precooling hydrogen before fueling is vital because hydrogen has a negative Joule Thompson coefficient, which means it gets warmer when its pressure drops, unlike natural gas, which cools down. Since hydrogen is less energy-dense than diesel, fueling has to happen at a very high flow rate for the truck to have enough energy to match a full diesel tank, further increasing the risk of overheating. GTI Energy won a competitive federal solicitation process to secure $2.2M of US Department of Energy (DOE) funds for this project, with an additional contribution of $250k from SoCalGas. The project goal is a pre-cooler design capable of fueling 10 kg/min of hydrogen (equivalent to diesel fueling speeds) at less than $500,000. The Project will facilitate high-flow fueling of hydrogen heavy-duty trucks at the same speed as diesel fueling. This is important as California and other states adopt aggressive zero-emission vehicle targets for heavy-duty vehicles, such as California's Advanced Clean Truck Regulation and the recently signed 15-state Memorandum of Understanding to advance the electric medium- and heavy-duty vehicles market.

Co-Funders: UTD Members, DOE

Start Date: 7/31/2022
End Date: 6/30/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$2,450,000**
Total PG&E Cost:	**$29,000**
Total Co-Funding:	**$2,421,000**

Benefits

2.22.H—Heavy-Duty Hydrogen Truck Deployment

The Project will address a critical technology gap for heavy-duty hydrogen fuel cell-powered trucks. No zero-emissions vehicle can operate more than 250 miles in one shift. This project aims to design and build a hydrogen-fueled, zero-emissions regional-haul Class 8 vehicle and demonstrate the technology for 12 months on a 400-mile route from Fontana to Lathrop, California. The team selected this range because it is representative of most intra-state freight movements. By demonstrating the viability of hydrogen fuel cell trucks as a feasible zero-emission solution for long-distance operation, the Project will encourage the adoption of hydrogen-powered trucks and help create substantial demand for hydrogen as a transportation fuel.

Co-Funders: UTD Members, CEC

Start Date: 7/1/2022
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$5,300,000**
Total PG&E Cost:	**$25,000**
Total Co-Funding:	**$5,275,000**

Benefits

2.23.A Decarbonizing Large Commercial and Industrial Equipment with Hydrogen

The Project seeks to identify and resolve research and technology gaps for using hydrogen in various combustion equipment in commercial and large commercial and industrial (C&I) buildings and processes. It does this through experimentation to establish upper limits for hydrogen blending for 3 to 6 different equipment or equipment categories and testing up to 100% hydrogen blends. The partnership with the University of California Irvine, the Air-conditioning, Heating, and Refrigeration Institute, and the Electric Power Research Institute ensures that the research effort is based on comprehensive existing knowledge, is coordinated with other global research efforts, and has significant manufacturer involvement. Leverage funding includes $2.735M in UTD co-funding and the CEC providing the prime financing. Key project goals are to 1) identify technology and research gaps review and analysis with hydrogen, 2) establish technical upper limits for hydrogen for 3 to 6 different equipment or equipment categories through experimental tests with up to 100% hydrogen blends, and 3) demonstrate the emissions, safety, operational, and performance variation of the equipment. Of the total US emissions, the C&I sector emits about 2 billion tonnes. These emissions must be reduced to near zero in the US by 2050. Energy efficiency and conservation remain critical to reducing GHG emissions. Still, decarbonization is needed to meet these aggressive climate goals, including adapting or converting combustion equipment to use renewable or low-carbon energy carriers such as hydrogen as a combustion fuel. During 2023, the project team 1) developed draft test plans for the different equipment and submitted them to the California Energy Commission (CEC); 2) continued HAZOP analysis, job safety analysis, and review safety procedures for installation and testing; 3) continued equipment selection; and 4) designed test rigs.

Co-Funders: UTD Members, CEC, SoCalGas, Low-Carbon Resources Initiative

Start Date: 7/1/2023
End Date: 7/31/2026
Status: Active

2023 Funds Expended: $26,100
Total Project Cost: $2,735,000
Total PG&E Cost: $26,100
Total Co-Funding: $2,708,900

Benefits

5.21.k HyBlend Collaborative Research Partnership to Address Technical Barriers to Blending Hydrogen in Natural Gas Pipelines

The Project was a joint effort of natural gas operators, research consortia, and four national laboratories: Sandia National Laboratory, Pacific Northwest National Laboratory, Argonne National Laboratory, and National Renewable Energy Laboratory. It aimed to evaluate technical and economic considerations for transporting hydrogen blends and other low-carbon fuels using existing natural gas infrastructure. Increasing hydrogen knowledge can reduce greenhouse gas emissions, for example, through coupling energy efficiency and decarbonized fuels. The project team addressed high-priority research topics, including 1) hydrogen compatibility with metals and polymers, 2) life-cycle analysis (LCA), and 3) techno-economic analysis (TEA). The project team 1) developed general principles for the operation of HyBlend delivery systems regarding structural integrity; 2) assessed the role of natural gas impurities in the degradation of metal pipelines and HyBlend for plastic pipeline degradation and lifetime predictions; 3) performed an LCA on the technology pathways for hydrogen and natural gas blends and alternative routes; and 4) quantified the costs, opportunities, and alternative paths for hydrogen production and blending within a natural gas 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 will be published in early 2024. The final report is scheduled for release in Q2 2024. PG&E will use these results to support the development of a hydrogen blending standard and to guide future research.

Co-Funders: OTD Members, HyBlend, US Department of Energy, NREL

Start Date: 8/19/2021
End Date: 7/31/2023
Status: Completed

2023 Funds Expended: $0
Total Project Cost: $15,050,000
Total PG&E Cost: $150,000
Total Co-Funding: $14,900,000

Benefits

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

The objective of the Project was to review national and international regulations, safety standards, and pipeline industry standards for the transportation of hydrogen and natural gas (H2NG) blends, with the goal of identifying and listing gaps and providing potential solutions to the gaps. Regulations, safety standards, and pipeline industry standards identified as applicable to this project were the Code of Federal Regulations Title 49 Parts 190, 191, and 192; the American Society of Mechanical Engineers (ASME) B31.8; and the International Organization for Standardization (ISO) 24078. PG&E has prioritized reducing its carbon footprint and greenhouse gas emissions and is investigating using H2NG blends to achieve this goal. In pursuit of this, PG&E focused on understanding the potential impacts of H2NG blending on pipeline operations. The project team completed interviews with national and international hydrogen system operators and natural gas utilities investigating, experimenting, or seeking to implement H2NG blending. The project team compiled applicable codes and standards into a spreadsheet with an abstract summary. The project's final report includes 1) hydrogen codes, standards, practices, and common terminology, 2) a gap analysis identifying regulations and standards that may need revisions for H2NG blending, and 3) recommendations for H2NG blending guidelines and best practices. PG&E 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: 12/15/2021
End Date: 5/20/2023
Status: Completed

2023 Funds Expended:	**$0**
Total Project Cost:	**$170,000**
Total PG&E Cost:	**$1,100**
Total Co-Funding:	**$168,900**

Benefits

5.21.t Ph1 Effect of Hydrogen-Blended Natural Gas on Performance of Gas Meters and Diaphragm Type Service Regulators

The objective of the Project is to study the effect of hydrogen-natural gas (H2NG) 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 research project results will aid in understanding 1) material compatibility impacts on gas meters and regulators in H2NG blend service, 2) meter accuracy in H2NG blends, and 3) feasible H2NG 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 test rigs, each with nine regulators and nine meters. Construction of the test rigs began in late 2023. Project delays were due to rescoping, supply chain issues related to 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. PG&E could use the results from this research to contribute to the creation of a statewide hydrogen injection standard.

Co-Funders: OTD Members

Start Date: 10/1/2021
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$55,000**
Total PG&E Cost:	**$1,515**
Total Co-Funding:	**$53,485**

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

7.16.e Ph3 On-Line Biomethane Gas Quality Monitoring

The Project aims to develop the selected analyzer's product and test the modified analyzer to monitor 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 online 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 following 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. PG&E needs to continuously monitor TC levels to determine the variability of the TC concentration. If this project shows that the concentration exceeds the limits, PG&E may require biomethane quality monitoring systems to make sure gas quality is consistent.

Co-Funders: OTD Members

Start Date: 11/1/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$267,000
Total PG&E Cost:	$25,000
Total Co-Funding:	$242,000

Benefits

7.16.g Ph2 Universal Analytical Technique for Siloxane

The objective of the 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 measuring 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 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 demonstration schedules are ongoing, as the project had delays due to equipment and supply chain issues. PG&E intends to use the research to determine the repeatability and reproducibility levels of the siloxane analysis. Once approved, PG&E 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 sites using renewable natural gas.

Co-Funders: OTD Members

Start Date: 5/22/2019
End Date: 3/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$253,000
Total PG&E Cost:	$50,600
Total Co-Funding:	$202,400

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

7.21.d Accuracy of Hydrogen Analyzers and Survey Instruments

The Project will conduct a laboratory evaluation on the precision, accuracy, and bias of analytical equipment for natural gas blended with hydrogen at concentrations between 5% and 20%. The project team will evaluate a hydrogen analysis train for ABB's Natural Gas Chromatographs (NGC) 8206 for online British thermal units (BTU) gas chromatographs. The team will select two to four current-market leak detection and leak survey instruments to evaluate the calibration impacts of lower explosive readings when measuring natural gas/hydrogen blends. Blending hydrogen into the natural gas pipeline to reduce carbon emissions has gained traction over the last several years. Many online natural gas BTU NGC manufacturers already offer a train or module for their NGCs capable of hydrogen analysis. Still, historically, the industry has not used them at custody transfer sites. As a result, the industry does not have experience with the precision, accuracy, and bias of these hydrogen analysis systems. Additionally, there is a growing concern related to the impacts of hydrogen on gas leak detection instrument performance and whether the presence of hydrogen will change gas leak results.

Co-Funders: OTD Members

Start Date: 4/21/2021
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$248,000
Total PG&E Cost:	$19,528
Total Co-Funding:	$228,472

Benefits

7.21.j Assessing Performance Impacts of Blended Hydrogen on Thread Sealants

The Project aims to observe the impacts of hydrogen-blended natural gas on specific components in the distribution system. Specifically, low-pressure thread sealants are typically used on meter set assemblies. This work will leverage equipment designed and fabricated in another proposal (OTD 5.21.t). The Project studied the effect of hydrogen-blended natural gas on the performance of gas meters and diaphragm-type service regulators. This project is delayed due to supply-chain issues with thread gauges, blended gas, and a lack of resources. The project team is assessed reallocating resources to reduce the delay impacts. The project team has made some progress with the Test Procedures and Job Safety Analyses (JSA). Testing is expected to begin in Q1 2024. The project once completed will provide value by 1) establishing a baseline for understanding the effect hydrogen-blended natural gas has on elastomers and sealants within the delivery infrastructure and 2) taking advantage of and adding to a testing rig being designed and built as part of another OTD project proposal; this will highlight the ability of test rig to provide modular solutions for closed-loop testing as well as continuous monitoring.

Co-Funders: OTD Members

Start Date: 9/1/2021
End Date: 4/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$150,000
Total PG&E Cost:	$4,500
Total Co-Funding:	$145,500

Benefits

Brimstone Energy Carbon Negative Cement Production

Brimstone Energy is developing a carbon-negative cement production process by changing the chemistry, so limestone is no longer used as a raw material. This process would also allow for capturing carbon dioxide (CO2) from the air through the mineral co-product magnesium hydroxide. At the core of their technology is a chemical leaching process that takes silicate rocks as raw materials (abundant in California) and generates calcium oxide, which can be used to make clinkers for Ordinary Portland Cement (OPC). Unlike limestone, calcium oxide does not emit CO2 when heated to high temperatures. Brimstone can run the carbon capture process at zero cost by generating revenue from OPC and cementitious materials sales. Reducing industrial carbon emissions is difficult and expensive, especially for cement manufacturers, whose two-thirds of emissions come from heating raw materials. This process will enable cement manufacturers and big natural gas consumers to achieve their decarbonization goals while using natural gas as heating fuel.

Co-Funders: Advanced Research Projects Agency-Energy

Start Date: 9/30/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended: $0
Total Project Cost: $13,000,000
Total PG&E Cost: $500,000
Total Co-Funding: $12,500,000

Benefits

Effects of Hydrogen in End-Use Equipment for Commercial and Industrial Applications

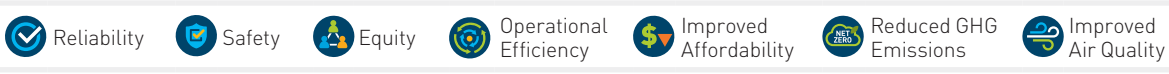
The Project supports the CEC's GFO-21-503—Examining the Effects of Hydrogen in End-Use Appliances for Large Commercial Buildings and Industrial Applications. The objective is to conduct a technical study of the impacts of utilizing hydrogen and hydrogen-blended natural gas in existing appliances and equipment to decarbonize large commercial and industrial buildings in California. The research aims to identify and resolve critical 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 hydrogen adoption's cost, performance, safety implications, and emission reduction benefits. The project team will also identify and address critical benefits, challenges, and potential solutions for increasing hydrogen use in end-use equipment. GTI Energy is leading the effort to complete this wide-reaching study with the Electric Power Research Institute and the University of California, Irvine. The team will establish a methodology to select equipment categories based on the magnitude of greenhouse gas emissions and reduction potential associated with 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 compare business-as-usual and alternative pathways (e.g., electrification vs. diversified path). In 2023, the team drafted test plans and prepared the HAZOP analysis, job safety analysis and reviewed safety procedures for installation and testing.

Co-Funders: CEC, UTD members

Start Date: 11/14/2022
End Date: 11/28/2025
Status: Active

2023 Funds Expended: $0
Total Project Cost: $3,557,500
Total PG&E Cost: $50,000
Total Co-Funding: $3,507,500

Benefits



EFI-00-01 Talking Points

The Project sought to develop white papers with talking points about using emerging fuels to meet the world's energy needs. This helps Emerging Fuels Institute members educate internal and external parties on emerging fuels. These could be leaders, policy-makers, coworkers, and the general public. The project team developed the following white papers: 1) Hydrogen Natural Gas Blending and Separation, 2) Hydrogen Natural Gas Blends and Compressor Stations, 3) Hydrogen Natural Gas Blends and End User Equipment, 4) Hydrogen Natural Gas Blend Measurement and Gas Quality, 5) Hydrogen Natural Gas Blends and Pipeline Integrity, 6) Hydrogen Natural Gas Blending and Safety, Inspection, and Maintenance, 7) Hydrogen Natural Gas Blends in Existing Natural Gas Pipelines, and 8) Storage of Hydrogen Natural Gas Blends. These white papers describe hydrogen challenges, the current status of knowledge, and research & development plans and needs.

Co-Funders: PRCI Members

Start Date: 8/5/2022
End Date: 1/4/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$40,000
Total PG&E Cost:	$4,000
Total Co-Funding:	$36,000

Benefits

EFI-02-01 RNG Trace Constituents Database

The Project created an online searchable database of major, minor, and trace constituent concentrations in natural and renewable gas, along with sampling and measurement techniques. This database is a valuable gas quality resource for Pipeline Research Council International (PRCI) and OTD members. It can eventually become part of a larger global dataset as part of a Center for Gas Quality effort. The groundwork for developing a trace constituent database was established in OTD project 7.18.h—Trace Constituent Database. The goal of that project was to create a database identifying major, minor, and trace constituent concentrations found in various sources of fuel gas. During Q4 2023, the final report draft was circulated for comment and will be released in early 2024. Simultaneously, the database hosted by GTI was launched for member use. The database is intended to provide users with quantitative data on the gas constituents to 1) evaluate concentration ranges in renewable gas derived from agriculture waste, landfill, and wastewater treatment plant sludge and 2) make an equitable comparison to pipeline-quality natural gas. For this Project, the term "gas quality" describes a broad spectrum of fuel gases' chemical, microbiological, and physical properties destined for multiple end-use applications.

Co-Funders: PRCI Members, OTD Members

Start Date: 8/23/2022
End Date: 12/28/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$125,000
Total PG&E Cost:	$4,250
Total Co-Funding:	$120,750

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

Evaluation of Hydrogen-Blended Natural Gas on Engine Performance and Durability

The 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 (UCR) research team will operate the motor on hydrogen-blended natural gas for 500 to 1,000 hours, simulating typical heavy-duty truck and transit duty cycles. After completing the 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 Compressed Natural Gas (CNG) engines will help reduce CO2 emissions. In 2023, the UCR team sourced all 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: University of California Riverside, SoCalGas

Start Date: 1/15/2021
End Date: 2/28/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$489,977**
Total PG&E Cost:	**$125,000**
Total Co-Funding:	**$364,977**

Benefits

G4 Insights PCH Process Confirmation Project

The Project leverages the latest iteration of the process testing apparatus built by G4 Insights Inc. (G4) for its $2.2M ATCO Gas demonstration project. The Project will benefit from the baseline data and operating experience acquired on the ATCO project. G4 PyroCatalytic Hydrogenation (PCH) is a proprietary thermochemical process to convert forestry biomass into renewable natural gas. PG&E is interested in evaluating the G4 PCH process for potential commercial applications. G4 will conduct a series of test runs leading to a 7-day continuous operation run. During 2023, G4 continued its scaled-up PCH Reactor project to achieve 3 tons/day biomass. G4 also began to focus on government and industry grants to supplement current funding, continued to seed strategic partners and secure a commercial site and project developers. The project team will collect, analyze, and share data with PG&E in a final report.

Co-Funders: G4 Insights, ATCO

Start Date: 2/15/2022
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	**$0**
Total Project Cost:	**$80,000**
Total PG&E Cost:	**$40,000**
Total Co-Funding:	**$40,000**

Benefits

GTI 2023 Carbon Monoxide Sensor Interference from Hydrogen

The Project performed a series of tests to determine the rate of false positives on carbon monoxide (CO) sensors in several residential fuel gas detectors and personal gas monitoring devices in the presence of hydrogen at various concentration levels. Avoiding false alarms has been a critical need in the industry. Still, there has yet to be an extensive laboratory study on the interference level of hydrogen blends or pure hydrogen on CO sensors. Multiple recent OTD projects have noted the phenomenon where CO sensors have alarmed without the presence of the gas being recognized nearby. The project results helped address gaps in knowledge about the risks of using hydrogen in buildings, and they can be used to update existing hydrogen acceptance recommendations and documents.

Co-Funders: GTI Energy, OTD Members

Start Date: 9/1/2022
End Date: 3/30/2023
Status: Completed

2023 Funds Expended:	**$0**
Total Project Cost:	**$80,000**
Total PG&E Cost:	**$11,000**
Total Co-Funding:	**$69,000**

Benefits

GTI 2023 Hydrogen Storage for Load-Following & Clean Power—Ph2

The Project objectives are to 1) advance hydrogen energy storage solutions to address variable renewable energy impacts on fossil-fueled assets and 2) use low-cost electricity to generate hydrogen from fossil energy and store it for utilization during peak demands in duct-burning applications. Using stored hydrogen as an energy carrier enables the system to support peak energy demands with minimal impact on the fossil asset. The low-carbon hydrogen produced is a fossil-based source that provides dispatchable hydrogen production and is cheaper than steam methane reforming-based hydrogen. The Project will demonstrate the utilization of stored hydrogen in an economical and low-carbon manner. In 2023, the team completed the Pre-FEED study and confirmed the system to be economically attractive. The final report is being prepared and the team is pursuing multiple paths for demonstration and commercialization.

Co-Funders: GTI Energy, US Department of Energy

Start Date: 10/5/2022
End Date: 9/30/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,131,971
Total PG&E Cost:	$37,500
Total Co-Funding:	$1,094,471

Benefits

GTI 2023 Port of West Sacramento Hydrogen Fuel Cell Switcher Rail Demonstration

The Project leverages CEC GFO-20-604—Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports to design, build, and demonstrate a hydrogen-fueled, zero-emission switcher locomotive. The project scope includes the integration of advanced fuel cell and battery technologies, representing a new platform that will enable commercialization within a few years. The locomotive will be demonstrated in Sierra Northern Railway's short-line operations that serve the railyard and seaport in West Sacramento, California. GTI Energy and Sierra Northern Railway compose Group 1 partners. Shell and Sierra Northern Railway are submitting a fully integrated Group 2 application to establish a long-term hydrogen fueling facility for locomotives and on-road vehicles consistent with the California Energy Commission's goals and efforts. This fueling facility will be on Sierra Northern Railway's territory, in the heart of its short-line operations in the Port of West Sacramento. As PG&E looks for future opportunities to decarbonize its gas system, heavy-duty transportation fueled by hydrogen is a promising solution. PG&E serving on the Technical Advisory Committee will enable them to learn the drivers and challenges experienced while requiring no disbursement of funds.

Co-Funders: GTI Energy, CEC

Start Date: 11/1/2021
End Date: 12/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$9,000,000
Total PG&E Cost:	$0
Total Co-Funding:	$9,000,000

Benefits

GTI Testing of Ultra-Low NOx Burners with Hydrogen-Blended Gas

The objective of the Project was to determine the feasibility of an electrochemical portable analyzer test to measure parts per million (ppm) nitrogen oxide (NOx) levels of less than five ppm and carbon monoxide (CO) levels of less than 20 ppm. The Environmental Protection Agency 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 five ppm for NOx and less than 20 ppm for CO. This project tested and developed recommendations for using 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 could detect 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 portable analyzers to demonstrate compliance with ultra-low NOx and CO limits. SoCalGas intends to perform further 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: GTI Energy, SoCalGas (PG&E did not fund)

Start Date: 11/1/2021
End Date: 4/30/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$190,000
Total PG&E Cost:	$0
Total Co-Funding:	$190,000

Benefits

HYREADY

The goal of the Project was to complete a literature review of existing research projects to prepare engineering guidelines on how to adapt existing natural gas transmission and distribution networks for hydrogen blending (up to 30% by volume). The Project focused on the consequences of hydrogen injection and the countermeasures to mitigate these consequences. The research covered the following components of the gas transmission and distribution systems: 1) pipelines (steel and plastic), 2) measurement and regulation stations, 3) meter set assemblies, 4) compressor stations, 5) underground storage facilities, 6) customer appliances, and 7) hydrogen injection facilities. In 2023, the Project expanded to cover 100% hydrogen pipelines.

Co-Funders: Enbridge, ATCO, Fortis BC, SoCalGas, NW Natural, Enagas, Polska, China Petroleum Pipeline Engineering Co., Berkshire Hathaway Energy, Gas Networks Ireland, Gaz-System, Gasunte, GRDF, GRTgaz, Fluxys, Terega, TokyoGas, PipeChina, NAurgy, Rosen, DBIGut, Dominion Energy, Snam, GERG, DNV

Start Date: 1/23/2017
End Date: 12/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$600,000
Total PG&E Cost:	$46,000
Total Co-Funding:	$554,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

JEFI-01-01 Change Management Hydrogen Compressor Stations

The Project developed a guidance document to assist operators with the safe management of operations associated with introducing hydrogen into a compressor facility. Specifically, the proposed research can be used as a starting point for operators to safely manage the process change associated with having hydrogen blended with natural gas at existing compressor stations. Project results can help guide the decision-making and development of future compressor station design methodologies and give insight into the potential impacts of hydrogen blending.

Co-Funders: PRCI Members

Start Date: 4/28/2022
End Date: 1/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$75,000
Total PG&E Cost:	$7,500
Total Co-Funding:	$67,500

Benefits

JEFI-03-01 DNV JIP Guidelines for Integrity Management of Hydrogen Pipelines

The Project focuses on developing guidelines for assessing pipeline defects for transporting hydrogen-blended natural gas. The guidelines will be based on compiling information from various ongoing industry efforts and developing specific information on relevant materials under representative environmental and loading conditions. The guidelines will provide a framework to assess the feasibility of transporting hydrogen blends in existing pipelines and provide a basis for constructing new pipelines for hydrogen service. The benefits include 1) properties of relevant fatigue crack growth rate (FCGR) and fracture toughness (FT) in relevant environments and loading conditions, 2) the role of metallurgical variables on the FCGR and FT parameters in hydrogen to enable the development of guidelines for defect assessment in existing as well as new pipelines, and 3) an integrity management framework based on representative properties of relevant materials in typical operating environments. In 2023, the project team completed several in-situ fracture mechanics testing to understand hydrogen interactions with defects.

Co-Funders: PRCI Members

Start Date: 7/15/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$450,000
Total PG&E Cost:	$15,000
Total Co-Funding:	$435,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

JEFI-04-01 EWI JIP Material Qualification New Steel Pipe H2

This program will evaluate Option B of the current American Society of Mechanical Engineers (ASME) B31.12 standard. Option B requires a series of tests to characterize the effects of hydrogen embrittlement on toughness and fatigue resistance in the pipe body, seam welds, and the seam weld heat-affected zones (HAZs). Current fracture toughness and fatigue crack growth rate test methods specified in B31.12 are very conservative and do not explicitly address aspects specific to parent pipe, weld, or HAZ test protocols. For example, guidance on notch placement in welds and HAZs is non-specific. Test specimen constraints, loading rates, notch depths, and other factors that could potentially influence toughness properties have important implications for the integrity and safety of pipeline operations. The proposed scope of work will address some of these gaps to identify best practices for quantifying fracture toughness in pipelines and their associated welds and HAZs for gaseous hydrogen service. ASME B31.12 provides conservative methodologies for qualifying pipe steels and welding procedures for hydrogen pipelines. These have worked well to minimize integrity threats to hydrogen lines. However, a significant future expansion of the hydrogen pipeline network would likely increase the need to operate these pipelines at higher pressures than what has been typical for current hydrogen lines. Approaches to qualify future hydrogen lines for higher operating pressures are critical gaps that will be addressed in this project. These higher pressures and design factors may be necessary for the economic performance of the pipeline, considering the longer distance over which hydrogen will be piped and the lower energy density of hydrogen gas compared to natural gas.

Co-Funders: PRCI Members

Start Date: 9/7/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$340,000
Total PG&E Cost:	$34,000
Total Co-Funding:	$306,000

Benefits

JEFI-05-01 DNV JIP Material Selection Underground Storage

The Project will focus on ensuring the integrity of underground storage facilities transitioned to hydrogen-blended service by 1) developing an understanding of damage mechanisms, 2) building models for quantitative damage prediction in low-strength materials in the presence of hydrogen, 3) improving engineering practices, 4) transitioning from allowable stress-based design to a fracture mechanics approach, and 5) improving inspection methods. The project team will achieve these objectives by 1) characterizing the damage response of the various materials of interest in hydrogen storage applications to both environmental and loading variables, 2) developing an appropriate fracture mechanics framework to incorporate the material damage mechanisms, and 3) leveraging existing data on various materials in sour environments as well as seawater under cathodic protection conditions to help correlate materials data to long term in-service performance. In 2023, the project team discussed the operational conditions, environmental conditions and potential materials that should be tested.

Co-Funders: PRCI Members

Start Date: 8/19/2022
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$300,000
Total PG&E Cost:	$12,000
Total Co-Funding:	$288,000

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

M2012-002 Ph1a Living Lab for Biogas/Biomethane Treatment

The objectives of the Project were to 1) Study the impact on the gas infrastructure of processed biogas from the Newtown Creek wastewater treatment facility and 2) Compare information from this system to a pipeline system specifically designed to be equivalent but with the utilization of traditional pipeline quality natural gas. The study is designed to evaluate and compare immediate impacts and impacts over time from the first startup through five years of operation. Commissioning of the conditioning system began in August 2022. Sending out of on-spec renewable natural gas (RNG) into National Grid's gas distribution system started in October 2022. Commissioning of the odorant system was completed in February 2023. The Project achieved 24/7 operation and conducted a high-flow performance test in March 2023. The plant went online, and all systems were in service on March 28, 2023. Ribbon Cutting with New York City was on June 14, 2023. The Living Lab received the first flow in the summer of 2023.

Co-Funders: NYSEARCH Members

Start Date: 4/1/2018
End Date: 3/29/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$157,888
Total PG&E Cost:	$42,947
Total Co-Funding:	$114,941

Benefits

M2018-011 Ph3 Scaling of Microbial P2G Conversion

The proposed Phase III effort aims to build, test, and scale a new generation of advanced bioelectrochemical reactors for high-current-density power-to-Gas conversion at high energy efficiency exceeding the current state-of-the-art efficiency values. Stanford University and a collaborating research group at Aarhus University in Denmark will complete this work. There is a need for long-term storage of excess renewable electrical energy. In addition, converting renewable power to renewable natural gas from carbon dioxide is an emerging platform for producing carbon-neutral methane. This technology addresses this need using an electromethanogenic system to convert excess renewable electrical energy into renewable natural gas while capturing carbon dioxide.

Co-Funders: NYSEARCH Members

Start Date: 9/7/2023
End Date: 12/7/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$339,000
Total PG&E Cost:	$37,905
Total Co-Funding:	$301,095

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

M2020-002 Ph2 Impact of Hydrogen/Natural Gas Blends on LDC Infrastructure

The Project sought to determine if blending hydrogen into natural gas would change the physical properties of elastomers in a natural gas delivery system. The most common elastomers are styrene-butadiene rubber (SBR) and acrylonitrile butadiene rubber (NBR). Both are used as seals in compression applications and gaskets for flanges in joining pipes and fittings. More data is needed to determine the effect of hydrogen concentrations in hydrogen/natural gas blends on elastomers in a natural gas infrastructure (e.g., piping, piping components, and appurtenances), as it may impact the safety and reliability of the gas delivery system. In Phase 1, the team performed exploratory tests using a limited set of test gas mixtures. Phase 2 focused on a complete and systematic test program leveraging Phase 1 findings and testing new and vintage materials with a wide range of hydrogen blends (up to 20%), pressures, and temperatures. In 2023, the project team completed virgin NBR and SBR tests, with results showing the impact on the elastomers at 5%, 12%, 20%, and 30% hydrogen concentrations. During Phase 1 of this project, the team saw an impact on the elastomers during the creep test. They observed no effect in Phase 2, likely due to the more accurate data from the thermomechanical analyzer purchased for this project phase. This project will help PG&E determine if and how hydrogen blending affects 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: 6/25/2021
End Date: 7/13/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$432,760
Total PG&E Cost:	$57,700
Total Co-Funding:	$375,060

Benefits

M2020-008 Study on the Impact Trace Constituents in RNG

The Project aims to study trace constituents' impact in renewable natural gas (RNG) and traditional pipeline gas on Local Distribution Company (LDC) infrastructure and customer appliances. The Project aims to determine appropriate trigger limits for deleterious trace constituents to preclude any safety or maintenance risks on LDC infrastructure and gas appliances. This testing helps PG&E reduce uncertainties and variations in limits set by different utilities for the trace constituents in RNG by providing scientific data to back up the trigger limit recommendations. In light of the growing demand for RNG production and injection into distribution infrastructure in North America, the testing should help producers and developers determine the optimum upgrading and measurement system for biomethane. For LDCs, it will aid decision-making and help advance specifications to address safety and reliability issues. The project was completed in 2023. Four test media were used including terpene, hydrocarbon, aldehyde and ketone based on trace components identified as potentially having an effect on these materials.

Co-Funders: NYSEARCH Members

Start Date: 1/15/2021
End Date: 6/9/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$606,810
Total PG&E Cost:	$71,390
Total Co-Funding:	$535,420

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality

M2021-008 Hydrogen Living Lab

The Project aims 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 impacts 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 also tests the sensitivity and 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. This project will yield valuable data to PG&E on hydrogen blending impacts concerning safety and pipeline integrity, measurement, regulation, and procedures for safety and maintenance. In 2023, the project team developed and iterated the Test Plan.

Co-Funders: NYSEARCH Members, SoCalGas

Start Date: 5/4/2022
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,222,402
Total PG&E Cost:	$83,855
Total Co-Funding:	$1,138,547

Benefits

NSF 22-546 Four Networks for Geologic Hydrogen Storage

The Project focuses on creating 1) community engagement networks to allow community priorities to inform natural, physical, and social science research around geologic hydrogen storage, 2) an international network of experts to develop a public, open-science research plan for a field research study of geologic hydrogen storage, and 3) an inclusive hydrogen education network. Hydrogen from renewable energy will provide opportunities for transitioning energy-intensity industries to carbon-free energy, a critical step for combating the climate crisis. Establishing geologic storage in porous rock reservoirs would unlock distributed capacity for hydrogen hub development. This Project addresses critical scientific, environmental, and socioeconomic questions associated with the proposed development of geologic hydrogen storage in porous rock.

Co-Funders: NSF, UC Berkeley, Lawrence Berkeley National Laboratory

Start Date: 12/1/2022
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$1,500,000
Total PG&E Cost:	$0
Total Co-Funding:	$1,500,000

Benefits

RNG and Value-Added Chemicals from Biomass

The Project seeks to demonstrate production and separation technology that will convert forest biomass residues to pipeline-quality renewable gas and value-added byproducts. PG&E participates only as a Technical Advisory Committee member. Presently, 25 Biomass power plants operate in California for a total power output of over 600 megawatts. These power plants were built in the early 1980s and supported by the Public Utility Regulatory Policy Act Standard Offer Contracts. In 2016, Senate Bill 859 awarded biomass power plants approximately $900M in grants and contracts. Still, these facilities have been struggling to compete with other renewable electricity sources and to comply with air quality regulations as they are old and relatively inefficient. For example, the Tracy facility, with a capacity of 1,000 bone dry ton/day and 23 MW of electricity, yields a conversion rate of about 12%. Therefore, there is an opportunity for new technologies to be deployed in 5 to 10 years. West Biofuels' gasification system is an example of a new technology using woody biomass to produce renewable natural gas. In 2023, PG&E announced a bio-mass to RNG project and initiative to purchase California-produced RNG for natural gas customers.

Co-Funders: CEC, West Biofuels

Start Date: 11/15/2019
End Date: 3/31/2024
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$2,560,000
Total PG&E Cost:	$0
Total Co-Funding:	$2,560,000

Benefits

Screening of Depleted Gas Fields for Hydrogen Storage

While there is some information on the general acceptability of gas fields for hydrogen, individual gas fields still need to be evaluated on a case-by-case basis to understand their current capabilities for accepting hydrogen. Research completed in this area has developed screening criteria that can be applied to individual gas fields. As PG&E looks to accept renewable gas, including hydrogen-natural gas blends, into its existing infrastructure, it will be essential to understand the impacts on its gas fields, as these will eventually need to be used for seasonal hydrogen storage. This project gives PG&E a foundation upon which it can build. In 2023, the final report was issued with factors to consider avoiding leakage and loss. In addition, the reservoir dynamics, geochemical reactions, and the microbial aspects are considered the principal key components in the subsurface, especially in the depleted gas reservoirs. Density, viscosity, diffusivity, and solubility in relation to the petrophysical properties (permeability and porosity) are also important to understand and study and incorporate in a UHS evaluation. The final report also provided recommendations on the ideal conditions to inject hydrogen such as best reservoir temperature to inhibit microbial growth and optimal permeability. Lastly, the controlling environmental factors (particularly temperature, salinity, and pressure) as well as the native gas/brine compositions play another key part.

Co-Funders: Rockpoint Gas Storage, University of Edinburg

Start Date: 12/13/2022
End Date: 8/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$58,000
Total PG&E Cost:	$29,000
Total Co-Funding:	$29,000

Benefits

T-792 Market/Technical Study on High-Concentration Hydrogen Leak Detector

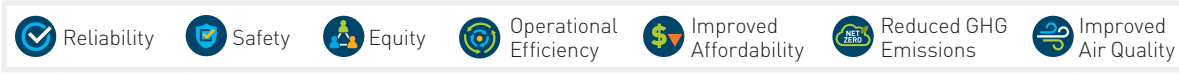
The Project aims to determine what technologies are available or need further adaptation to meet specifications for stationary and mobile leak survey instruments for up to 100% hydrogen-blended gas detection. The first part of the proposed work focused on technical and economic requirements for the detection of hydrogen at volume percentages of 20, 30, 50, and 100%. Four small tasks are proposed as part of this market and technology assessment work. The essential specifications of the funders will be reviewed and agreed upon before the state-of-the-art market survey. In Task 2, the project team will complete a survey and identify and evaluate technologies that meet the specifications for commercial readiness and Technology Readiness Level if they are not already commercial. The funders would be presented with technology descriptions, and with input from the funders, the most promising options would be shortlisted. Task 4 will create an R&D roadmap of the work that remains. This Project could provide a shorter-term solution for hydrogen leak detection that, if implemented, could ensure safety and save time and money to aid the transition toward blends of hydrogen concentrations greater than 20%. The final report was issued in September 2023. 5 potential hydrogen sensors were identified; however, these sensors did not meet all of the Operator's requirements. A subsequent phase is being proposed to field test a subset of these tools.

Co-Funders: NYSEARCH members

Start Date: 1/2/2023
End Date: 9/21/2023
Status: Completed

2023 Funds Expended:	$3,470
Total Project Cost:	$71,127
Total PG&E Cost:	$6,940
Total Co-Funding:	$64,187

Benefits



T-794 Crack Assessment of Squeeze-Off Locations with Blended Hydrogen

The objective of the proposed Project is to examine whether hydrogen blended with natural gas has the potential to leak from flaws induced by pipe squeeze-off operations on medium-density and high-density polyethylene. The test design would consider the various plastic pipes installed for gas pipelines over the past 40 years. For the test design, the contractor would assume that blended hydrogen gas will flow throughout the existing distribution pipeline infrastructure. This is to include a pipe sampling based on the year of installation (age), material, and diameter as a basis for selection. PG&E is interested in understanding the effects of hydrogen blending into existing natural gas pipelines. This project will provide essential knowledge, contributing information to a larger group of physical considerations and concerns that may impact existing pipeline infrastructure. PG&E prepared several pipe samples to contribute to the project for testing.

Co-Funders: NYSEARCH Members, DNV

Start Date: 7/1/2023
End Date: 7/31/2024
Status: Active

2023 Funds Expended:	$15,615
Total Project Cost:	$160,075
Total PG&E Cost:	$15,615
Total Co-Funding:	$144,460

Benefits

T-795 Standardized Hydrogen Blending & Injection Skid for Local Distribution Companies

The Project seeks to pioneer a digital database to provide a common framework for hydrogen blending and interconnection. This would allow utilities to select the optimal design for their systems as they begin to accept hydrogen and control blend percentages and hydrogen volume consistency throughout the distribution system. The database would serve as a valuable resource for local distribution companies as the gas industry continues to evaluate and fully understand the impact of hydrogen on the gas utility system and would help establish best practices for hydrogen system planning using this database tool. As part of the scope of work, the California Environmental Policy Council (CEPC) would develop standard process flow diagrams, pipeline and instrumentation diagrams, and fabrication drawings. Utilities could choose the skid that best fits their needs and select customized instrumentation and equipment from the database. CEPC also proposes to develop a manufacturing specification that would accompany the skid design to guide the skid's fabrication. NYSEARCH and its members are investing early to develop a standard approach to hydrogen blending and injection to minimize cost and maximize the opportunities for hydrogen interconnection with Local Distribution Companies. Utilizing a standard design and approach should save on design and development costs and make procurement of materials, testing and commissioning of a hydrogen blending and injection skid, and development of record drawings (as-builts) more accessible. The project team has prepared drawings and documents to review. PG&E provided design comments and feedback.

Co-Funders: NYSEARCH Members, Campos Engineering

Start Date: 7/1/2023
End Date: 5/31/2024
Status: Active

2023 Funds Expended:	$35,885
Total Project Cost:	$376,810
Total PG&E Cost:	$35,885
Total Co-Funding:	$340,925

Benefits

Targeted Hydrogen Blending in Gas Infrastructure for Decarbonization

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

Co-Funders: CEC

Start Date: 2/9/2023
End Date: 12/31/2025
Status: Active

2023 Funds Expended:	$0
Total Project Cost:	$7,250,021
Total PG&E Cost:	$0
Total Co-Funding:	$7,250,021

Benefits

UCI Natural Gas Grid as a Long-Duration Storage Resource

As the fraction of renewable energy in the electric resource portfolio increases, the consequences of intermittent and mismatched renewable energy production and demand increase. Power-to-gas (or hydrogen energy storage) is another solution for long-term storage and one of great promise that leverages existing natural gas infrastructure to provide long-duration (seasonal) storage at a massive scale. This Project modeled the dynamics of injecting renewable gas (e.g., hydrogen or synthetic methane) into the PG&E gas grid to understand how much energy the system can absorb at different times, considering variability in producing these renewable gases. This study demonstrated the value of hydrogen and synthetic methane for long-duration storage.

Co-Funders: University of California Irvine

Start Date: 2/25/2022
End Date: 3/31/2023
Status: Completed

2023 Funds Expended:	$0
Total Project Cost:	$100,000
Total PG&E Cost:	$100,000
Total Co-Funding:	$0

Benefits

Reliability · Safety · Equity · Operational Efficiency · Improved Affordability · Reduced GHG Emissions · Improved Air Quality