

PG&E Gas Research, Development and Demonstration



Annual Report **2025**

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MESSAGE FROM THE SENIOR DIRECTOR Of Grid Research, Innovation and Development

At PG&E, innovation fuels our mission to provide clean, reliable, and affordable energy for all Californians.

Our Gas Research, Development, and Demonstration (RD&D) team plays a vital role in that mission by advancing the technologies, processes, and partnerships that help us deliver reliable, affordable energy while preparing the gas system for a decarbonized future.

RD&D is where ideas become impact.

By investing in projects that improve leak detection, predictive maintenance, and system inspection, we're strengthening safety and reliability across our 50,000-mile gas network while reducing costs and emissions through data, automation, and advanced analytics. Through foundational research into low-carbon fuels like renewable natural gas, we're charting a practical path toward integrating cleaner energy into our system.

In 2025, PG&E's Gas RD&D program delivered outcomes that support California's priorities for safety, methane emissions reduction, and affordability. Completed research across pipeline integrity, leak detection, emissions measurement, and low-carbon fuel evaluation strengthened the technical foundation used by regulators and utilities to understand risk, improve emissions transparency, and inform system planning. Together, these efforts reflect Gas RD&D's role in contributing practical, evidence-based insights that support a safer and more resilient energy system statewide.

We also see unbounded opportunity in artificial intelligence (AI) to revolutionize our energy system. AI can drive advanced efficiencies and orchestration across operations, unlock robust predictive capabilities, personalize interactions with customers, and magnify the capabilities of our coworkers. Used responsibly, it can be a powerful enabler of ratepayer affordability, delivering better outcomes at lower cost while reinforcing the reliability Californians depend on every day.

RD&D is essential to PG&E's transformation and to California's clean energy future. By partnering with innovators, researchers, and industry peers, we're not just solving today's problems—we're building the knowledge and tools needed to keep energy safe, affordable, and sustainable for generations to come.

Quinn Nakayama

Senior Director

Grid Research, Innovation and Development

1 Executive Summary

1.1 Gas RD&D Program Background

PG&E's Gas Research, Development, and Demonstration (RD&D) program supports the safe, reliable, affordable, and environmentally responsible operation of one of the nation's largest natural gas systems. Consistent with Public Utilities Code §740.1, the program uses ratepayer funds to conduct applied research and field demonstrations that generate decision-use information to support evaluation of system safety, reliability, cost management, and greenhouse gas (GHG) emissions reduction strategies. RD&D focuses on work that is not well suited to routine utility operations but is essential to reducing technical, regulatory, and financial risk before broader deployment.

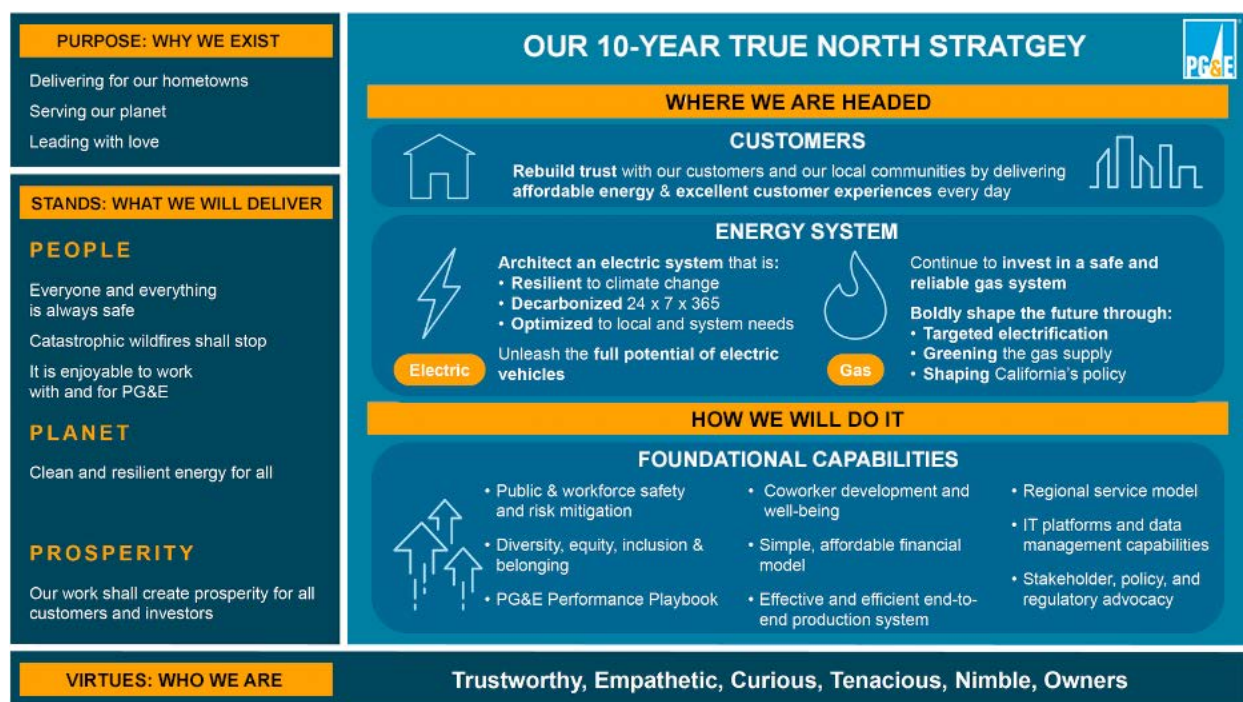


Figure 1: PG&E's True North Strategy drives long-term strategy while focusing on near-term priorities.

Gas RD&D is a key enabler of PG&E's True North Strategy, supporting the company's long-term transition to a safer, cleaner, and more resilient energy system while staying grounded in near-term operational needs. Through research focused on gas system integrity and decarbonization, the program develops practical data and insights that inform planning, support evaluation of emissions-reduction opportunities, and assess the safe integration of lower-carbon fuels—while keeping affordability and measurable benefits to ratepayers front and center. Gas RD&D's work is influenced by PG&E's 2024 R&D Strategy Report, which identifies priority technology gaps across the gas system and provides a clear framework for selecting and advancing research investments.

Affordability is a central principle applied in the Gas RD&D program, guiding project selection, scope, and evaluation to avoid unnecessary cost exposure to ratepayers. As California’s energy system evolves and gas throughput declines, RD&D prioritizes innovations that lower operating and maintenance costs, extend the useful life of existing assets, and reduce the cost of meeting safety, reliability, and climate goals. Every research investment is evaluated not only for technical merit, but also for its potential to deliver measurable, long-term value to ratepayers.

Safety and system integrity remain foundational. Gas RD&D supports research, testing, and demonstration projects that enhance system awareness, improve inspection and monitoring capabilities, and strengthen predictive risk management. Increasingly, this work leverages advanced analytics, artificial intelligence (AI), and machine learning (ML) to transition from reactive to predictive operations—helping identify emerging risks earlier, optimize maintenance strategies, and reduce the likelihood and cost of unplanned events.

At the same time, Gas RD&D plays a vital role in charting the course toward a decarbonized gas system. By investing in both foundational research and applied demonstrations, the program helps evaluate how renewable natural gas (RNG) and other clean fuels can be safely and cost-effectively integrated into existing infrastructure. This evidence-based approach supports PG&E’s goal of achieving a net zero energy system by 2040 while protecting affordability, reliability, and safety.

Inclusion and belonging are integral to Gas RD&D’s mission. Guided by PG&E’s commitment to Environmental and Social Justice (ESJ), the program considers stakeholder and ESJ input as an important source of information to inform project evaluation, while balancing that input against eligibility, affordability, and ratepayer benefit criteria. RD&D helps ensure that the benefits of innovation and the clean energy transition are shared equitably across PG&E’s service territory.

1.2 Summary of Report Contents

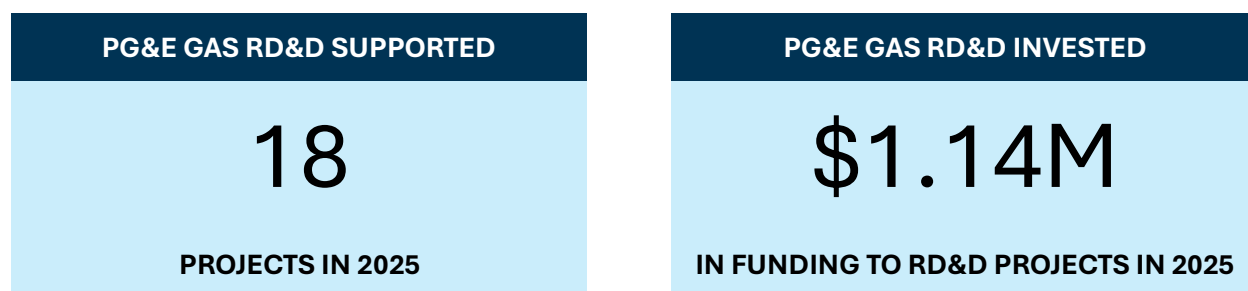
1.2.1 2025 Reporting Year

This Annual Report is intended to inform Commission staff and stakeholders of prior-year Gas RD&D activities and outcomes and to provide context for discussion at the subsequent Annual Workshop, consistent with Commission direction regarding program transparency and continuity.

In reporting year (RY) 2025, PG&E Gas RD&D operated under the program structure approved by the CPUC in Decision (D.) 23-11-069¹. This report fulfills the requirement described in D.19-09-051 that PG&E submit an annual report describing the previous year's RD&D program.²

1.2.2 Portfolio Accomplishments

In RY2025, PG&E completed 18 projects, including three that directly engaged or benefited ESJ communities. Across its portfolio, when appropriate, the program leveraged ratepayer-funded investments to attract third-party support. This leverage expanded the scope and impact of RD&D activities while reducing the cost burden on ratepayers.



Projects supported by Gas RD&D generate system-level analytical insights by strengthening understanding of safety and reliability performance, informing methane and GHG emissions reduction strategies, supporting regulatory confidence, and evaluating cost drivers over time. Examples such as the field pilot of the SPADE real-time pipeline threat detection system and non-intrusive electromagnetic inspection at challenging river crossings (Section 5.4) demonstrate how RD&D validates emerging technologies under real-world conditions and informs evaluation of potential operational applications—improving system integrity while avoiding costly and disruptive interventions.

A complementary case study highlights how RD&D strengthens emissions measurement and regulatory confidence. By developing and validating a component-level methane emissions quantification methodology for transmission metering and regulation (M&R) stations, Gas RD&D enabled PG&E to accurately measure and report emissions reductions from equipment upgrades and leak mitigation. CPUC approval of this methodology allows PG&E to demonstrate measurable progress toward methane reduction and its 2040 net zero goal, while ensuring emissions abatement investments are transparent, defensible, and cost-effective.

¹ California Public Utilities Commission, Decision (D.) 23 11 069, Decision Adopting Test Years 2023–2026 General Rate Case for Pacific Gas and Electric Company, issued November 16, 2023, available at: <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M520/K896/520896345.pdf>

² California Public Utilities Commission, Decision (D.) 19-09-051, Decision Adopting Test Year 2019 General Rate Case for Southern California Gas Company, issued October 1, 2019, available at: <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M316/K704/316704666.PDF>

1.2.2.1 Quantified Impacts

For the 2025 reporting year, PG&E presents project-level benefits in a structured format that preserves the same analytical discipline used in the decommissioning roadmap: benefits are framed to show clear, reviewable pathways to ratepayer value while maintaining explicit boundaries between (1) authoritative policy and planning inputs, (2) the gas–electric assumption handoff, and (3) utility-led research execution that stops short of operations or implementation. This approach is designed to improve transparency and comparability, avoid role conflation, and ensure benefits are communicated as decision-support value rather than as implied execution outcomes.

Consistent with that methodology, the Annual Report’s benefits fields reflect (a) near-term analytical benefits produced directly through research outputs (e.g., improved assumption integrity, analytical defensibility, structured treatment of uncertainty, and reusable decision-support methods) and (b) what those outputs enable later—without claiming that enabled outcomes have occurred absent downstream adoption and attributable evidence. This approach preserves traceability between research-enabled learning and any later operational or program outcomes, while reinforcing that Gas RD&D’s role is to produce bounded analytical outputs and written records, not to authorize or execute implementation. The table below demonstrates how this framing is applied by mapping Public Utilities Code § 740.1 considerations to EPIC framework and the corresponding Gas RD&D benefits treatment used throughout the Annual Report.

PUC §740.1 Consideration	EPIC Framework	Gas RD&D Benefits Framing	How this Methodology is Reflected
Reasonable probability of ratepayer benefit	Focuses on articulating clear problem statements and reviewable benefit pathways	Recognizes value associated with improved analytical clarity and planning consistency	Frames analytical work so that potential benefit pathways can be examined and reviewed
Incremental benefits	Emphasizes RD&D that produces learning and methods not otherwise expected to occur	Distinguishes research-enabled learning from compliance-driven outcomes	Identifies analytical outputs that would not typically arise absent focused research activity
Avoidance of unnecessary duplication	Calls for role differentiation and coordination across administrators	Requires non-duplication with electric planning and CEC-funded research	Treats external planning and research outputs as fixed inputs rather than re-creating them
Safety, reliability, affordability, environmental	Encourages transparent	Treats benefits as enabled downstream rather than presumed	Allows benefit implications to be examined without

and efficiency considerations	discussion of how benefits may arise		asserting near-term outcomes
Research role (distinct from execution)	Draws a clear distinction between RD&D and operations	Limits scope to decision-support and analytical work	Constrains outputs to analytical methods and documentation, excluding implementation

For more information about the benefits associated with PG&E RD&D by funding initiative, see Sections 3.3 and 3.4.

2 Requirements Matrix

Table 1: Requirements matrix.

Req. #	Description	Source	Annual Report Section(s)
1	“Submit an Annual Report ... describing the prior year’s RD&D program.”	D.19-09-051 OP 30, p.783	Section 1.2.1
2	“...summary of ongoing and completed projects.”	D.19-09-051 OP 30, p.783	Sections 5.6 and 5.7
3	“...funds expended.”	D.19-09-051 OP 30, p.783	Section 4
4	“...funding recipients.”	D.19-09-051 OP 30, p.783	Section 7.2
5	“...leveraged funding.”	D.19-09-051 OP 30, p.783	Section 7.3
6	“...explanation of processes used for selecting RD&D project areas.”	D.19-09-051 OP 30, p.783	Section 7.10
7	“...structure of the RD&D portfolio.”	D.19-09-051 OP 30, p.783	Section 3
8	“...future annual reports ... should include an explanation of how [PG&E] has used (or intends to use) the results.”	Resolution G-3573, p.16	Sections 5.2 and 5.3

3 Background: Introduction & Overview

3.1 Gas RD&D Program Purpose

3.1.1 Value Statement

PG&E’s Gas RD&D program supports applied research and field testing focused on improving the gas system, making the system safer, cleaner, and more affordable for customers during the energy transition. Aligned with PG&E’s True North Strategy, the program tests and applies emerging technologies and approaches that strengthen system integrity, reduce emissions, and support the transition to lower-carbon fuels—while delivering clear benefits to ratepayers.

By working with researchers, industry partners, and peer utilities, Gas RD&D reduces risk, supports informed decision-making, and helps ensure the gas system can evolve safely, reliably, and equitably as California’s energy system changes.

3.1.2 Program Basis

PG&E’s Gas RD&D program operates under the authority of the California Public Utilities Commission (CPUC) and California Public Utilities Code § 740.1, which authorizes the use of ratepayer funds for research, development, and demonstration activities that provide public interest

benefits. Consistent with this statutory direction, PG&E Gas RD&D supports applied research that informs evaluation of gas system operations, safety and reliability considerations, cost drivers, and GHG emissions reduction strategies.

The Gas RD&D program is governed by CPUC decisions, resolutions, and advice letter determinations that establish program scope, funding levels, reporting requirements, and oversight expectations. Key program authorities include:

- **D.19-09-051**, Decision Addressing the Test Year 2019 General Rate Cases of San Diego Gas & Electric Company and Southern California Gas Company, established the modern framework under which IOU Gas RD&D Administrators submit its Gas RD&D activities for Commission review.
- **D.23-11-069**, Decision on Test Year 2023 General Rate Case for Pacific Gas and Electric Company, established specific Gas RD&D program requirements for PG&E.
- **Annual Tier 3 Advice Letters** submitted by PG&E to the CPUC Energy Division, including Advice Letter 5077-G-A (2024 Plan) and Advice Letter 5069-G (2025 Plan), both of which were denied in CPUC Resolution G-3618, and are being resubmitted via revised Tier 3 Advice Letters as directed by the Commission, which seek approval of Gas RD&D research plans and budgets and implement Commission guidance regarding program priorities, scope, and reporting.
- **CPUC Resolutions**, including Resolutions G-3601 and G-3618, which provide additional direction regarding reporting, transparency, and participation in broader Commission-led efforts to develop consistent RD&D impact metrics and best practices.^{3 4}

Together, these authorities define eligible research areas, establish funding and reporting requirements, and provide the framework for CPUC oversight of PG&E's Gas RD&D program.

From a program design standpoint, PG&E Gas RD&D is intended to address technical, operational, and regulatory challenges that are not well suited to routine utility activities. Projects emphasize applied research, pilots, and demonstrations that test emerging technologies, validate methodologies, and generate field data needed to reduce uncertainty and risk before broader deployment. This work supports risk-based planning, compliance strategies, and long-term decision-making related to system integrity, emissions reduction, decarbonization, and affordability.

Gas RD&D activities are coordinated to support knowledge transfer to PG&E's operational teams, facilitate potential implementation, and avoid duplication of effort. Consistent with CPUC direction

³ California Public Utilities Commission (CPUC). Resolution G-3601. Adopted by the Commission. Available at: <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M521/K085/521085692.PDF>

⁴ California Public Utilities Commission (CPUC). Resolution G-3618: Denial of PG&E's 2024 and 2025 Gas Research, Development, and Demonstration Investment Plans and Direction to Resubmit. Adopted January 15, 2026. Available at: <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M595/K045/595045490.pdf>

regarding the prudent and reasonable use of ratepayer funds under Public Utilities Code § 740.1, PG&E Gas RD&D collaborates with peer utilities, the California Energy Commission (CEC), industry research consortia, national laboratories, universities, and other research partners to coordinate research roles, avoid duplication, and leverage shared expertise and co-funding. In alignment with the CPUC's ESJ Action Plan, these collaborations are intended to advance research outcomes that can deliver tangible benefits to communities that have been historically underserved or disproportionately impacted.

This program basis enables PG&E to evaluate emerging risks, assess new tools and approaches, and make evidence-based decisions before deploying solutions at scale. By operating within CPUC-approved frameworks and aligning research investments with PG&E's operational priorities, policy objectives, and R&D Strategy Report, PG&E Gas RD&D supports continuous improvement of gas system performance while maintaining a clear focus on delivering measurable benefits to ratepayers.

3.2 Investment Theme Overview

In 2025, PG&E Gas RD&D invested \$1,136,755 in 18 projects across two investment themes: Gas System Integrity and Decarbonization.

3.2.1 Gas System Integrity

Projects in the Gas System Integrity theme seek to develop or advance technologies that, if deployed widely, could improve gas system integrity and reduce methane emissions. Given the broad scope of PG&E's inspection, maintenance, repair, and emissions reduction efforts, there are numerous avenues through which novel technologies and solutions could make a meaningful impact on company operations.

Generally, projects in this investment theme seek solutions that could help automate, optimize, and improve existing processes based on a more comprehensive, on-demand and/or real-time understanding of conditions across the system. If deployed widely, these technologies—including AI—could proactively address emerging challenges and efficiently direct resources based on risk level or other factors without the need for as frequent systemwide inspections to ensure safe and reliable delivery of energy across the system.

Projects in this theme are grouped into four initiatives:

- Proactive Geohazard Risk Management
- Innovative and Cost-Effective Integrity Management
- Advanced Leak Detection and Repair
- Emission Reduction Activities and Refined Reporting

These projects will maintain and/or increase the safety and reliability of PG&E's existing gas system while reducing emissions and lowering unitized costs of work, which will improve affordability for all customers—including those from ESJ communities.

3.2.2 Decarbonization

In this research category, Gas RD&D 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.

Decarbonizing 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. Research continues, however, about what this transition will look like at scale and how it will occur.

While it is accepted that RNG and other clean 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 fossil-based natural gas. Foundational R&D and earlier stage research are 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.

Projects in this theme are grouped into two initiatives:

- Clean Fuels Integration
- Decarbonization

3.3 Investment Theme 1: Gas System Integrity

PG&E operates one of the nation's largest natural gas systems, comprising more than 50,000 miles of combined transmission and distribution pipeline serving approximately 4.5 million customer accounts.



Figure 2: Expected declines in gas through put may create rate pressures for fewer remaining customers.

PG&E efforts take a variety of forms—from routine, periodic inspections and monitoring to emergency actions following natural disasters—and employ a wide array of technologies, ranging from aerial surveys to in-line and nondestructive inspection technologies. PG&E has also set ambitious goals for decreasing emissions over the next 15 years as part of our broader climate strategy. While PG&E continually seeks and deploys state-of-the-art solutions to achieve these goals, the changing dynamics of its natural gas system in the face of accelerating electrification and decarbonization make innovation in these pursuits more imperative than ever.

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These projects will maintain and/or increase the safety and reliability of PG&E’s existing gas system while reducing emissions and lowering unitized costs of work that will improve affordability for all customers, including those from ESJ communities.

Relevant Technology Gaps	
Improving Pipeline Crack Assessment Technologies	Improving Accuracy of Well Life Estimations
Verifying Material Properties for Existing Pipeline Cost-effectively	Increasing Accuracy of Geohazard Risk Assessment and Monitoring
Reducing Cost of Well Inspection and Monitoring	Improving Pipeline Locating Technologies
Enabling Corrosion Inspections for Difficult to Access Spans	Reducing Cost of Pipeline Integrity Inspection and Monitoring
Streamlining Aboveground Leak Repairs	Enhancing Scalability of Aboveground Leak Detection and Monitoring
Reducing the Cost of T&D Leak Detection	Improving Emissions Calculation Methodologies
Reducing False Positives on Leak Detection Surveys	Eliminating Methane Emissions from Transmission Pipeline Blowdowns
Enabling Remote Meter Set Corrosion Inspections	

Gas RD&D’s efforts in this theme are broadly focused on four initiatives:

- Proactive Geohazard Risk Management
- Innovative and Cost-Effective Integrity Management
- Advanced Leak Detection and Repair
- Emission Reduction Activities and Refined Reporting

3.3.1 Proactive Geohazard Risk Management

As climate change and natural forces reshape California’s landscape, the frequency and severity of geohazard events—such as earthquakes, landslides, flooding, soil subsidence, and wildfires—are increasing. These hazards pose a significant and evolving threat to gas infrastructure, yet current assessment methods rely heavily on costly, labor-intensive techniques like inline inspections and excavation. However, many current assessment approaches are not designed to provide timely, predictive, and system-level insight into rapidly evolving geohazard conditions.

To address these gaps, PG&E’s Gas RD&D Program is advancing the development of more capable inline inspection devices, less-intrusive monitoring systems, and sophisticated modeling tools. These innovations aim to improve visibility into asset conditions, lower maintenance and repair costs, and reduce the likelihood of service disruptions or safety incidents. Guided by CPUC policy

direction—including R.13-11-006’s risk-based framework and General Order 112-F—this research supports safe, cost-effective, and resilient gas infrastructure. Projects are designed with real-world testing in PG&E’s diverse service area, and incorporate technoeconomic analysis to ensure scalable, cost-efficient deployment.

Identified Need	Proposed Solution	Anticipated Impacts
Gas transmission and distribution assets face increasing seismic, landslide, and erosion risks from climate related impacts, threatening safety and reliability. Current geohazard monitoring methods lack real-time visibility and predictive capability for proactive mitigation. Regulatory requirements demand risk-based decision-making for maintenance, replacement, and cost recovery.	Deploy advanced sensors and distributed fiber optic sensing (DFOS) for continuous strain and vibration monitoring Integrate remote sensing surveys for terrain movement analysis and early warning Apply AI/ML models to interpret geospatial and sensor data, enabling predictive risk modeling and faster decision-making	Affordability: Lower emergency repair and remediation costs through proactive maintenance strategies Safety & Reliability: Reduce pipeline failure risk and service disruptions caused by geohazard events Regulatory Compliance: Provide data to support CPUC policy development and risk-based asset management Energy Transition Support: Enable safe coordination of gas and electric systems during California’s clean energy transition

3.3.2 Innovative and Cost-Effective Integrity Management

Maintaining the integrity of PG&E’s gas infrastructure is increasingly complex—and costly—under evolving regulatory requirements, aging assets, and emerging risks. The recent implementation of PHMSA’s Mega Rule and ongoing mandates from the California Geologic Energy Management Division (CalGEM) have intensified the need for more frequent and advanced inspections, particularly for unpiggable pipelines and underground storage wells.

Traditional methods, such as high-resolution in-line inspections for underground storage wells, are not only intrusive and expensive—costing up to \$3 million per well—but also pose operational risks and strain ratepayer affordability. Meanwhile, third-party damage remains the leading cause of pipeline incidents, yet viable, cost-effective technologies for accurate geolocation and real-time damage detection are still lacking.

To meet these challenges, PG&E’s Gas RD&D Program is advancing a new generation of integrity management tools and practices. By integrating 3D mapping, AI-enabled sensors, on-demand and/or real-time monitoring solutions, the program aims to enhance safety, reduce maintenance

costs, and ensure compliance with federal and state regulations—all while improving operational efficiency. These innovations are tailored to PG&E’s unique system conditions and aligned with CPUC priorities, including those articulated in R.13-11-006, R.24-09-012, and General Orders 112-F and 167. Through targeted research, development, and field testing, PG&E is helping lead the industry toward more effective, affordable integrity management solutions.

Identified Need	Proposed Solution	Anticipated Impacts
Increasing cost to address stringent PHMSA MEGA Rules, especially in the following areas: • Third-party damage • Corrosion, crack, dent • Underground storage well	3D Mapping and Real-Time Impact Detection for Underground Assets Non-intrusive (above-ground) assessment of pipeline coating and corrosion integrity AI/ML-Powered Fiber Optic Sensor Monitoring of pipeline and storage well integrity	Affordability - Decreased maintenance costs from compliance efforts and proactive management strategies Improved Reliability & Safety - Reduced service interruptions due to pipeline operation incidents and monitored by both frequency and duration Maintain Regulatory Compliance

3.3.3 Advanced Leak Detection and Repair

As California moves toward a cleaner and more resilient energy system, detecting and repairing methane leaks quickly and efficiently is critical for improving safety, reducing GHG emissions, and maintaining affordability. Traditional leak survey and repair methods are often time-consuming and labor-intensive, creating delays in addressing potentially hazardous leaks and increasing operational costs. Meanwhile, the regulatory landscape—driven by proceedings such as R.24-09-012, D.17-06-015, and General Order 112-F—demands greater accuracy, responsiveness, and innovation in leak management practices.

PG&E’s Gas RD&D is responding by advancing a suite of next-generation leak detection and repair solutions. These include mobile and aerial detection technologies, such as drones, helicopters, fixed-wing aircraft, and satellites, as well as continuous monitoring systems for station assets. In parallel, the program supports the development of new leak repair technologies designed to minimize downtime while ensuring lasting, high-quality seals. By piloting and validating these solutions across PG&E’s diverse infrastructure, the program aims to reduce emissions, increase operational reliability, and help meet evolving state policy goals—while also ensuring each approach is tailored to the utility’s unique system conditions and avoids redundancy with other R&D administrators.

Identified Need	Proposed Solution	Anticipated Impacts
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Traditional LDAR methods can be inefficient and time consuming. New technologies are emerging to expedite LDAR.	Align the 26 best practices and investigate: • Continuous monitoring solutions for gas facilities • Aerial leak detection for transmission assets • AMLD for distribution assets	• Affordability - accelerating detection/ improving localization reduces costs • Enhanced Safety – less risk related to leaks • Improved Reliability – timely LDAR enhances reliability • Reduced GHG Emissions – finding/fixing leaks quicker reduces GHG emissions.
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3.3.4 Emission Reduction Activities and Refined Reporting

As California pursues its goal to reduce methane emissions 40 percent below 2013 levels by 2030, consistent with Senate Bill 1383 and the Commission’s methane leak abatement framework, PG&E continues to advance efforts that ensure both operational effectiveness and environmental responsibility. While meaningful progress has been made, challenges remain—particularly in the accuracy of emissions quantification. Much of PG&E’s current reporting still relies on generalized, population-based emission factors, which can obscure the company’s actual performance and hinder its ability to demonstrate the impact of its emissions reduction programs.

To address these challenges, PG&E’s Gas RD&D Program is focused on two complementary strategies: deploying technologies that directly reduce operational emissions and refining emissions reporting frameworks through more precise data collection. Collecting data to enhance emissions reporting frameworks is crucial, as it enables PG&E to accurately assess system emissions in real time. Improved visibility allows PG&E to identify the highest emitting assets and strategically focus mitigation efforts, to ensure deployment of emissions-reducing technologies achieves the greatest possible impact. These efforts directly support key CPUC proceedings such as D.17-06-015 and R.24-09-012, which emphasize improved emissions measurement and planning to support gas system safety and reliability. By tailoring solutions to PG&E’s specific infrastructure and validating technologies in the field, this work ensures emissions reduction efforts are both effective and verifiable, contributing to a cleaner, safer energy future for California.

Identified Need	Proposed Solution	Anticipated Impacts
• As PG&E continues emissions reduction progress, remaining emissions require better targeting and more reliable measurement.	Continuing to identify new technologies to help reduce methane emissions by: • Ensuring the solution is effective for PG&E’s specific needs	• Enhanced Safety – less risk/ climate impacts related to GHG emissions • Improved Reliability – Better emissions data enhances reliability through better planning

- Decisions about what to pursue next depend on accurate, comparable emissions information—not assumptions. - PG&E needs evidence on which methods perform effectively under real field conditions and how results should be interpreted.	- Confirming it performs as marketed within PG&Es territory - Collecting necessary data to facilitate adjustments in the reporting framework to improve reporting accuracy	Reduced GHG Emissions - finding/fixing leaks quicker reduces GHG emissions
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3.4 Investment Theme 2: Decarbonization

In this research category, Gas RD&D 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.

Decarbonizing 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. Research continues, however, about what this transition will look like at scale and how this transition will occur.

While it is accepted that hydrogen and other clean 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 fossil-based natural gas. Foundational R&D and earlier stage research are 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	
Understanding Risks and Impacts from Trace RNG Chemicals	Reducing Uncertainty of Storage Facility Performance for Hydrogen Blends
Increasing Availability of Operational Data for Hydrogen Effects on Gas System	Eliminating Gas Appliance Combustion Emissions
Mitigating Hydrogen Embrittlement at Scale	Facilitating Cost-effective and Safe Deblending
Understanding Safety Risks of Hydrogen Blend Leaks	Enhancing Gas Quality Analysis
	Reducing Costs of Interconnection Skids

Improving Metering Accuracy with Hydrogen Mixtures	Identifying Cost-effective and Scalable Sources for RNG Production
Ensuring Compatibility of Customer Applications with Mixed Gas	Eliminating 100% of Carbon Emissions Cost-Effectively

To determine the optimal path to a net zero future, PG&E is seeking the help of the scientific community to deepen PG&E’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 clean alternatives. Beyond foundational research, Gas RD&D staff are 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 RD&D needs related to decarbonizing the gas system will shift away from foundational research and towards deployable technology necessary to effect the transition.

Gas RD&D’s efforts in this theme are broadly focused on two initiatives:

- Clean Fuels Integration
- Sustainable Energy Solutions

3.4.1 Clean Fuels Integration

As California accelerates its transition to a low-carbon energy future, integrating clean fuels such as renewable hydrogen, RNG, and syngas into the existing natural gas system presents both challenges and opportunities. Hydrogen’s unique physical and chemical properties, in particular, raise important questions about infrastructure compatibility, safety, and end-use appliance performance. In addition, blending these emerging fuels with natural gas requires updates to gas quality standards and metering systems, alongside cost-effective interconnection solutions.

PG&E’s Gas RD&D is addressing these challenges through targeted research, development, and demonstration projects that assess the technical, operational, and economic implications of clean fuel integration. This work not only explores the feasibility of repurposing existing assets—helping to contain costs and avoid the need for costly new infrastructure—but also informs statewide strategies for carbon reduction, system reliability, and energy affordability. Aligned with CPUC directives such

as D.22-12-057 and D.22-02-025, and in collaboration with partners including the CEC and national laboratories, PG&E is leading efforts to ensure that California’s gas infrastructure can safely and effectively support a more sustainable energy mix.

Identified Need	Proposed Solution	Anticipated Impacts
Evaluate existing infrastructure and its longevity – with hydrogen in use – to understand the impact of hydrogen on the gas system. RNG has feedstock limitations and interconnection can be costly. There is not yet an industry standard methodology for gas quality analysis with clean fuels in use.	Supporting the integration of traditional energy resources with emerging fuels can help to achieve net-zero carbon goals and enhance affordability by: - Integrating low- to zero-carbon fuels like RNG, clean renewable hydrogen, and synthetic methane - Investigating repurposing natural gas pipelines - Ensuring reliable clean fuel implementation by verifying monitoring, analysis capabilities across PG&E assets	- Safety – safe delivery of clean fuels that enhance air quality, comparatively - Energy Supply & Resilience – reduced power outage impact by leveraging clean fuels for load balancing - Energy Storage Capacity – enhanced energy storage by leveraging clean fuels - GHG Reduction – reduced use of GHG-intensive traditional energy sources.

3.5 Total Gas RD&D Spending in RY2025

In 2025, PG&E’s Gas RD&D team funded \$4,645,704 to 18 projects across its two investment themes, as well as management and administration.

Theme/Initiative	2025 Spending ⁵
Gas System Integrity	
Proactive Geohazard Risk Management ⁶	\$0
Innovative and Cost-Effective Integrity Management	\$893,988
Advanced Leak Detection and Repair	\$61,615
SUBTOTAL	\$955,603
Decarbonization	
Clean Fuels Integration	\$181,152
SUBTOTAL	\$181,152

⁵ Total Gas RD&D spending reported for RY2025 (\$4,645,704) reflects actual expenditures incurred during the reporting year, including \$3,508,949 in administrative costs recorded in accordance with Commission accounting and audit guidance. This differs from the \$1,945,797 reflected in PG&E’s 2024 Gas RD&D Plan, which represents prospective funding proposed for Commission approval and applies a 10% administrative cost cap (\$809,200) based on the imputed Gas RD&D funding amount adopted in D.23-11-069. If the 2024 Gas RD&D Plan is approved as proposed, rate payer would be funding \$1,945,797 of the \$3,508,949 of the 2025 Spending.

⁶ Proactive Geohazard Risk Management is retained as an active initiative despite \$0.00 RY2025 spending, reflecting its status as an ongoing system integrity challenge for which PG&E Gas RD&D continues to evaluate and pursue future research solutions.

Administration	
Management and Administration	\$3,508,949
SUBTOTAL	\$3,508,949
TOTAL	\$4,645,704

Commission guidance establishes an expectation that administrative costs remain within 10 percent of total Gas RD&D program funding. In reporting year 2025, the administrative cost share exceeded this guideline.

As summarized in the below table, the administrative cost share reported for RY2025 reflects the following factors:

- CPUC Utility Audits Branch (UAB) guidance, issued through its audit of Southern California Gas Company's Gas RD&D program, clarifying that certain staff activities supporting individual projects should be classified as administrative based on the nature of the work performed. Resulting reclassification of some staff time from project categories to administrative accounts to ensure consistent treatment across Gas RD&D administrators.
- Audit-related activities associated with the Commission-initiated UAB financial audit of PG&E's Gas RD&D program in 2024, which continued into 2025 and was subsequently withdrawn prior to completion, included data collection, documentation, internal review, and coordination efforts appropriately recorded as administrative costs.

PG&E continues to manage administrative activities with the objective of maintaining alignment with Commission expectations.

ACTIVITIES CATEGORY	ACTIVITY TOTALS
Administrative Activities	\$812,687
Intellectual Property Coordination	\$0
Internal Management Coordination	\$630
Investment Plan Development	\$151,012
Post-Initiation Vendor Sourcing	\$8,894
Program and Process Coordination Improvements	\$484,238
Project Initiation	\$7,792
Project Oversight and Governance	\$41,871
Project Planning	\$29,764
Regulatory Support and Compliance	\$332,585
Stakeholder Comms Engage Outreach	\$1,615,392
Tech Implementation and Knowledge Transfer	\$24,084
TOTAL	\$3,508,949

3.6 Number of Completed Projects in RY2025

In 2025, PG&E RD&D completed 18 projects, broken down as follows:

Theme/Initiative	Projects Completed
Gas System Integrity	
Innovative and Cost-Effective Integrity Management	11
Advanced Leak Detection and Repair	4
SUBTOTAL	15
Decarbonization	
Clean Fuels Integration	3
SUBTOTAL	3
TOTAL	18

3.7 Preview of Quantified Impacts from Portfolio

PG&E reports interim program-level metrics and qualitative outcomes to demonstrate benefits to ratepayers. Where quantitative values are still under development or pending validation, PG&E provides narrative context and system-level examples elsewhere in this report to support transparency and understanding of program outcomes.

Benefit	Metric
Total Number of Active Projects	0
Total Number of Projects Completed	18
Number of Projects in ESJ Communities	3 ⁷
Percentage of Projects Focused on Ratepayer Benefits:	
Improved Affordability	72%
Improved Air Quality	28%
Operational Efficiency	83%
Reduced GHG Emissions	50%
Reliability	83%
Safety	89%

3.8 Recent Changes to Program Requirements

During the 2025 reporting year, PG&E's Gas RD&D activities incorporated Commission guidance clarifying expectations related to spending eligibility, project scope, and the demonstration of ratepayer benefits. Portions of the 2023 and 2024 Gas RD&D Plans were not approved, creating uncertainty regarding cost recovery and continuity for certain proposed research activities. In CPUC Resolution G-3618, the Commission denied PG&E's 2024 Gas RD&D Investment Plan (AL 5077-G-A) and 2025 Gas RD&D Investment Plan (AL 5069-G), and denied PG&E's request to recover \$7,207,712 in expenses for Calendar Years 2023 and 2024; the Commission directed PG&E to submit revised Plans via Tier 3 Advice Letters with specified modifications. As a result, PG&E prioritized

⁷ The ESJ project count reflects where projects were active, not a quantified measure of equity benefits. Reported benefit categories are tracked separately based on project outcomes rather than location.

implementation of previously approved projects and deferred or re-scoped select activities pending further clarification from the Commission.

Resolution G-3618, finalized on January 15, 2026, provided additional direction regarding project eligibility, impact attribution, and alignment with CPUC policy priorities. Resolution G-3618 also denied PG&E's pending 2024 and 2025 Gas RD&D Plans (AL 5077-G-A and AL 5069-G) and directed resubmittal of revised Plans via Tier 3 Advice Letters. Although the final Resolution post-dates the 2025 reporting year, draft feedback received in late 2025 informed internal planning adjustments, including strengthened documentation of ratepayer value, clearer articulation of complementarity, and enhanced alignment with Commission proceedings. These refinements primarily affect forward-looking planning and reporting practices rather than the technical work completed in 2025.

Collectively, these developments underscore the importance of earlier and clearer articulation of project eligibility, ratepayer value, and policy alignment to support predictable plan outcomes and continuity of research investments.

4 Budget

4.1 Total Gas RD&D Spending in RY2025

See Section 3.5 for total Gas RD&D spending in the reporting year. PG&E administers the Gas RD&D program on a calendar year- basis. Funding is tracked within the reporting year, and unspent funds are not carried forward to future years. Therefore, Pending Funds is \$0.

4.2 Plan Funding Balances Table by Initiative

Theme	Initiative	Approved Funding ⁸	Encumbered (in reporting year)	Spent (in Reporting Year)	Unspent (in reporting year)
Gas System Integrity	Advanced Leak Detection and Repair	\$0	\$845,393	\$61,615	\$783,778
Gas System Integrity	Innovative and Cost-Effective Integrity Management	\$0	\$1,523,907	\$893,988	\$629,919
Decarbonization	Clean Fuels Integration	\$0	\$201,152	\$181,152	\$20,000
TOTAL		\$0	\$2,570,452	\$1,136,755	\$1,433,697

4.3 Unspent Funds Summary Table

Unspent Funds Summary ⁹					
	Approved Plan Funding	Reallocated Funds	Total Unspent Funds (in reporting year)	Pending Funds (for approved initiatives)	Funds to be Reallocated
2024 Gas RD&D Plan (AL # 5077-G-A)	\$0	\$0	\$1,433,697	\$0	\$0
TOTAL		\$0	\$1,433,697	\$0	\$0

⁸ Total annual funding allocation *and* supplemental budget if applicable.

⁹ The Commission denied PG&E's 2024 Gas RD&D Investment Plan (AL 5077-G-A) in CPUC Resolution G-3618 and directed PG&E to submit a revised Tier 3 Advice Letter with specified modifications; this table reflects reporting-year balances pending Commission action on the revised resubmittal.

5 Portfolio Accomplishments

5.1 Summary Paragraphs for Investment Themes

5.1.1 Gas System Integrity

During the reporting year, PG&E's Gas RD&D Gas System Integrity portfolio delivered significant safety, reliability, and emissions-reduction outcomes that directly support CPUC priorities and PG&E's progress toward its long-term decarbonization goals. Gas RD&D supported 15 projects focused on improving system awareness, inspection, and risk management, producing field-validated tools and methodologies that support integrity evaluation while informing affordability considerations for ratepayers. Notable accomplishments included successful pilots of real-time pipeline threat detection and non-intrusive electromagnetic inspection technologies, which demonstrated earlier identification of third-party damage, geohazard risks, and integrity concerns in challenging environments where conventional inspection methods are costly or impractical. These projects enable more targeted maintenance, reduce unplanned events, and lower inspection costs, delivering measurable operational and ratepayer benefits.

A major program milestone under the Gas System Integrity theme was the development and CPUC approval of a component-level methane emissions quantification methodology for transmission M&R stations. This Gas RD&D-led work replaced population-based emission estimates with measurement-informed methods, improving emissions accuracy and transparency in support of the CPUC's Natural Gas Leak Abatement Program (SB 1371; R.15-01-008) and California's statewide goal to reduce methane emissions 40 percent below 2013 levels by 2030. Adoption of the methodology in 2025 strengthened regulatory confidence and enabled PG&E to more precisely demonstrate methane abatement progress using defensible, cost-effective, and measurement-based reporting consistent with Commission expectations.

5.1.2 Decarbonization

In the reporting year, PG&E's Gas RD&D Decarbonization portfolio advanced foundational research and planning activities that support evaluation of pathways for a safe, reliable, and affordable transition of the gas system toward lower-carbon operation, consistent with CPUC policy direction and PG&E's long-term climate goals. Gas RD&D supported 3 decarbonization-focused projects aimed at evaluating the technical feasibility, operational implications, and cost considerations associated with RNG, hydrogen, and other low-carbon fuels. These efforts generated data and analytical tools to inform system compatibility, safety, emissions impacts, and economic tradeoffs, helping reduce uncertainty before potential broader deployment. RD&D also supported research to assess pathways that balance near-term affordability with long-term emissions reductions, including strategies to avoid premature asset retirement and minimize cost impacts to ratepayers as gas throughput evolves.

Collectively, the Decarbonization portfolio provided PG&E and regulators with a stronger technical and economic evidence base to inform decision-making, supported alignment with CPUC proceedings addressing gas system transition planning, and helped ensure that progress toward decarbonization is grounded in evidence, risk management, and measurable public interest benefits.

5.2 Transformational, System-level Integration in Methane and Emissions Management

5.2.1 Concrete Gas RD&D Projects Enabling Methane and Emissions Management

PG&E does not treat methane reduction as one project or one technology. Instead, it has built a coordinated system where different research projects work together in a continuous cycle following this basic pattern:

- **DETECT & MONITOR — Expanding Emissions Visibility**

First, PG&E works to find and measure methane leaks, with the goal of getting better, more accurate visibility into where methane is being emitted. Examples of these types of projects include:

- Transmission Metering & Regulating (M&R) Emissions Measurement Campaigns
- Fixed-Point Laser Methane Monitoring at Transmission M&R Stations
- Continuous Methane Monitoring at Underground Storage Facilities (Phase 1 and Phase 2)
- Advanced Mobile Leak Detection (AMLD) Evaluations
- Aerial Leak Detection Pilots (helicopter, drone, and fixed-wing platforms)

- **PRIORITIZE — Measurement-Informed Decision-Making**

PG&E uses that data to decide what matters most, applying component-level measurement methods and analytics tools to identify and address the biggest sources. Examples of these types of projects include:

- Component-Level Methane Emissions Quantification Methodology for Transmission M&R Stations
- Detection Analytics and Data Integration Tools Supporting Super-Emitter Identification

- **ABATE — Targeted Emissions Reduction Actions**

PG&E then takes targeted action to reduce emissions. Examples of these types of projects include:

- LLFA (“Alfa”) Tape for Rapid Meter-Set Leak Repair (Phase 1 and Phase 2)
- Best Purging Practices for Minimizing Methane Emissions
- Modify Pipeline Purging Program

- **VERIFY & LEARN — Reporting Fidelity and Continuous Improvement**

Finally, PG&E verifies the results, using the feedback to inform the next round of improvements. Examples of these types of projects include:

- Emissions Reporting Framework Refinement Projects Supporting Component-Level Reporting
- Field Validation Activities Supporting CPUC-Approved Methane Quantification Methodologies

These projects collectively enable PG&E's methane management system to detect, prioritize, mitigate, and verify emissions reductions over time through measurement-informed, regulator-credible processes, rather than reliance on any single technology.

While methane and emissions projects in the Gas RD&D portfolio are often described as discrete efforts, PG&E's emissions outcomes reflect the integrated operation of multiple implemented controls, including transformative research, functioning together as a system-level capability rather than as isolated technologies or programs.

5.2.2 Integrated Methane Management — Detection, Prioritization, Abatement, And Reporting Fidelity

A clear illustration of this integration is the way PG&E's methane activities link detection and monitoring to decision-making and targeted mitigation, and then to improved quantification and reporting fidelity. In practice, this integration unfolds over multiple years through iterative engagement with the Commission, where research findings are shared, clarified, and refined in response to feedback, which in turn informs subsequent research directions and operational focus. As improved measurement and analysis identify dominant emission drivers, utilities direct attention toward the highest-impact opportunities, prompting additional research, validation, and refinement. This feedback-driven progression is strengthened by Gas RD&D work that advances field-validated measurement approaches, including emissions quantification methodology improvements for transmission M&R stations.

- **DETECT & MONITOR**

These initiatives expand visibility of emissions across distribution, transmission, stations, and storage assets using a combination of methods matched to different operating contexts, including fixed monitoring, targeted measurement campaigns, and continuous monitoring approaches. Within the portfolio, this includes Evaluating Emissions from Transmission M&R Stations, fixed-point laser methane monitoring and direct emissions measurement campaigns at transmission M&R stations, and Continuous Methane Monitoring for Underground Storage (Phase 1 and Phase 2). In parallel, Advanced Mobile Leak Detection (AMLD) evaluations and aerial leak detection pilots (helicopter, drone, and fixed-wing platforms) expand detection coverage across distribution and transmission assets. Together, these efforts characterize emissions behavior, improve visibility into intermittent and component-level emissions, and generate the data needed to inform subsequent analysis and action.

- **PRIORITIZE**

These initiatives translate detection indications into actionable decisions by improving data-driven decisions regarding where emissions occur, which assets contribute most materially, and which mitigation actions will be most impactful. A core enabling element is the shift from population-based assumptions toward measurement-informed approaches that allow PG&E to compare conditions over time and focus work where it matters most. This is reflected in field validation activities supporting component-level quantification approaches for M&R stations, including measurements of continuous-bleed pneumatic devices and intermittent-bleed stations, which improve confidence and defensibility when prioritizing mitigation actions and characterizing outcomes.

- **ABATE**

These initiatives apply field-deployable repair, equipment upgrades, and mitigation approaches once conditions are identified and prioritized. The value of the system emerges when abatement actions are paired with measurement methods that can confirm impact and support transparent characterization of results. At the system level, this aligns with PG&E's comprehensive methane reduction approach, including accelerated repair of high-emitting leaks, LLFA ("Alfa") tape for rapid meter-set leak repair (Phase 1 and Phase 2), Best Purging Practices for Minimizing Methane Emissions, and the Modify Pipeline Purging Program—actions that rely on detection, prioritization, and measurement working together to demonstrate effectiveness.

Together, these efforts function as an integrated system:

- **DETECT:** Identifies emissions conditions and provides visibility into asset behavior.
- **PRIORITIZE:** Directs attention to material contributors and supports targeted work planning.
- **ABATE:** Reduces emissions through repairs and equipment upgrades, while producing new "before/after" data.
- **IMPROVE REPORTING FIDELITY:** Enables consistent, defensible characterization of the impact of upgrades and mitigations over time.

None of these elements delivers its full value independently. Their impact emerges from their combined, operational deployment, particularly when measurement-informed methods allow emissions reductions to be identified, targeted, validated, and sustained in a transparent, repeatable, and regulator-credible manner.

5.2.3 System-Level Impact And Transformational Outcomes

Viewed collectively, this integrated approach demonstrates how emissions-related research, regulatory engagement, and operational programs reinforce one another to produce material, system-level transformation. The cumulative effect of these coordinated efforts—spanning enhanced leak surveys, advanced leak detection, accelerated repair of high-emitting leaks,

mitigation of planned venting, and improved emissions quantification—reflects a durable shift in how methane emissions are managed across the gas system.

As reflected in PG&E's reported outcomes, this integrated model supported a 42 percent reduction in methane emissions in 2024 relative to a 2015 baseline, exceeding the CPUC-directed 2025 target. Importantly, this outcome reflects transformational change in practice, rather than the performance of any single project or program. It demonstrates how measurement-informed decision-making and improved reporting fidelity enable mitigation actions to be targeted, validated, and refined over time, while also revealing new opportunities for continued improvement.

Consistent with Commission expectations articulated in the EPIC 5 Workshop Report, the value illustrated here lies in the system-level integration of transformative research into routine practice, the accumulation of learning across multiple efforts, and the ability for those learnings to inform subsequent research, operational focus, and regulatory engagement. This integrated approach also aligns with PG&E's longer-term climate objectives, including the company's commitment to achieve a net-zero energy system by 2040 and an ambition to become climate positive by 2050.

5.2.4 Transformational Impact

This illustration does not reinterpret individual project status or outcomes to any single program or activity. It makes explicit how transformative research, together with other implemented efforts, collectively functions as transformational, system-level integration supporting methane and emissions management, improved reporting fidelity, and measurement-informed decision-making over time.

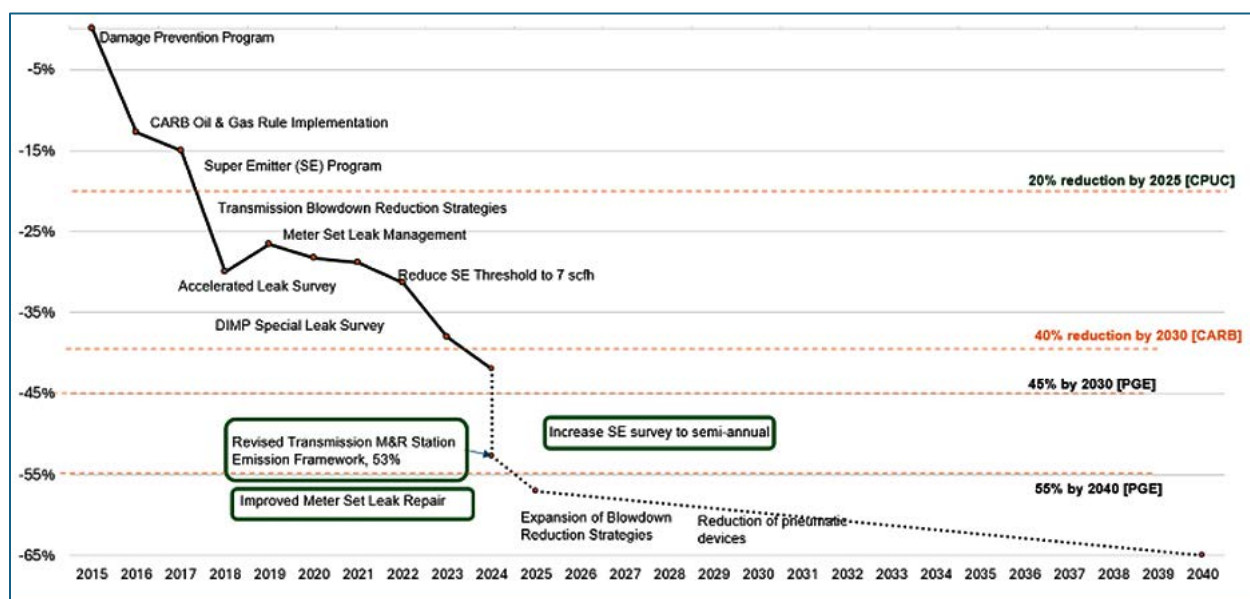


Figure 3: PG&E's methane emissions reduction timeline.

5.3 Transformational, System-Level Integration In Transmission Pipeline & Storage Integrity Management

5.3.1 Concrete Gas RD&D Projects Enabling System-Level Integrity Management

Safety and integrity improvements across PG&E's transmission pipelines and storage facilities are supported by several Gas RD&D projects that work together as a coordinated system, rather than as stand-alone tools or one-time inspections. This system includes:

CONDITION AWARENESS & MONITORING

These projects focus on improving real-time visibility into asset condition by deploying advanced sensing technologies that detect emerging threats before they escalate.

- OTD 5.24.m Field Pilot of the Real-Time Pipeline Threat Detection System (SPADE System)
- Distributed Fiber Optic Sensor Monitoring for Pipeline Strain at Geohazard Locations
- Fiber Optic Sensor Monitoring of Underground Storage Well Integrity

RISK EVALUATION & PRIORITIZATION

These efforts translate monitoring data into actionable insight by assessing integrity risks and helping prioritize resources toward the highest-risk locations.

- Field Trial of EMPIT Current Magnetometry Inspection (CMI) at River Crossings
- Electromagnetic and Optical Sensor Technologies for Storage Well Safety Monitoring (EM-TDR and BO-TDR)

ASSESSMENT & MITIGATION SUPPORT

These projects support timely and targeted response by enabling non-intrusive condition assessment and early intervention where integrity concerns are identified.

- Non-Intrusive Above-Ground Integrity Screening Using EMPIT CMI
- SPADE-Enabled Early Detection Supporting Targeted Field Response

LEARNING & REFINEMENT

These activities ensure continuous improvement by incorporating field results, performance data, and operational experience into future deployment and decision-making strategies.

- Iterative Field Trials and Performance Evaluation of Non-Intrusive Integrity Technologies
- Analytics Refinement and Deployment Strategy Development Informed by Fiber Optic Monitoring Data

These projects collectively enable PG&E's integrity management approach to identify emerging conditions, prioritize risk, support targeted response, and incorporate learning over time through measurement-informed, regulator-credible processes, rather than reliance on any single technology.

While integrity-focused projects within the Gas RD&D program are often described as discrete efforts, integrity outcomes observed in practice reflect the integrated operation of multiple tools, data streams, and analytical approaches functioning together as a system, rather than the

performance of any single project or technology. This section describes how research, field application, and operational learning reinforce one another over time, strengthening integrity decision-making and supporting long-term system performance across both transmission pipelines and storage facilities.

5.3.2 Integrated Integrity Management — Condition Awareness, Evaluation, Response, and Learning

A clear illustration of this integration is the way integrity activities connect condition awareness to risk evaluation, and then to targeted assessment and mitigation actions, with learning from field application feeding back into subsequent analysis, planning, and research focus. In practice, this integration unfolds over multiple years through iterative cycles of research, field deployment, evaluation, and refinement spanning both transmission pipelines and storage facilities.

- **CONDITION AWARENESS & MONITORING**

These efforts expand visibility beyond periodic inspection intervals by providing earlier indications of changing conditions that may warrant attention. Monitoring and sensing approaches supported through Gas RD&D improve understanding of asset behavior between inspections, supplementing traditional integrity data and generating condition signals that inform subsequent evaluation and prioritization. Examples include the OTD 5.24.m Field Pilot of the Real-Time Pipeline Threat Detection System (SPADE System), distributed fiber optic sensor monitoring for pipeline strain at geohazard locations, and fiber optic sensor monitoring of underground storage well integrity.

- **RISK EVALUATION AND PRIORITIZATION**

These efforts translate condition signals into actionable integrity decisions by integrating new information with existing integrity data, models, and engineering judgment. This integration improves confidence in where attention is warranted, supports differentiation between background variability and significant integrity concerns, and helps focus follow-up actions where they are most relevant. This includes non-intrusive electromagnetic inspection using EMPIT Current Magnetometry Inspection (CMI) at river crossings and electromagnetic and optical sensor technologies (EM-TDR and BO-TDR) for storage well evaluation.

- **ASSESSMENT & MITIGATION SUPPORT**

These apply targeted evaluation methods and responses once conditions are identified and prioritized. The value of the system emerges when these actions are informed by stronger condition awareness and clearer prioritization, and when resulting field observations and inspection outcomes generate additional insight that informs future decisions. EMPIT CMI screening and SPADE-enabled early detection support more timely, focused field response at integrity blind spots.

- **LEARNING & REFINEMENT**

This completes the closed-loop process. Results from monitoring, evaluation, and field application reveal limitations, uncertainties, and emerging questions that shape subsequent Gas RD&D research focus and day-to-day operational practice. Iterative EMPIT field trials, continued evaluation of fiber optic monitoring data, and refinement of analytics and deployment strategies carry insights forward into future cycles of analysis, planning, and response.

Together, these elements function as an integrated integrity management system:

- **Condition Awareness & Monitoring:** Expands visibility into changing conditions.
- **Risk Evaluation & Prioritization:** Directs attention to areas of greatest concern.
- **Assessment & Mitigation Support:** Addresses identified conditions while generating new information.
- **Learning & Refinement:** Feeds insights back into future research and decision-making.

5.3.3 System-Level Impact And Transformational Outcomes

Viewed collectively, this integrated approach reflects a shift in practice toward more adaptive, learning-based integrity management. Impact emerges from the combined deployment of condition awareness, evaluation, and response—particularly when reinforced through an explicit feedback loop that improves what the system can observe, how it interprets risk, and how it targets follow-up actions over time.

The cumulative effect is a durable, system-level approach in which insights gained through Gas RD&D research and application are carried forward to inform future cycles of integrity planning and execution across transmission pipelines and storage facilities.

5.3.4 Transformational Impact

This illustration does not reinterpret individual project status or assign outcomes to any single activity. Instead, it makes explicit how Gas RD&D, together with other implemented efforts, collectively functions as transformational, system-level integration supporting integrity management over time. As shown below, integrity management operates as a closed-loop system, where condition awareness, risk-informed prioritization, targeted assessment and response, and continuous learning reinforce one another through the ongoing integration of information, analysis, and field experience.



Figure 4: Gas integrity management overview—closed-loop flow.

5.4 Successful or Promising Projects

5.4.1 OTD 5.24.m Field Pilot of Real-Time Pipeline Threat Detection System (SPADE System)

The SPADE technology is developed for real-time detection and localization of mechanical impacts, illegal tapping, stray currents, and lightning strikes on operating pipelines. By leveraging cathodic protection (CP) monitoring and integration with existing Remote Monitoring Units (RMUs), this

technology offered pipeline operators increased safety, reduced operational costs, improved reliability of alarm interpretation, and enhanced environmental protection. It complements other monitoring technologies (such as fiber optics, acoustic sensors, and satellite surveillance) by leveraging existing CP infrastructure for cost-effective pipeline integrity management.

Field feasibility validation and pilot activities conducted at PG&E gas transmission pipelines in agricultural areas subject to high risk of third-party damages have confirmed the SPADE System's ability to detect mechanical impacts in real time, demonstrated long-term robustness under field conditions, and highlighted cost-benefit advantages compared to alternative monitoring approaches. Initial limitations included restricted accuracy in locating impacts (limited to "between two rectifiers"), the need for improved event classification, and a more ergonomic user interface.

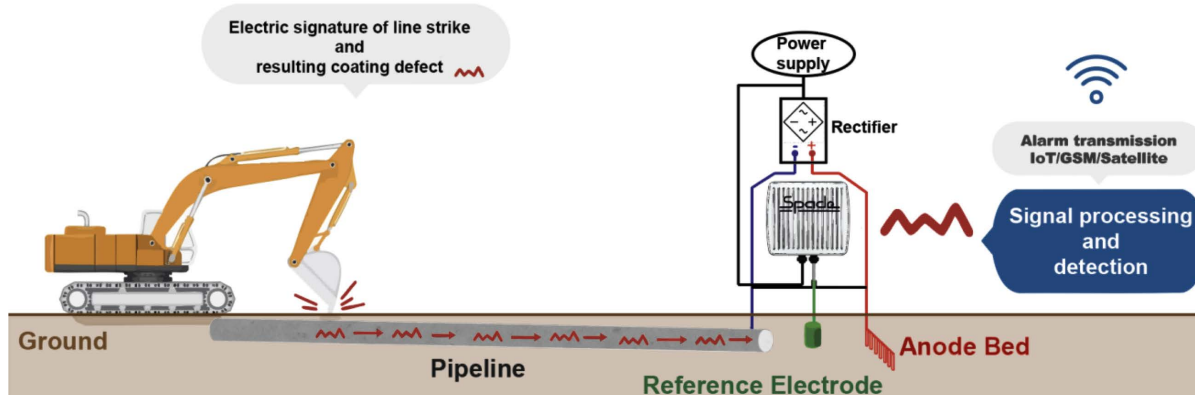


Figure 5: Schematic of a SPADE system installed on an operating pipeline, showing an excavator impacting the pipeline.



Figure 6: Examples of SPADE installations in agriculture fields.

In 2025, the project team completed five major improvements through field pilot and continuous improvement:

1. Mechanical Impact Simulator is developed as a dedicated signal generator ("Topper") that replicates the electrical signature of an excavator impact, which allows for system verification, operator training, and periodic maintenance without physical excavation, making validation and calibration more practical and repeatable.

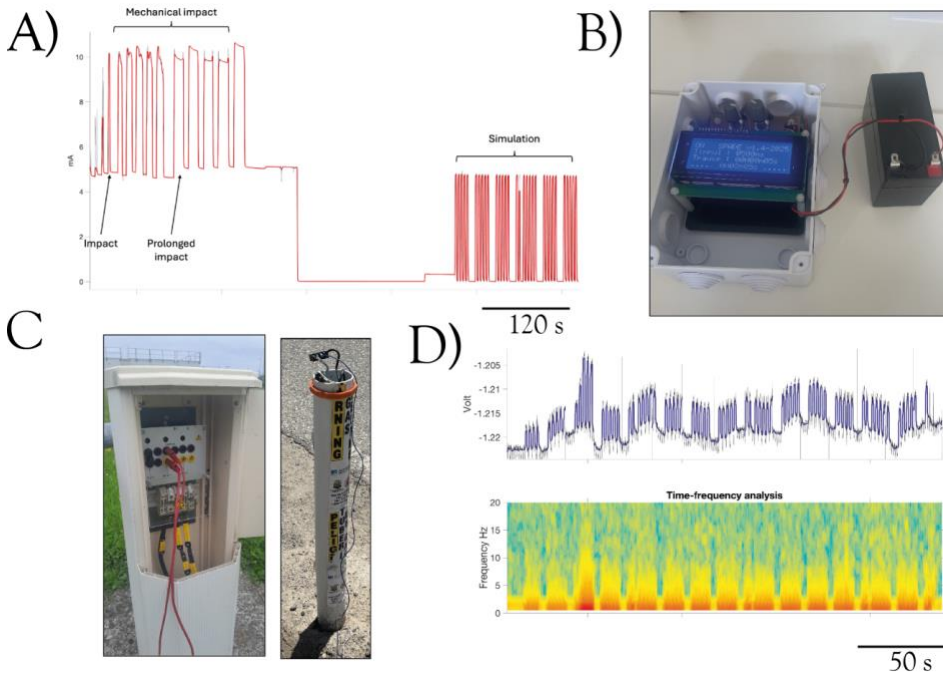


Figure 7: A) Mechanical impact signal and simulated signal generated by the Topper, B) Signal generator ('Topper'), C) Topper connection points on the rectifier, D) Measurement of the potential and frequency generated by the Topper.

2. Event Localization: By synchronizing multiple detectors along a pipeline, the system can now more accurately pinpoint the location of mechanical impacts as far as 1.25 miles.

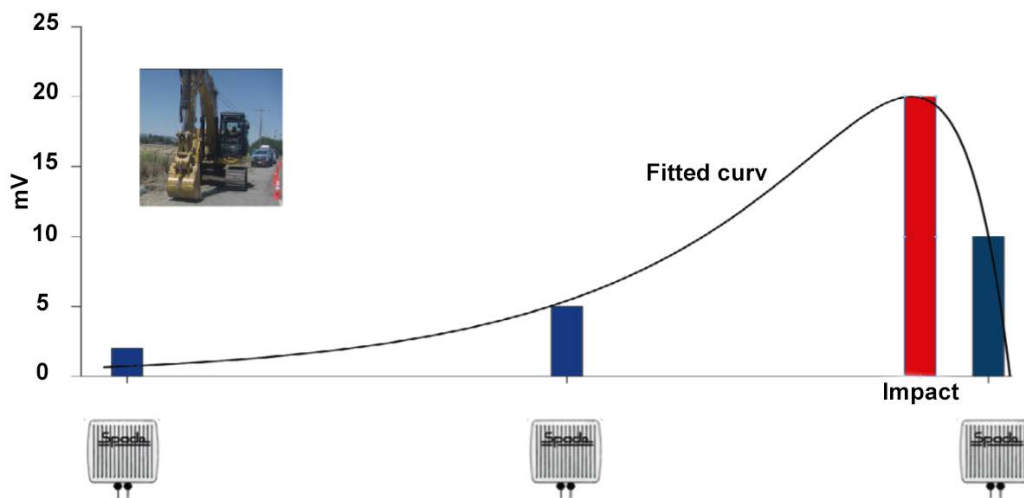


Figure 8: Signal amplitude at the impact location and attenuation at rectifiers located at different distances.

3. Enhanced Event Classification: New algorithms filter and classify electrical disturbances, reducing false positives and enabling experts to distinguish between genuine mechanical impacts and other events (e.g., lightning, stray currents).
4. User Interface Upgrade: The real-time monitoring dashboard has been redesigned for greater ergonomics and operator orientation, supporting day-to-day integrity management tasks with improved data management capabilities including event alert notification via email/text message.
5. SPADE detectors now incorporate the existing commercial RMU functions, enabling consolidated CP monitoring and third-party damage detection within a single device.

The next step is in planning for continuous improvement of event detection and classification algorithms plus the accuracy of event localization, and expansion of the pilot scale toward commercial deployment.

5.4.2 Field Trial of EMPIT Non-Intrusive Survey of Pipeline Integrity at River Crossing



Figure 9: CMI non-intrusive survey of transmission pipeline integrity on boat platform at a Sacramento River Crossing site in Red Bluff.

Pipeline river crossings represent critical segments for integrity management. Submerged pipelines are difficult to access and exposed to dynamic environmental loads. Conventional inspection methods frequently prove inadequate.

This project involved three parallel backbone gas transmission pipelines in a non-consequence area at a Sacramento River crossing site in Red Bluff, California. The crossing has been identified as a location of concern following bathymetric surveys of two lines indicating progressive riverbed erosion, with exposed pipe sections increasing from 10 to 12 feet in 2018 to more than 25 feet by 2022, and a complete exposure of the third line at the shore-to-bank transition in Spring 2025. Previous dive inspections yielded incomplete results due to adverse water stream and depth conditions. The close proximity of two unpiggable lines and one piggable line precluded conventional survey techniques that can be quickly implemented techno-economically. Consequently, the crossing constituted an unresolved blind spot resulting in compliance issues with California State Land Commission.

To address these constraints, EMPIT's Current Magnetometry Inspection (CMI) was conducted using a boat-based sensor array (Figure 8). The method determines pipeline position through measurement of the magnetic field induced by a controlled alternating current. Multi-sensor data acquisition combined with AI-signal processing enables three-dimensional pipeline mapping, depth of cover determination, bending strain detection, and coating defect localization with corrosion risk classification in one single pass.

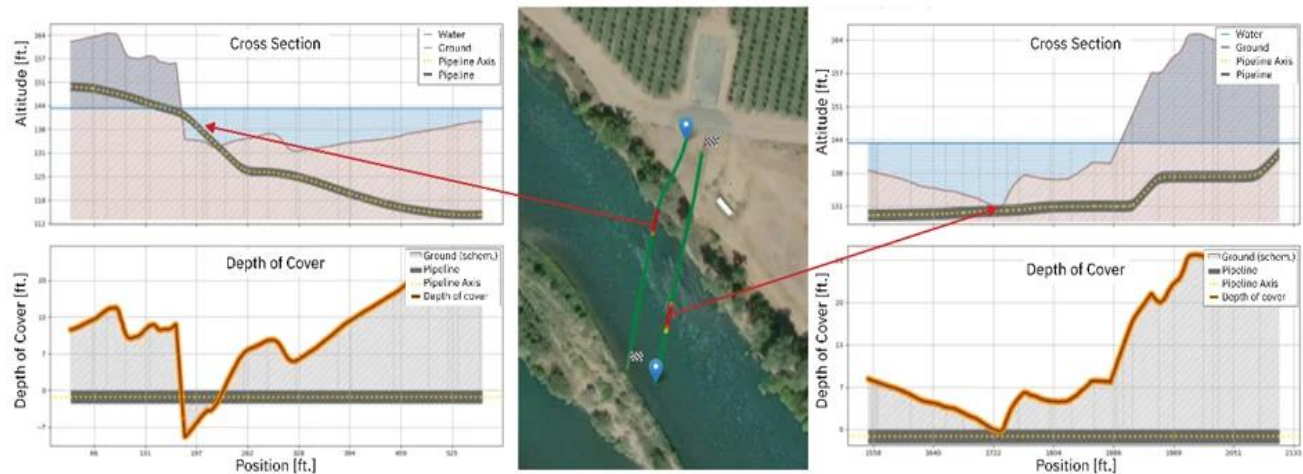


Figure 10: Cross-sectional profiles showing water level, ground surface, and pipeline elevation with corresponding depth of cover. Left: Complete exposure at shore transition. Right: Partial exposure at river center. Center: Aerial overview with inspection locations.

Inspection results confirmed pipeline exposure at two distinct locations. Two unpiggable pipelines exhibited partial exposure near the river center, while the third line was completely exposed at the shore transition where the riverbed had fully eroded (Figure 9). These findings were validated through targeted dive inspections. Several coating anomalies were identified; however, corrosion risk assessment indicated no immediate remediation requirements. Comparison of CMI-derived bending strain with existing inline inspection data demonstrated good agreement in both location and amplitude of principal bending features (Figure 10).

This work illustrates the capability of non-intrusive electromagnetic inspection to deliver actionable integrity data for pipeline segments where inline or direct assessment methods are impractical. The combination of geometric assessment, depth of cover mapping, and coating condition evaluation provided the operator with a comprehensive basis for risk-informed decision making.

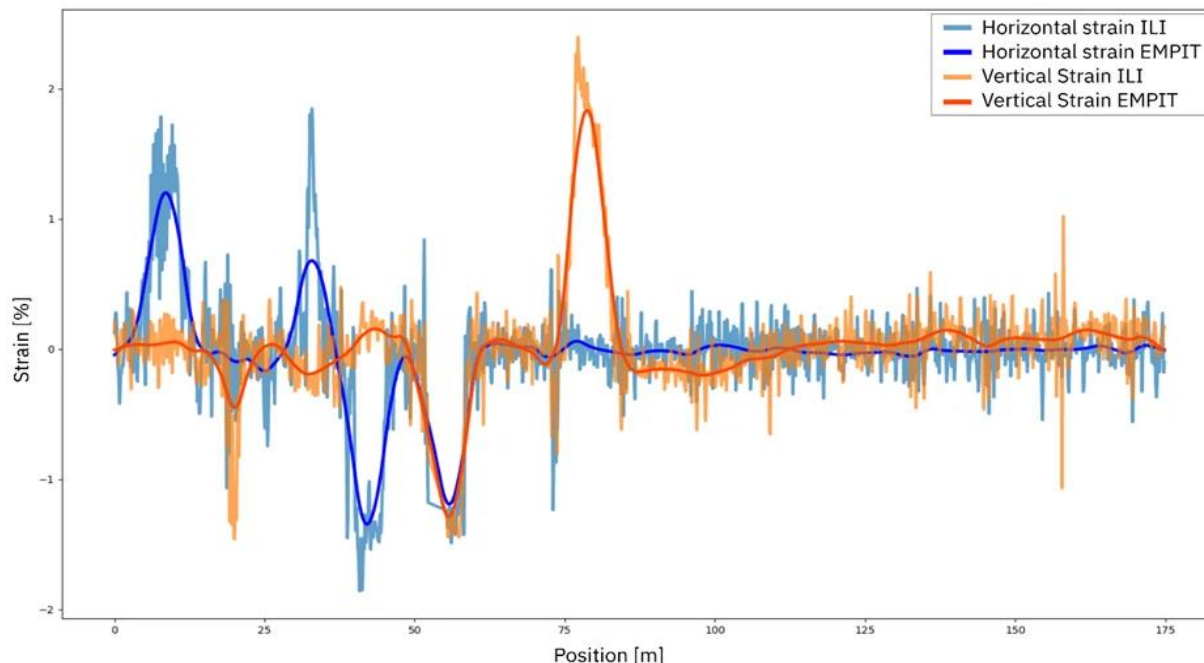


Figure 11: Bending strain comparison between IMU-based Inline Inspection (light traces) and Current Magnetometry Inspection (dark traces), demonstrating consistent identification of principal bending features.

5.5 Introduction to and Context for Data in the Annual Report

The data summarized in this annual report and provided in the accompanying Annual Report Appendix is intended to support transparency into PG&E's Gas RD&D program funding, expenditures, and project activity during the reporting year. The information reflects Gas RD&D program reporting for the reporting year, including project and financial activity associated with applicable Commission oversight and reporting requirements. Where this report references the 2024 and 2025 Gas RD&D Investment Plans (AL 5077-G-A and AL 5069-G), those Plans were denied in CPUC Resolution G-3618 and are being resubmitted via revised Tier 3 Advice Letters as directed by the Commission.

Gas RD&D activities are typically multi-year in nature, and funding commitments and expenditures may vary significantly over the life of a project. Accordingly, reported totals for encumbered, spent, and unspent funds should be interpreted in the context of project timing, contractual milestones, and technical development schedules. Variations in annual spending generally reflect the planned progression of research and demonstration activities rather than changes in project scope or performance.

Where quantified impacts are reported, they represent outcomes achieved to date and may not fully reflect longer-term benefits that are expected as projects advance, inform operational practices, or support broader deployment. Together, the data and narrative presented in this report are intended to provide a clear and accurate accounting of Gas RD&D program activity for the reporting year, while

recognizing the iterative and long-term nature of research and development efforts conducted under CPUC oversight.

5.6 Completed and Active Projects in RY2025

Per D.19-09-051, PG&E Gas RD&D tracks the number of projects that it initiates and completes every year. In RY 2025, PG&E Gas RD&D completed 18 projects. See Appendix 2, Sheet 2—Project Reporting.

Theme/Initiative	Initiated ¹⁰	Completed
Gas System Integrity		
Innovative and Cost-Effective Integrity Management	6	11
Advanced Leak Detection and Repair	1	4
Subtotal	7	15
Decarbonization		
Clean Fuels Integration	0	3
Subtotal	0	3
TOTAL	7	18

5.7 Completed Project Summaries

As seen above, PG&E Gas RD&D completed 18 projects in RY 2025. Below are the descriptions and impact for these projects.

Project Title	Theme	Initiative	Project Description
M2020-007 Ph2c 4"NDE Sensor Robotic	GSI	Innovative and Cost-Effective Integrity Management	This project completed Phase 2c development activities for a 4-inch robotic system intended for live inline inspection of plastic distribution mains. Work concluded with laboratory testing and documentation of system capabilities, including non-destructive evaluation and visual inspection functions, operating range expectations, and defect detection capabilities. Findings support evaluation of future prototype development outside the Gas RD&D program.

¹⁰ “Initiated” reflects projects for which PG&E Gas RD&D began funding or formal work activities during RY2025. “Completed” reflects projects for which PG&E Gas RD&D funding and formal program activities concluded during RY2025. Projects may appear in both categories if initiation and completion occurred within the same reporting year. While PG&E’s Gas RD&D program participation may conclude within a given year, some projects may continue outside the Gas RD&D program.

Project Title	Theme	Initiative	Project Description
5.24.m Field Pilot of Real-Time Pipeline Threat Detection System (SPADE System)	GSI	Innovative and Cost-Effective Integrity Management	This project completed a field pilot demonstrating real time detection of mechanical impacts and external threats on transmission pipelines using cathodic protection monitoring in agricultural environments. The pilot generated field performance data, identified system strengths and limitations, and documented lessons learned to inform future consideration of monitoring approaches.
Field Trial of EMPIT's Technology for Inspecting Pipeline Exposed at Sacramento River Bottom	GSI	Innovative and Cost-Effective Integrity Management	This project completed a two-year field trial of non-intrusive active magnetometry for inspection of exposed transmission pipelines at a Sacramento River crossing. The work produced validated inspection results, comparisons to available inline inspection data, and documentation of applicability and limitations for challenging river crossing conditions.
EddyFi's Eddy Current NDE Tool for Hard Spots	GSI	Innovative and Cost-Effective Integrity Management	This project completed the development, field validation, and procedural integration of eddy-current non-destructive evaluation (NDE) screening methods for identifying pipeline hard spots. Gas RD&D activities included laboratory evaluation, field deployment, and validation of tool performance, followed by development of field implementation and direct-examination procedures. The work concluded with documented methods that inform standard H-form integrity processes and support rapid, in-ditch hard-spot identification under PG&E operating conditions.
JCAS-01 Pipeline Integrity Tool Ext.	GSI	Innovative and Cost-Effective Integrity Management	This project completed an extension of crack assessment modeling and software improvements, including refinement of fracture toughness databases, empirical correlation analysis, and notch effect modeling. Deliverables included updated analytical tools and documentation supporting integrity assessment.
M2021-011 Ph2 Battery Feasibility Study	GSI	Innovative and Cost-Effective Integrity Management	This project completed a feasibility assessment of battery technologies for Explorer autonomous inspection robots. Work concluded with definition of performance requirements, evaluation of candidate battery technologies, and documentation of feasibility findings.

Project Title	Theme	Initiative	Project Description
M2021-011 Ph3 Extending Energy Harvesting	GSI	Innovative and Cost-Effective Integrity Management	This project completed Phase 3 design and feasibility work for an energy harvesting system supporting Explorer inspection robots. Deliverables included a preliminary system design and a final feasibility report documenting performance expectations and development considerations.
Emerging 3D Underground Mapping Field Trial-1	GSI	Innovative and Cost-Effective Integrity Management	This project completed initial structured field trials of advanced underground mapping technologies, including baseline testing at the PG&E Winters Academy Test Bed. Gas RD&D involvement concluded with comparative performance documentation and identification of strengths, limitations, and research gaps.
M2021-006 Ph4 Explorer Wi-Fi Extender	GSI	Innovative and Cost-Effective Integrity Management	This project completed Phase IV development of extended wireless communication capabilities for Explorer inspection robots. Work concluded with development and testing of an engineering prototype and documentation supporting readiness for subsequent commercialization phases.
Rosen Dresser Couplings in Vintage Transmission Pipe	GSI	Innovative and Cost-Effective Integrity Management	This project completed PG&E's first field trial of non-intrusive Large Standoff Magnetometry technology for locating legacy Dresser couplings. Field demonstrations at two sites validated detection capability, reduced excavation needs, and documented applicability for integrity risk management.
ADV/Acuren Lab Verification Study on Non- Destructive Residual Stress Measurement	GSI	Innovative and Cost-Effective Integrity Management	This project completed a laboratory verification study of indentation-based non-destructive residual stress measurement technologies for potential in-ditch pipeline applications. Commercially available tools from Frontics (Korea) and Plastometrex (United Kingdom), both previously used for in-ditch steel pipe material yield strength measurement, were evaluated using existing Frontics equipment available at ATS and applied within PG&E's FIMP and TIMP

Project Title	Theme	Initiative	Project Description
			material verification programs. The study examined the technical distinctions between residual stress measurement and material strength measurement, including the role of modified indentation tips and associated data analytics. Findings were documented in a lab study summary that captured feasibility considerations and limitations to inform future research decisions related to hard-spot integrity management.
Cross compression / pipeline purging demonstration	GSI	Advanced Leak Detection and Repair	This project completed a field demonstration of Zero Emissions Vacuum and Compression (ZEVAC) technology for pipeline purging and blowdown operations. The demonstration evaluated operational feasibility, safety considerations, and emissions reduction potential, producing documented insights for future consideration.
Pilot Eval LLFA Tape on Gas Meters	GSI	Advanced Leak Detection and Repair	This project completed field evaluation of LLFA tape and putty products for meter set leak repair following successful laboratory testing. Gas RD&D concluded with documentation of field performance and applicability under PG&E conditions.
M2017-004 Ph3 Methane Oxidation Catalysts to Replace Flaring	GSI	Advanced Leak Detection and Repair	This project completed Phase 3 development and evaluation of low temperature methane oxidation catalyst materials. Work concluded with proof of concept findings and documentation of performance and potential application constraints.
Demonstration at Los Medanos of continuous emission monitoring at UGS Ph. 2	GSI	Advanced Leak Detection and Repair	This project completed Phase 2 demonstration of continuous emissions monitoring at the Los Medanos underground storage facility. Results documented labor reduction potential and performance considerations relative to traditional wellhead survey practices.

Project Title	Theme	Initiative	Project Description
G4 Insights PCH Process Confirmation	Decarb	Clean Fuels Integration	This project completed a final evaluation of the G4 PCH process for converting forestry waste into renewable natural gas. Gas RD&D concluded with a final report summarizing a seven day test run, performance data, and commercial feasibility findings.
C-ZERO Feasibility Study Program	Decarb	Clean Fuels Integration	This project completed feasibility analysis activities related to distributed methane pyrolysis technologies. Gas RD&D involvement concluded with synthesis of prior evaluations and documentation of technical and economic considerations before project cancellation due to vendor business closure.
M2021-005 P2 Odor Detection Study	Decarb	Clean Fuels Integration	This project completed Phase 2 testing of odorant detectability in natural gas blended with up to 20 percent hydrogen. Results confirmed no change in odorant detectability at tested blend levels and documented limitations and considerations for future research.

5.8 Cancelled Projects in RY2025¹¹

In RY 2025, PG&E Gas RD&D cancelled one project.

Project Title	Explanation ¹²¹³
C-ZERO Feasibility Study Program	C-Zero went out of business in 2025. In response, PG&E Gas RD&D cancelled this project.

5.9 Patents, Copyrights, Publications, and Citations

¹¹ Describes delivered outputs, quantified impacts, and coordination and pathways to scale outcomes.

¹² Explanation of any disencumbered funds or cancelled projects.

¹³ While the project listed in this table was cancelled during the reporting year, it is presented as completed elsewhere in this Annual Report for consistency in reporting. This treatment reflects that Gas RD&D program activities for the project were documented and no further Gas RD&D work occurred following the vendor's business closure.

In 2025, no new patents or copyrights were associated with any of the projects. Likewise, there were no known publications or citations in 2025.

The following publications are associated with Gas RD&D work related to the SPADE real time pipeline threat detection project and were published in 2025:

- *Using Cathodic Protection to Detect Mechanical Damage in Real Time*, co authored with SPADE and GRTgaz, presented at the EPRG–PRCI–APGA 24th Joint Technical Meeting (JTM), June 2025.
- Utilizing Cathodic Protection for Real Time Detection of Mechanical Damage and Interference, co authored with SPADE and GRTgaz, in *Oil and Gas Pipelines: Integrity, Safety, and Security Handbook*, Multi Volume, 2nd Edition, Volume 1, Part V, Chapter 23, edited by R. Winston Revie, Wiley, March 2025.

5.10 Successful Commercialization of Gas RD&D Funded Projects

Measuring what matters

A data-driven approach that finally shows the true impact of equipment upgrades and leak mitigation.

The Challenge

At one point, Transmission Metering and Regulating (M&R) station emissions represented the largest share of PG&E's reported methane emissions—roughly 40%. The main sources of methane emissions from these stations are gas-powered pneumatic devices that utilize natural gas to operate regulators and control valves. Once the desired position is reached, the power gas is vented, emitting methane to the atmosphere.

Until recently, PG&E estimated these emissions using station-level, population-based emission factors, which significantly overstated actual emissions. “That approach didn’t consider site-specific variation, station survey frequency, or vented emissions from components,” said Sammy Ahmed, Expert Engineer with PG&E’s GHG Emission Strategy Team. “No matter how many components we upgraded, we could not demonstrate a reduction on paper unless we decommissioned the station, which is an operationally infeasible solution.”¹⁴

The Solution

To address this challenge, Ahmed collaborated with PG&E’s Gas Research, Development, and Demonstration (RD&D) team to adopt the Subpart W emission factors, standardized methane

¹⁴ Quoted statements in this section are drawn from interviews conducted by PG&E with the individuals cited, including subject-matter experts from PG&E’s GHG Emission Strategy and Gas RD&D teams, as part of developing this Annual Report.

emission rates published by the U.S. Environmental Protection Agency (EPA) for different types of natural gas and petroleum equipment. “This approach would enable us to estimate emissions at the component level rather than the station level,” said Ahmed. “That means we can demonstrate reductions and receive credit for equipment upgrades and leak repairs, ensuring that abatement efforts are measurable and reportable.”

To adopt the new methodology, PG&E needed to demonstrate to the California Public Utilities Commission (CPUC) that it was more accurate than the existing approach and, importantly, that it applied to PG&E’s gas system. “That process involved a considerable amount of field work and detailed analytics,” said Monique Montague, Gas Engineer, at PG&E Gas RD&D.

Montague first targeted the company’s Transmission M&R stations with continuous high-bleed pneumatic devices, defined as those that emit more than six standard cubic feet per hour. “We visited each station multiple times, taking direct measurements of every emitting component,” said Montague.



Figure 12: The project team setting up the QLM camera at one of the test sites, Station A.

She also conducted field studies at transmission stations with intermittent-bleed pneumatic devices, which emit gas only while actuating to adjust pressure in the pipeline. “That made measuring the baseline at these stations more challenging,” said Montague. Ultimately, the team used a quasi-continuous leak monitoring (QLM) camera for these measurements. “It gave us a reasonably accurate representation of emissions over a 24-hour period.”

The Result

“When we compared results using the continuous- and intermittent-bleed data with the numbers we calculated using the EPA’s Subpart W emissions factors, we found that the estimated emissions were

very similar,” said Ahmed. “That substantiated our case to the CPUC for adopting the new methodology.”

To estimate recent emissions reductions using the EPA’s Subpart W emissions factors, PG&E chose 2022 as its baseline year. “Using the new methodology, we calculated the emissions for that year,” said Montague. Then, in 2024, the team recalculated the emissions, factoring in improvements it had made in the intervening years. “The difference between the two numbers was our methane abatement. It was a big success.”

The CPUC approved the new methodology in October 2025. “Now, we can take credit for a lot of the work that we do to reduce emissions,” said Ahmed. “If you replace a continuous-, high-bleed pneumatic device with a zero- or low-bleed one, you’re going to see the impact on reported emissions. The new methodology enables us to accurately measure and report emissions reductions from equipment upgrades and leak mitigations.”

With the new methodology, PG&E can provide regulators with clearer visibility into the effectiveness of its mitigation and abatement strategies, such as replacing high-bleed components, on an annual basis.

This work illustrates the role of research and development in addressing operational challenges by identifying, testing, and validating emerging technologies. Through this process, PG&E is able to evaluate the performance and cost-effectiveness of potential solutions prior to broader deployment, supporting informed investment decisions.

5.11 Development of Codes, Standards, or Protocols

Project results directly informed the development and regulatory acceptance of an improved methane emissions quantification protocol for transmission Metering and Regulating (M&R) stations. Through Gas RD&D-supported field measurement campaigns, PG&E generated component-level emissions data for both continuous- and intermittent-bleed pneumatic devices, validating the applicability of U.S. EPA Subpart W emission factors to PG&E’s system. This work demonstrated that component-based quantification provides a more accurate and defensible representation of actual emissions than prior station-level, population-based methods.

The resulting methodology established a repeatable, data-driven approach for estimating methane emissions reductions associated with equipment upgrades and leak mitigation activities. Following technical review and supporting analysis, the California Public Utilities Commission approved the use of this methodology in October 2025. This approval effectively established a new reporting protocol for PG&E, enabling consistent measurement, verification, and regulatory reporting of emissions reductions at M&R stations. The protocol now provides a clearer standard for demonstrating methane abatement, improves regulatory confidence in reported results, and supports alignment with state methane reduction goals. More broadly, the work offers a model that

can inform future utility practices, regulatory guidance, and potential standardization of component-level emissions reporting across the gas industry.

In addition, Gas RD&D-supported work conducted through Pipeline Research Council International (PRCI) and related collaborative efforts has directly informed updates to PG&E internal standards, procedures, and operational protocols. Several projects focused on hard spot detection and characterization—including in-ditch non-destructive examination (NDE), eddy current inspection technologies (e.g., EddyFi tools), and PRCI MAT-7-2 series studies—contributed to the development and deployment of new and revised procedures for validating in-line inspection (ILI) results. These include ATS Procedure WP 347-51 for use of EddyFi “Spyne” and “Sharck” tools, updates to TD-4810P-18 Direct Examination procedures, and revisions to TD-4820S Gas Operations Repair Standards to clarify evaluation and repair approaches for cracks associated with hard spots and calculated failure pressures.

Gas RD&D projects have also advanced new inspection and monitoring protocols for challenging pipeline environments. Field pilots of non-intrusive inspection technologies—including EMPIT Current Magnetometry Inspection (CMI) and Rosen’s non-intrusive pipeline assessment (NIPA)—have demonstrated viable, lower-cost approaches for assessing integrity in difficult-to-access or unpiggable pipelines. Notably, deployment at the Sacramento River crossing established a practical protocol for rapidly obtaining critical integrity data in high-risk or compliance-driven scenarios, supporting timely mitigation decisions while reducing cost and operational disruption.

Additional RD&D efforts have informed emerging protocols for real-time monitoring of third-party threats. Field validation of the SPADE system demonstrated a cost-effective method for detecting and capturing mechanical impacts on buried pipelines, particularly in agricultural regions. This work supports the development of operational practices and future standards for continuous monitoring technologies aimed at preventing pipeline damage and enhancing system safety.

5.12 Success Metrics

Consistent with Ordering Paragraph 4(c) and Commission guidance, PG&E evaluates the success of its Gas RD&D Program using qualitative and outcome-based metrics that reflect how research results are translated into operational practice, regulatory confidence, and system-level learning. Because many Gas RD&D projects are applied research, pilots, or demonstrations, success is not measured solely by patents, publications, or immediate commercialization outcomes. Instead, PG&E focuses on whether projects produce actionable insights, validated methodologies, or field-tested capabilities that inform utility decision-making and support ratepayer benefits.

In Reporting Year 2025, program success was demonstrated through several key qualitative outcomes:

- **Operationalization of Advanced Leak Detection and Monitoring Technologies**

Gas RD&D projects evaluating advanced methane detection technologies—including mobile, aerial, and continuous monitoring approaches—supported the transition from research evaluation to operational consideration during Reporting Year 2025 through structured field pilots, side-by-side comparisons, and deployment assessments under PG&E system conditions. Work involving Bridger Photonics and other advanced detection platforms improved understanding of detection sensitivity, localization performance, survey coverage, and practical deployment considerations, including how these tools complement existing regulated leak survey and repair programs. These evaluations informed decisions about where advanced detection technologies add the greatest value—particularly for identifying high-emitting sources and supporting targeted follow-up—while clarifying limitations, integration requirements, and cost considerations. Collectively, this work strengthened PG&E’s ability to identify and prioritize material emission drivers more efficiently, supported measurement-informed emissions reduction strategies, and advanced the disciplined incorporation of emerging detection technologies into routine operations while maintaining cost discipline and regulatory credibility. [bridgerphotonics.com]

- **Recognition and Advancement of Real-Time Pipeline Threat Detection (SPADE)**

The SPADE real-time pipeline threat detection project achieved significant progress through field validation and continuous improvement, demonstrating the capability to detect and localize mechanical impacts and third-party damage risks on operating pipelines in real time. Success metrics included successful pilot deployment under field conditions, measurable improvements in event localization accuracy, enhanced event classification, and increased usability for operators supporting integrity management activities. Based on these demonstrated outcomes, SPADE received industry recognition through nomination in 2025 and subsequent selection as a finalist and recipient of the PPIM 2026 Innovation Award, presented through the Pipeline Pigging & Integrity Management (PPIM) Conference, an industry forum focused on pipeline integrity, inspection, and risk management. This recognition provides external validation of the project’s technical merit, practical applicability, and relevance to integrity management challenges.

- **Improved Emissions Quantification and Regulatory Confidence**

A major qualitative success of the Gas RD&D portfolio was the development and regulatory acceptance of a component-level methane emissions quantification methodology for transmission Metering and Regulating (M&R) stations. Gas RD&D-supported field measurement campaigns validated the applicability of U.S. EPA Subpart W emission factors to PG&E’s system, replacing population-based estimates with measurement-informed approaches that directly link emissions reductions to specific equipment upgrades and leak mitigation actions. The California Public Utilities Commission’s approval of this methodology in 2025 represents a critical success metric, as it enabled PG&E to accurately measure, report, and receive regulatory credit for verified emissions reductions while strengthening transparency, defensibility, and confidence in reported outcomes. This work is reflected in the California Public Utilities Commission and California Air Resources Board Joint Staff

Report, Analysis of the Gas Companies’ June 13, 2025 Natural Gas Leak and Emission Reports, prepared by CPUC Safety Policy Division staff and California Air Resources Board analysts, which documents the use of updated emissions methodologies and recognizes the integration of field-validated measurement approaches to support system-level emissions reduction reporting.

Collectively, these outcomes demonstrate that Gas RD&D success is measured by how effectively research reduces uncertainty, informs operational practice, and supports Commission-approved decision-making, rather than by standalone research artifacts. These qualitative success metrics reflect the program’s role in advancing safety, reliability, emissions reduction, and affordability for ratepayers, consistent with Commission expectations and the public interest mandate of Public Utilities Code § 740.1.

5.13 Challenges and Lessons Learned

Challenge	Lesson Learned
As identified in the CPUC Utility Audits, Risk and Compliance Division, audit of Southern California Gas Company’s Gas RD&D Program, audit findings highlighted that Gas RD&D staff time must be charged to administrative categories when activities support compliance, reporting, coordination, and project oversight. When staff time was reclassified accordingly, administrative costs were found to exceed the Commission’s 10% administrative cost cap, illustrating that the baseline effort required to meet expanding program requirements can materially increase reported administrative costs.	As staff time associated with project oversight and mandatory compliance activities is classified as administrative, Gas RD&D programs must actively reprioritize portfolios, scopes of work, and discretionary activities to remain within the 10% administrative cap, while recognizing that core obligations—such as annual plans and reports, workshops, coordination, and stakeholder engagement—create unavoidable baseline administrative costs.
Hydrogen research was deprioritized or paused following the Commission’s determination that hydrogen blending currently provides limited value to gas ratepayers.	Gas RD&D portfolios benefit from staying closely aligned with current Commission priorities and maintaining the ability to adjust research focus as policy direction evolves, even when earlier plans reflected broader industry or statewide interest.
Uncertainty regarding the appropriate role of gas ratepayers in funding hydrogen and other emerging fuel research in the absence of explicit Commission guidance.	In areas where regulatory guidance is still developing, more narrowly scoped, exploratory research and a clear distinction between foundational analysis and deployment-oriented work can help manage expectations.
Requirement that Gas RD&D projects be conducted within California, with limited exceptions, reduced participation in some national or multi-state research efforts.	Considering geographic eligibility early in project development helps ensure that partnerships and research activities deliver clear, California-specific benefits.
Increased expectation that Gas RD&D projects prioritize zero-carbon or	Clearly describing how each project supports emissions reduction, affordability, or transition planning—whether

emissions-reducing outcomes or clearly explain why such outcomes are not feasible.	directly or through foundational insights—helps provide transparency and context for stakeholders.
New requirements to clearly link each project to an approved Initiative and Investment Plan in future Plans and Reports.	Consistent project classification and portfolio structure improve transparency and make it easier for external readers to understand how individual projects fit within the overall program.
Restrictions on recording Gas RD&D expenses until annual funding plans are formally approved through the regulatory process.	Closer coordination between regulatory approvals, project scheduling, and financial planning helps reduce timing challenges and supports compliance.
Reclassification of research consortium membership dues as administrative costs and increased scrutiny of administrative spending levels.	More detailed tracking and explanation of administrative activities helps demonstrate how these costs support effective research execution.
Commission concerns regarding inconsistent use of standardized administrative budgeting templates.	Clear and consistent use of prescribed reporting formats supports transparency and improves regulatory understanding of program expenditures.
Heightened emphasis on avoiding duplication with research funded by the CEC or administered through the EPIC program.	Early coordination and documentation of roles across research administrators and peer utilities helps clarify responsibilities and avoid overlap.
Absence of a Commission-approved Gas RD&D impact framework, alongside increasing expectations for quantified benefits.	Using interim metrics that are clearly explained and consistently applied can help communicate program value while broader impact frameworks continue to be developed.
Rapid issuance of the draft and final Resolution created near-term disruption to portfolio planning and stakeholder expectations.	Maintaining flexibility in portfolio design and incorporating scenario planning can help programs adapt to regulatory changes while maintaining continuity.
Demonstrating ratepayer benefits and affordability impacts for a diverse portfolio of multi-year projects.	Distinguishing near-term outputs, mid-term outcomes, and long-term impacts helps communicate RD&D value more clearly and set appropriate expectations.
Managing uneven spending profiles driven by project timing, contracting, and technical milestones.	Clear documentation of project schedules and funding status improves interpretation of encumbered, spent, and unspent funds.
Coordinating RD&D activities across internal teams, external partners, and peer utilities while avoiding duplication.	Early engagement and structured coordination improve efficiency, leverage external expertise, and reduce redundant research efforts.
Applying consistent impact and reporting metrics in the absence of a Commission-approved Gas RD&D framework.	Using interim, program-level metrics aligned with CPUC direction supports transparency while allowing flexibility as formal frameworks evolve.
Balancing administrative, reporting, and compliance requirements with timely project delivery.	Standardized templates, clearer internal processes, and early alignment with reporting needs reduce administrative burden and support on-time delivery.

6 Conclusion

6.1 Key Findings

PG&E's Gas RD&D portfolio accomplishments during the reporting year demonstrated how targeted, applied research can deliver near-term analytical value while building an evidence-based foundation for long-term system transformation. Across both investment themes—Gas System Integrity and Decarbonization—the program generated actionable data, validated methodologies, and field-tested technologies that reduce uncertainty, strengthen decision-making, and support alignment with CPUC priorities related to safety, reliability, affordability, emissions reduction, and transparency for ratepayers.

A key finding from the portfolio is the value of measurement-informed approaches in translating RD&D outcomes into regulatory and operational impact. Projects that replaced generalized assumptions with field-validated data—most notably in methane emissions quantification—enabled PG&E to demonstrate the effectiveness of mitigation investments. The CPUC's approval of a component-level emissions quantification methodology for transmission M&R stations illustrates how RD&D can inform standardized protocols that improve reporting consistency and support scalable application. Building on this success, a recommended program improvement is to prioritize RD&D projects that explicitly identify potential pathways to regulatory acceptance, standardization, or protocol development early in the project lifecycle.

Portfolio accomplishments also highlight the importance of field-based validation in advancing technologies toward broader deployment. Pilots of real-time pipeline threat detection and non-intrusive electromagnetic inspection showed that testing under real-world conditions is critical to understanding performance, limitations, and cost-effectiveness. These projects reduced technical and operational risk while clarifying where technologies can deliver the greatest value. To further strengthen outcomes, the program would benefit from more consistent use of predefined success criteria and scalability considerations at project initiation, helping focus resources on solutions with clear operational pathways.

Another finding is that advanced analytics and AI are most effective when deployed incrementally and in service of defined operational needs. RD&D pilots demonstrated that AI-enabled tools can improve inspection prioritization, anomaly detection, and predictive maintenance when integrated into existing workflows. A recommended improvement is to continue formalizing governance, validation, and knowledge-transfer processes for AI-related projects to ensure responsible deployment, repeatability, and alignment with safety-critical utility requirements.

In the Decarbonization theme, portfolio accomplishments reinforced the role of foundational research in a period of uncertainty about future fuels, infrastructure pathways, and customer impacts. Rather than immediate deployment, RD&D provided data to inform feasibility, safety, and

cost tradeoffs—supporting prudent, staged decision-making. To strengthen alignment with CPUC expectations, the program could enhance how these projects articulate interim decision points and how findings will inform future planning, proceedings, or pilot development.

Across the portfolio, the experience of the reporting year underscores that scaling impact depends on strong coordination and clear communication, not technology readiness alone. Projects that engaged operational teams, external partners, and regulators early were better positioned to inform implementation and reporting. As a program improvement, continued refinement of standardized reporting templates, clearer differentiation between outputs and longer-term impacts, and earlier alignment with annual reporting requirements will improve transparency and reduce administrative burden.

Collectively, these findings and recommendations reinforce the role of Gas RD&D as a disciplined, evidence-based program that supports continuous improvement. By building on successful practices—such as measurement-driven research, field validation, structured portfolio alignment, and early coordination—while refining planning and reporting processes, PG&E can further enhance the scalability, clarity, and ratepayer value of future RD&D investments in alignment with CPUC proceedings and program priorities.

6.2 Anticipated Developments and Opportunities

This section describes potential areas of technical development and learning identified through ongoing Gas RD&D activities. Gas RD&D activities are intended to advance knowledge, tools, and technologies that may inform utility decision-making related to safety, reliability, affordability, environmental performance, and evolving regulatory requirements, consistent with California’s long-term climate and energy transition goals.

Consistent with CPUC guidance and statutory requirements, PG&E’s portfolio focuses on delivering measurable ratepayer benefits through targeted research, field demonstrations, and technology validation efforts that inform operational decision-making and long-term system planning. The Commission denied PG&E’s 2025 Plan (AL 5069-G) in CPUC Resolution G-3618 and directed resubmittal; the allocations below are presented for transparency as part of PG&E’s revised planning/resubmittal posture rather than as Commission-approved funding.

Research Area	Share of Budget	Focus
Gas System Integrity	63%	Safety, risk reduction, inspection, emissions mitigation, infrastructure resilience
Decarbonization	27%	Low-carbon fuels integration and system transition support
Administration	10%	Program oversight and coordination

6.2.1 Proposed Gas System Integrity Initiatives

The initiatives described below reflect PG&E's proposed planning approach. PG&E's Gas System Integrity portfolio emphasizes proactive risk management, cost-effective compliance, emissions reduction, and system modernization.

- **Proactive Geohazard Risk Management**

Addresses increasing seismic, landslide, and erosion risks by deploying:

- Distributed fiber optic sensing (DFOS)
- Advanced sensors for strain and vibration monitoring
- Remote sensing and terrain movement analysis
- AI/ML-enabled predictive risk modeling

Expected Impacts

- Reduced emergency repair costs
- Lower pipeline failure risk
- Improved regulatory compliance
- Enhanced coordination with long-term system planning

- **Innovative and Cost-Effective Integrity Management**

Targets rising compliance costs (e.g., PHMSA MEGA Rule requirements) through:

- 3D mapping and real-time impact detection
- Non-intrusive corrosion and coating assessment
- AI/ML-enabled fiber optic monitoring of pipelines and storage wells
- Advanced in-line inspection tool development

Expected Impacts

- Reduced maintenance costs
- Improved reliability and safety
- Strengthened risk-based asset management

- **Advanced Leak Detection and Repair (LDAR)**

Seeks to improve cost-effectiveness and speed of leak detection by:

- Evaluating continuous monitoring technologies
- Expanding aerial and mobile leak detection
- Refining advanced metering (AM) algorithms
- Integrating multi-source emissions data

Expected Impacts

- Faster leak localization
- Reduced methane emissions

- Lower inspection and repair costs
- Improved system reliability
- **Emission Reduction Activities and Refined Reporting**
Supports continued methane reduction and improved emissions transparency by:
 - Validating new methane mitigation technologies
 - Confirming field performance under PG&E conditions
 - Collecting data to improve emissions reporting accuracy

Expected Impacts

- Reduced GHG emissions
- Enhanced reporting accuracy
- Improved planning reliability

6.2.2 Proposed Decarbonization Initiatives

PG&E's decarbonization investments focus on integrating low-carbon fuels safely and cost-effectively while maintaining system reliability.

- **Clean Fuels Integration**
Key activities include:
 - Evaluating infrastructure performance with renewable natural gas RNG
 - Assessing interconnection cost drivers and standardization
 - Developing improved gas quality monitoring methodologies
 - Investigating system compatibility and safety considerations

Expected Impacts

- Safe integration of RNG
- Improved air quality
- Increased energy resilience
- Reduced lifecycle GHG emissions

6.2.3 Program Characteristics

Across all initiatives, PG&E's RD&D program:

- Aligns with CPUC proceedings and policy direction
- Avoids duplication and coordinates with other Gas RD&D administrators
- Emphasizes field validation and operational applicability
- Supports risk-based decision-making
- Targets measurable ratepayer benefits

Projects range from early-stage evaluation to field demonstrations and deployment readiness, ensuring research translates into practical system improvements.

6.2.4 Conclusion

Over the next year, PG&E's Gas RD&D funding initiatives are structured to:

- Improve safety and system integrity through proactive monitoring and advanced inspection technologies
- Enhance affordability by reducing long-term compliance and maintenance costs
- Reduce methane emissions and improve emissions transparency
- Support safe and cost-effective integration of renewable natural gas
- Inform long-term system planning in alignment with California's clean energy transition

Collectively, these initiatives reflect a targeted, risk-informed RD&D portfolio designed to deliver tangible public interest benefits while supporting regulatory objectives and system modernization.

7 Appendices

Appendix	Title
1	Sheet 1: Plan Balance Reporting
2	Sheet 2: Project Reporting
3	Total Leveraged Funds to Date
4	Anchoring Innovation in Affordability
5	Strengthening System Integrity in a Changing Energy Landscape
6	Charting the Course to a Decarbonized Energy System
7	Powering a Smarter, Safer Future
8	The Value of R&D
9	Inclusion & Belonging at PG&E
10	Project Selection Process
11	Problem Statements

7.1 Appendix 1—Sheet 1: Plan Balance Reporting

[see attached spreadsheet]

7.2 Appendix 2—Sheet 2: Project Reporting

Appendix 2 includes a listing of Gas RD&D-related projects during the reporting year, including projects that were subsequently disallowed or not authorized for continued funding under the Gas RD&D program. These entries are provided for transparency and record-keeping purposes to reflect work performed, results generated, and expenditures incurred during the reporting period. In some cases, research activities documented here may continue or be concluded outside of the Gas RD&D program.

[see attached spreadsheet]

7.3 Appendix 3—Total Leveraged Funds to Date

Appendix 3 summarizes total leveraged funding associated with Gas RD&D activities through the reporting year, aggregated by investment theme. This summary is intended to illustrate the extent to which PG&E's Gas RD&D investments have attracted additional non-PG&E funding across Gas System Integrity and Decarbonization research portfolios.

Theme	2025 Actual Spend	Total PG&E Budget	Total Co-Funding	Leverage Ratio
Gas System Integrity	\$955,603	\$3,012,467	\$5,893,848	2
Decarbonization	\$181,152	\$2,583,605	\$42,542,704	16
TOTAL	\$1,136,755	\$5,596,072	\$48,436,552	9

To complement the aggregate funding summary, a second table is provided below that lists current 18 projects that have been determined Gas RD&D in-scope per Commission guidance.¹⁵

Theme	2025 Actual Spend	Total PG&E Budget	Total Co-Funding	Leverage Ratio
Gas System Integrity	\$955,603	\$2,945,316	\$0	0
Decarbonization	\$181,152	\$264,334	\$0	0
TOTAL	\$1,136,755	\$3,209,650	\$0	0

¹⁵ CPUC Resolution G-3618 (January 15, 2026), establishing Commission guidance for the scope, review, and classification of Gas Research, Development, and Demonstration (Gas RD&D) activities pursuant to Decision (D.) 23-11-069.

7.4 Appendix 4—Anchoring Innovation in Affordability

Affordability is a central pillar of PG&E’s Gas RD&D program and a guiding principle in shaping its research priorities and investment strategy.

As California accelerates electrification, overall gas throughput is expected to decline—even as the costs to maintain, upgrade, and ensure the safety of our pipeline infrastructure will remain largely fixed. As these costs are spread across a shrinking customer base—many of whom are from lower-income households—this dynamic could increase energy burdens for the very customers least able to absorb them.

To counter this risk and maintain or improve the affordability of energy, Gas RD&D’s funding strategy focuses on identifying and scaling innovations that directly reduce operational costs, extend the life and efficiency of existing assets, and minimize the financial burden of the transition to cleaner fuels.

PG&E’s Commitment to Stabilizing Customer Bills

Across the company, we are taking action to deliver safe, reliable, and climate-resilient energy at the lowest possible cost.

- Keep average annual combined bill increases within two to four percent through 2026
- Eliminated \$510 million in costs in 2023
- Targeted up to \$1 billion in additional savings in 2024 through improvements in planning, automation, labor efficiency, and material use
- Secure lower-cost financing
- Pursue federal grants and loans
- Collaborate with consumer advocates

Every investment is evaluated not only for its technical merit but also for its potential to deliver measurable cost savings to ratepayers over both the near and long term.

7.4.1 Driving Efficiency through Innovation

Gas RD&D seeks technologies and practices that lower the cost of safely operating and maintaining PG&E’s gas system. This includes developing:

- Advanced inspection and monitoring tools
- Predictive maintenance capabilities
- Data-driven prioritization methods

These innovations directly contribute to stabilizing customer bills by reducing the frequency and cost of maintenance activities, minimizing unplanned service disruptions, and optimizing the deployment of capital and labor. In doing so, they support PG&E’s broader company-wide efforts to stabilize customer bills by making core operations more efficient.

7.4.2 Balancing Transition Costs and Long-Term Savings

PG&E's net zero goal will require substantial changes to the gas system, including the integration of renewable natural gas (RNG), hydrogen, and other clean fuels. Gas RD&D is committed to pursuing this transformation in the most cost-effective manner possible. That's why we support research that:

- Evaluates the economic tradeoffs of new technologies
- Identifies pathways that balance near-term affordability with long-term emissions reductions
- Assesses the compatibility of existing infrastructure with cleaner fuels
- Prevents premature asset write-offs as the system evolves.

This disciplined, evidence-based approach complements PG&E's broader affordability initiatives, helping ensure that decarbonization advances in ways that protect customers from unnecessary costs.

7.4.3 Delivering Value through Collaboration and Continuous Improvement

Affordability is not achieved in isolation. It depends on collaboration across utilities, technology providers, and the research community. Gas RD&D actively engages with external partners to:

- Share data
- Pool resources
- Accelerate innovation that drives collective cost savings for customers statewide.

Internally, the program measures success by the tangible value its projects deliver—whether through direct operational savings, deferred capital investments, avoided emissions penalties, or improved asset performance. By continuously refining its research portfolio and aligning it with PG&E's company-wide cost-reduction efforts, Gas RD&D ensures that every research dollar invested works harder for customers.

Together, these efforts support PG&E's broader mission: to deliver safe, reliable, and clean energy at the lowest possible cost—helping all customers prosper as California transitions to a low-carbon future.

7.5 Appendix 5—Strengthening system integrity

Safety and reliability are the foundation of PG&E's Gas RD&D program. Every research investment—whether focused on innovation, decarbonization, or system modernization—is grounded in protecting the public, our coworkers, and the integrity of our gas infrastructure. As California transitions toward a cleaner energy future, Gas RD&D remains focused on ensuring that PG&E's natural gas system continues to operate safely, reliably, and efficiently.

To maintain this standard of excellence, Gas RD&D supports research, testing, and technology demonstrations that strengthen PG&E's ability to identify and mitigate risk, enhance system awareness, and optimize maintenance and repair activities. These efforts ensure that safety and reliability remain uncompromised, today and in the decades ahead.

7.5.1 Enhancing System Resilience through Innovation

PG&E's Gas RD&D team is advancing new technologies to detect, prevent, and respond to emerging risks before they impact service. Investments include:

- Developing and testing advanced leak detection systems
- Expanding in-line inspection, non-intrusive survey and monitoring, and nondestructive testing capabilities
- Using drone and aerial monitoring to provide near-real-time visibility into system conditions.

Through artificial intelligence (AI) and advanced analytics, Gas RD&D staff are transitioning from reactive to predictive safety management, enabling earlier identification of anomalies, more efficient inspection intervals, and data-driven prioritization of maintenance activities. These innovations enhance the reliability of gas delivery while reducing the cost and emissions associated with unplanned events.

7.5.2 Building a Smarter, More Adaptive Safety Framework

As PG&E prepares its gas system for the integration of RNG, hydrogen, and other alternative fuels, adaptability is key. Gas RD&D supports research that evaluates how these fuels interact with existing infrastructure and materials to ensure safe and efficient implementation.

By investing in data-driven tools and flexible operational methods, Gas RD&D enables continuous improvement of inspection, monitoring, maintenance, and operational protocols as system conditions evolve. This proactive approach ensures that PG&E can safely operate today's system while preparing for tomorrow's clean energy mix.

7.5.3 Proactive Risk Management and Continuous Improvement

Gas RD&D supports a culture of prevention, collaboration, and learning. Each project is assessed for its potential to reduce risk, improve efficiency, and strengthen the system's resilience over the long term.

Through partnerships with peer utilities, national laboratories, and industry research groups, Gas RD&D advances the collective understanding of system performance and emerging threats. Whether through advanced analytics, innovative inspection technologies, or streamlined field processes, these efforts ensure that PG&E continues to deliver safe, reliable, and affordable energy as it transitions toward a decarbonized future.

7.6 Appendix 6—Charting the course to a decarbonized energy system

PG&E is committed to achieving a net zero energy system by 2040, five years ahead of California's statewide goal.

Meeting this commitment requires transforming a gas system that delivers nearly 900 billion standard cubic feet of methane annually into one that can safely and efficiently transport RNG, hydrogen, and other clean fuels.

As this transformation unfolds, Gas RD&D plays a vital role in advancing the research and technologies needed to ensure that the transition to cleaner fuels is technically sound, economically responsible, and beneficial for customers.

The path to decarbonization will demand collaboration, experimentation, and a strong foundation of data-driven insights. By investing in both early-stage research and near-term demonstration projects, Gas RD&D is helping define how California's gas infrastructure can evolve to support a cleaner energy mix while maintaining safety, reliability, and affordability.

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

Greening the gas system is a core component of PG&E's True North Strategy and the company's broader efforts to achieve California's decarbonization goals.

Using its 2015 emissions levels as a baseline value, PG&E had achieved 52% emissions reductions by the end of reporting year (RY) 2024.¹⁶

¹⁶ The latest date for which data is available.

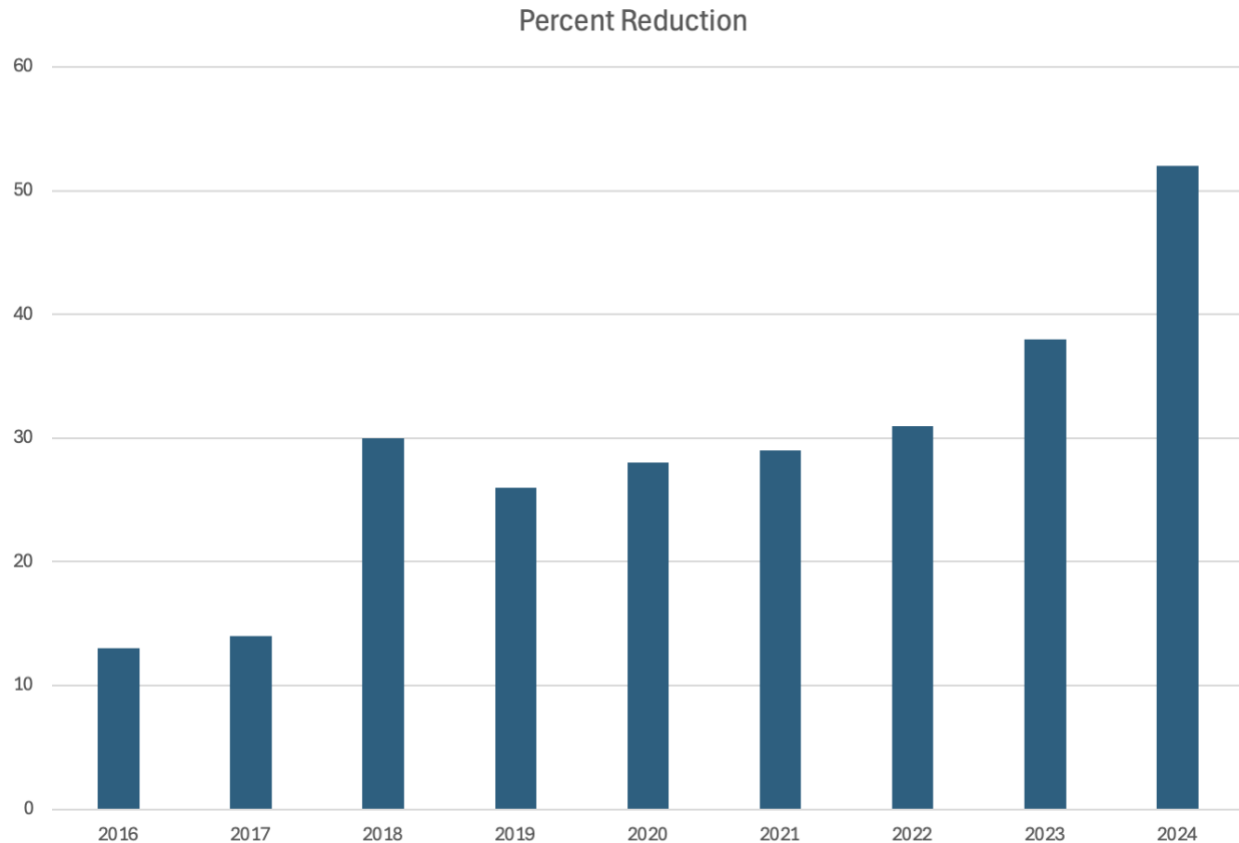


Figure 13: At the end of RY 2024, PG&E had achieved 52% emissions reductions in comparison to baseline year 2015.

7.6.2 Renewable Natural Gas plays a key role in decarbonization

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.

Between 2021 and 2023, PG&E began accepting RNG from 36 dairies across its service territory via seven interconnections with its gas infrastructure. By the end of 2024, that number had grown to 48. By December 2025, that number had grown to approximately 55.

7.6.3 A comprehensive approach to emissions reductions

PG&E's Gas Operations and Engineering teams has taken a comprehensive approach to reducing emissions from the natural gas system, including:¹⁷

¹⁷ Pacific Gas and Electric Company. PG&E Reduces Emissions from Gas Pipelines by More Than 20%. Press Release, 2023. Available at: <https://investor.pgecorp.com/news-events/press-releases/press-release-details/2023/PGE-Reduces-Emissions-from-Gas-Pipelines-by-More-than-20/default.aspx>

- Deploying new tools to our leak survey program in 2025, including a helicopter-based lidar sensor for transmission leak survey and a drone-mounted lidar sensor for survey in hard-to-reach areas. The new deployments will help us to improve safety for customers, reduce emissions, and strive for ratepayer affordability.
- Enhancing the PG&E Super Emitter Program, which applies advanced leak detection technologies to accelerate detection and repair of Super Emitters (SE) above a given threshold. In 2025, we reduced the SE threshold from 6 to 5 standard cubic feet per hour (scfh) to accelerate the identification and repairing of more high-emitting leaks.
- Piloting vacuum purging systems to reduce methane emissions when purging gas lines into service.
- Utilizing tools and methods such as cross-compression, drafting, flaring, and project bundling to minimize emissions during transmission pipeline maintenance, repair, or replacement projects.
- Performing quarterly leak surveys at compressor stations and natural gas storage facilities.
- Continued piloting the feasibility of compression tape to repair meter set leaks faster.

7.6.4 Accelerating Decarbonization through Innovation and RD&D

While Gas Operations and Engineering teams work every day to strengthen the safety, efficiency, and performance of the existing system, RD&D extends these efforts into the future—testing the technologies, materials, and processes that will define tomorrow’s cleaner energy network.

By investing in research that complements operational initiatives, RD&D ensures that PG&E’s transition to a low-carbon system is guided by rigorous data, field-tested solutions, and an understanding of both the technical and economic realities of implementation.

Through targeted RD&D investments, PG&E is exploring how cleaner fuels such as hydrogen and RNG can be integrated safely and cost-effectively into the existing system. This includes both foundational research, as well as applied demonstrations. As new insights emerge, RD&D staff share them across PG&E’s operational teams and with industry peers, amplifying the collective impact of every research dollar invested.

7.7 Appendix 7—Powering a smarter, safer future

Each breakthrough in RD&D strengthens PG&E’s foundation for the future. The next phase of that evolution is already underway: leveraging AI to transform data into foresight, automate complex decisions, and accelerate progress toward a cleaner, smarter energy system.

AI and machine learning (ML) are reshaping how PG&E plans, operates, and maintains its gas system. These technologies hold the potential to reduce the costs of maintaining current infrastructure while enabling a safe, efficient transition to cleaner fuels. From predictive maintenance and system planning to field operations and emissions reduction, AI is helping PG&E unlock new efficiencies and deliver greater value to customers.

7.7.1 Integrating AI into Gas RD&D’s Funding Strategy

PG&E’s Gas RD&D views AI not as a standalone innovation but as a foundational capability that supports its mission to deliver a cleaner, safer, and more affordable energy future. PG&E has begun to explore the potential for AI, developing more awareness of its capabilities through strategic hiring of AI experts and executing pilots to assess its effectiveness. As part of PG&E’s True North Strategy, Gas RD&D is assessing projects with the potential to leverage AI and ML to address some of the most complex challenges in gas operations: conducting inspections, monitoring data analytics, predicting maintenance needs, identifying potential leaks, optimizing capital planning, and enhancing workforce effectiveness.

These efforts ensure that research investments are focused on tools that advance progress toward our reliability, safety, and affordability goals.

7.7.2 Enhancing Safety and Efficiency through Predictive Intelligence

AI’s ability to detect patterns in large, complex data sets could enable PG&E to move from reactive to predictive operations. By analyzing sensor data, inspection records, and maintenance histories, AI-driven tools can identify anomalies and early indicators of potential equipment failure.

These insights enable maintenance teams to act before problems arise, reducing safety risks, unplanned outages, and emissions. In addition, AI-optimized project planning tools could evaluate multiple variables—such as weather, traffic, and resource availability—both historical and real-time, helping PG&E deploy crews more efficiently and minimize customer impacts.

7.7.3 Empowering the Workforce with Smart Tools

AI has the potential to transform how PG&E’s field teams work. AI-enabled mobile applications and augmented reality tools can guide technicians through complex repair procedures, display real-time pipeline schematics, and issue hazard alerts, all while optimizing safety protocols. By combining

human expertise with digital intelligence, PG&E can enhance both efficiency and safety for employees working in high-risk environments.

7.7.4 Building Foundational Capabilities for Responsible AI Deployment

PG&E's approach to AI emphasizes responsible and transparent use grounded in strong governance, data integrity, and human oversight. Gas RD&D's funding strategy reflects this commitment by supporting projects that incorporate cybersecurity safeguards, data quality standards, and explainable AI design.

By aligning with PG&E's enterprise-wide AI governance framework, these projects ensure that AI becomes a trusted, scalable enabler of operational excellence and customer affordability.

7.7.5 Collaborating to Accelerate the AI Transformation

To fully realize the potential of AI, PG&E continues to partner with industry consortia, peer utilities, research institutions, and technology providers in the industry to share insights and shape standards for AI adoption in energy systems.

These collaborations extend the impact of RD&D investments beyond PG&E, helping the entire industry harness AI to improve safety, reliability, and sustainability. By combining technical expertise with innovation leadership, PG&E is helping to define the intelligent, adaptive utility of the future.

7.8 Appendix 8—The Value of R&D

For PG&E Gas RD&D, research and development is fundamentally about practical problem-solving with measurable public value. Much of this work occurs behind the scenes, but its impacts are reflected in how safely, reliably, and affordably the gas system operates for customers across California. RD&D provides a structured environment in which ideas are tested under real-world conditions, data is used to challenge assumptions, and new approaches are evaluated before broader application.

Change in a safety-critical, highly regulated system does not occur quickly or through isolated actions. RD&D enables PG&E to test solutions deliberately, learn from field experience, and work through technical and regulatory questions in a disciplined manner. The objective is not simply compliance, but continuous improvement—strengthening system performance, managing costs, and supporting California’s energy transition in ways that deliver durable benefits to ratepayers over time.

7.8.1 Safety and System Integrity Impact

RD&D contributes to safety and system integrity by improving how risks are identified, evaluated, and managed before they result in adverse outcomes. Research projects support earlier detection of abnormal conditions, more precise characterization of system behavior, and improved understanding of failure mechanisms under real operating conditions.

Through applied research and field validation, RD&D has helped advance inspection, monitoring, and mitigation approaches that strengthen situational awareness and reduce uncertainty in integrity decision-making. These efforts complement routine operations by testing tools and methods before deployment at scale, supporting safer execution and reducing the likelihood of unplanned events.

7.8.2 Environmental and Emissions Reduction Impact

Reducing methane emissions across a gas system of PG&E’s scale requires more than intent; it requires credible measurement, repeatable methods, and defensible reporting. RD&D has played a central role in improving how emissions are detected, quantified, and tracked by strengthening advanced methane leak detection, refining emissions quantification methodologies, and expanding the use of continuous and component-level monitoring.

This work has supported a shift from population-based assumptions toward measurement-informed approaches. As a result, emissions reporting has become more accurate, regulatory expectations are better aligned with field conditions, and confidence in reported reductions has increased. RD&D has enabled methane reduction strategies to be evaluated, refined, and validated in a way that supports both environmental performance and system reliability.

Case Study: Methane Emissions Reduction Over Time

PG&E's methane emissions reduction timeline illustrates how sustained RD&D investment, combined with operational programs and regulatory requirements, produces cumulative environmental benefits. Using 2015 emissions as a baseline, PG&E has progressively improved how methane emissions are identified, prioritized, and reduced across the gas system.

Over time, this work has included launching and expanding the Super Emitter Program, lowering leak detection thresholds, improving transmission blowdown mitigation, refining meter set leak management, and strengthening repair prioritization frameworks. Many of these practices were shaped by RD&D projects that tested approaches before they were applied more broadly. Collectively, these efforts contributed to exceeding the CPUC's methane reduction target ahead of schedule and achieving a 52 percent reduction by the end of reporting year 2024.

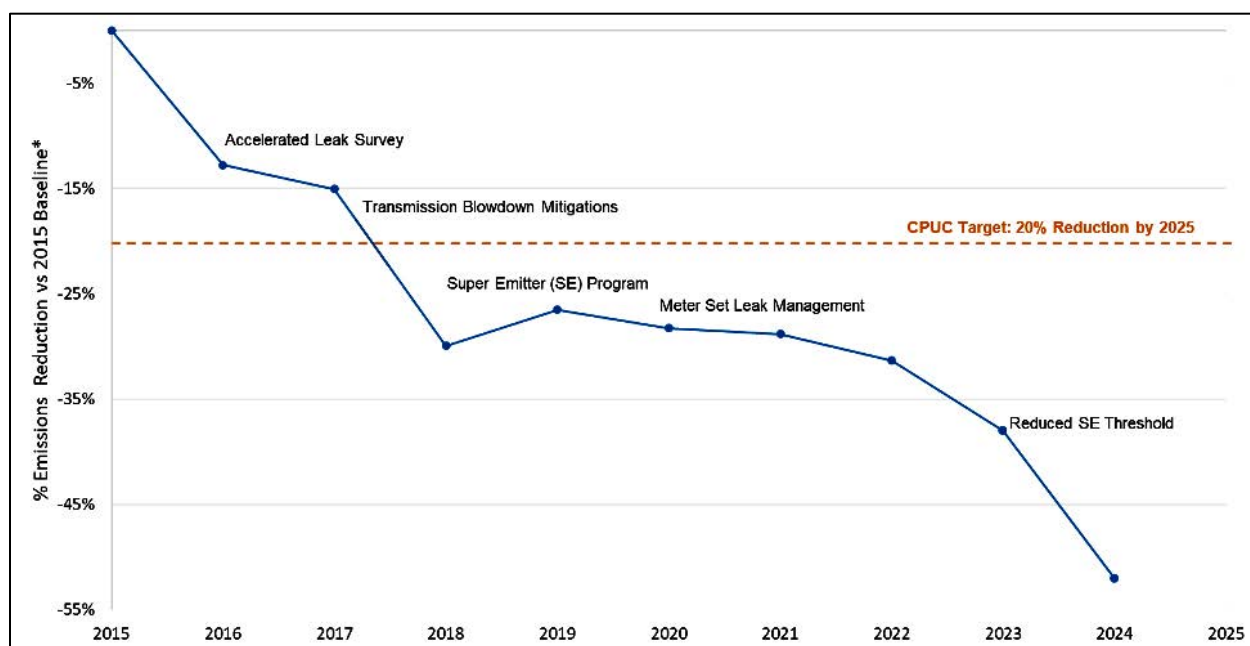


Figure 14: PG&E's methane emissions reduction timeline. Includes CPUC-approved baseline adjustments in 2022, 2023, 2025

The timeline underscores that progress is cumulative. Each research effort builds on prior work, strengthening the technical, operational, and regulatory foundation needed to sustain emissions reductions over the long term.

7.8.3 Affordability and Cost-Effectiveness Impact

RD&D supports affordability by identifying opportunities to reduce operating and maintenance costs while maintaining safety and reliability. Emissions-related research has helped improve leak detection efficiency, reduce time-intensive surveys, and enable more targeted use of field resources.

Pilot projects using continuous monitoring and improved analytics have demonstrated pathways to lower long-term costs by reducing repeat work, avoiding unnecessary interventions, and improving planning precision. Enhanced emissions quantification and reporting tools have also simplified compliance processes and reduced administrative effort. These outcomes illustrate how focused research can simultaneously advance environmental objectives and cost-effectiveness for ratepayers.

7.8.4 Regulatory Confidence and Transparency Impact

A key value of RD&D lies in strengthening the transparency and credibility of information used in regulatory oversight. By producing field-validated data, documented methodologies, and repeatable analytical approaches, RD&D helps ensure that regulatory reported outcomes are traceable, comparable over time, and clearly attributable to defined practices.

This contribution supports constructive engagement with regulators by improving alignment between reported results and observed system behavior. RD&D enables regulatory discussions to focus on evidence rather than assumptions, reinforcing confidence in both reported outcomes and the processes used to achieve them.

7.8.5 Long-Term System Value and Learning

RD&D does not produce immediate results, nor is it designed to. Many projects contributing to today's outcomes began years earlier as pilots or exploratory research and required time to test, refine, and integrate. Their value reflects persistence, cross-functional learning, and willingness to adapt based on evidence.

As California moves toward a net-zero future, RD&D helps PG&E manage uncertainty, evaluate emerging technologies and fuels, and work through complex technical and regulatory questions before large-scale decisions are made. Sustained investment in research supports careful, informed choices that balance safety, reliability, affordability, and equity—delivering value to customers and ratepayers both now and over the long term.

7.9 Appendix 9—Inclusion and Belonging at PG&E

Gas RD&D recognizes that inclusion and belonging extend beyond the workplace. They are essential to ensuring that the clean energy transition benefits all Californians. Guided by PG&E's purpose to deliver safe, reliable, and affordable energy to every community it serves, Gas RD&D integrates Environmental and Social Justice (ESJ) principles into every stage of its project development and selection process.

As California advances toward a net zero energy future, PG&E is committed to ensuring that low-income and historically underserved communities share equitably in the benefits of innovation through cleaner air, greater safety and energy reliability, workforce participation, and long-term affordability.

7.9.1 What is an ESJ community?

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:³

- 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**⁴
- **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**)



Gas RD&D aligns with the CPUC’s definition of ESJ communities: those that are predominantly low-income or communities of color, overburdened by environmental hazards, or underrepresented in policy and decision-making.

Gas RD&D projects are designed to ensure that the energy transition does not leave these ratepayers behind. Each year, Gas RD&D evaluates proposed projects not only for technical merit and emissions reduction potential but also for their ability to deliver tangible benefits to ESJ communities. These include improved air quality, energy affordability, workforce participation, and local economic opportunity.

7.9.2 Supporting Projects that Matter

PG&E Gas RD&D supports projects that increase operational efficiency, reduce emissions, and prepare the gas system for cleaner fuels—while prioritizing equity in who benefits from these innovations.

Recognizing that the path to net zero may have short-term impacts on disadvantaged communities, Gas RD&D evaluates every project for its potential to deliver equitable benefits and avoid disproportionate burdens. Examples of how we do or plan to do this include:

7.9.2.1 Short-Term Approaches

- Siting RD&D projects with no potential short-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 community-based organizations (CBOs) with technical training or funding so they can engage meaningfully in project design, data interpretation, and communication.
- Creating or supporting jobs during the project.
- Compensating community members for participating in project design or data validation.
- Modeling transparency by sharing data and findings in accessible formats and languages.

7.9.2.2 Long-Term Approaches

Environmental and Social Justice (ESJ) considerations are integrated into the Gas RD&D Program through a benefits based framework aligned with Public Utilities Code § 740.1, the EPIC Uniform Impact Analysis Framework, and PG&E’s Gas RD&D benefits methodology. Additionally, the California Public Utilities Commission’s Environmental and Social Justice Action Plan is a Commission policy and operating framework created to serve “as both a commitment to furthering

ESJ principles, as well as an operating framework with which to integrate ESJ considerations throughout the agency’s work.”¹⁸

Consistent with this structure, Gas RD&D projects are selected and evaluated based on their ability to deliver demonstrable safety, reliability, affordability, emissions reduction, and decarbonization enabling benefits to California ratepayers, including communities that experience disproportionate environmental and safety burdens. The ESJ Action Plan recognizes that “some populations in California face higher barriers to access to clean, safe, and affordable utility services,” and directs the Commission to focus on communities that have been underserved.

By prioritizing high impact research that improves methane detection and reduction, advances decarbonization related technologies and system pathways, enhances system integrity, and supports cost effective operations, the Gas RD&D portfolio contributes to improved air quality, reduced hazard exposure, and lower long term system costs. ESJ outcomes are reflected in how and where portfolio benefits accrue and are reinforced through transparent benefit accounting, avoidance of duplicative research, and meaningful stakeholder engagement. This approach is consistent with the ESJ Action Plan’s emphasis on “integrat[ing] equity and access considerations throughout CPUC regulatory activities.”

The table below illustrates how ESJ and DACAG priorities are operationalized across the governing statutory framework provided by Public Utilities Code § 740.1, the EPIC benefits accounting structure, and PG&E’s Gas RD&D benefits framework, demonstrating how equity related considerations translate into concrete research selection, evaluation, and reporting practices.

¹⁸ California Public Utilities Commission, Environmental and Social Justice Action Plan, Version 2.0, adopted April 7, 2022, available at: <https://www.cpuc.ca.gov/esjactionplan>

ESJ / DACAG Priority	PUC §740.1 – What the statute drives us to prioritize	EPIC Uniform Impact Framework – How benefits must be demonstrated	PG&E Gas RD&D Benefits Framework – How we implement in practice
Affordability / Ratepayer Bill Impact	Prioritize high-impact research with a clear line-of-sight to ratepayer benefit; emphasize projects that improve operating efficiency, system performance, and cost control while minimizing investment in low-probability or low-value work.	Require affordability claims to be transparent, attributable, and not overstated, ensuring bill-impact narratives are credible, comparable, and defensible.	Treat affordability as a core benefit category through operational efficiency and cost-reduction metrics (e.g., reduced O&M, avoided capital, avoided gas loss), reported consistently across the portfolio.
Equity / ESJ and Tribal Communities	Advance public-interest objectives (environmental improvement, safety, reliability, cost reduction) in a way that ensures benefits accrue to all ratepayers, including those experiencing disproportionate burdens.	Explicitly align benefits with state equity and ESJ goals, and require stakeholder engagement to support credible benefit framing.	Operationalize equity through portfolio-level measures such as projects and spending in ESJ communities, reliability improvements for DAC customers, and safety benefits inclusive of ESJ communities.
Air Quality and Emissions Where Burdens Are Highest	Support environmental improvement objectives by prioritizing research that reduces emissions and improves conditions in communities facing higher exposure and cumulative impacts.	Require emissions and air-quality outcomes to be measured, attributable, and comparable, avoiding inflated or duplicative benefit claims.	Track GHG reduction and air-quality benefits through validated measurement, monitoring, and reporting approaches that support targeted, cost-effective mitigation.
Public and Worker Safety / Hazard Exposure	Emphasize safety and reliable system operation, with ESJ relevance demonstrated through reduced hazard exposure, fewer disruptive events, and improved system integrity.	Ensure safety benefits are defined consistently and reported transparently so outcomes are credible and comparable across programs.	Measure safety through public and worker hazard-exposure reduction, integrated into integrity, monitoring, and risk-management research areas.
Meaningful Engagement, Transparency, and Accessibility	Engagement expectations are implemented through Commission guidance and program practice rather than statutory text, supporting informed and inclusive decision-making.	Treat transparency and stakeholder engagement as part of benefit credibility—methods and assumptions must be understandable and informed by stakeholder input.	Incorporate engagement through DACAG consultation, public workshops, and outreach to ESJ and Tribal stakeholders, using that input to shape portfolio design and benefit framing.
Non-Duplication and Coordination as an ESJ Protection Mechanism	Avoid unnecessary duplication to protect ratepayer funds and prevent repeated or redundant activity that can burden communities without added value.	Prevent double counting and ensure clear attribution so multiple programs do not claim the same equity or environmental benefit.	Apply portfolio discipline to clarify what RD&D uniquely adds, coordinate where appropriate, and document how projects complement—rather than duplicate—existing efforts.

7.9.3 2025 Milestones

- Continued to engage ENGs in the hiring process to help recruit and retain science, technology, engineering, and mathematics (STEM) talent at national conferences and educational institutions.
- Awarded more than 100 scholarships, totaling nearly \$200,000, through our ERGs and ENGs. The winners received awards ranging from \$1,000 to \$6,000 for exemplary scholastic achievement and community leadership.
- Celebrated 11 Heritage and Celebration months—reflecting the many cultures and populations of our workforce. This included Generations at Work, our most inclusive month celebrating five generations that work at PG&E.
- Recognized coworkers who embody our belonging pillars through annual awards, which honor coworkers for demonstrating inclusive leadership.

- Achieved a 52% emission reduction from the 2015 baseline, which has a meaningful impact on low-income and historically underserved communities, as emissions sources are often concentrated in areas where vulnerable populations live and work. By minimizing leaks, accelerating repair times, and improving emissions monitoring, PG&E not only advances its climate commitments but also improves air quality and public health in the communities most affected by pollution. In addition, by refining emissions reporting frameworks PG&E gets a better understanding of the highest emitting assets so mitigation efforts can be directed accordingly ensuring the greatest impact when introducing technologies that reduce emissions.
- Co-sponsored the largest-ever Tribal Leaders Energy Summit (August 4-6, 2025) at the Estom Yumeka Maidu tribe's Hard Rock Fire Mountain Casino. This event is the only one in the country hosted by investor owned utilities. It brought together leaders from all three California IOUs with representatives of more than 50 Federally-recognized tribes, numerous state agencies, the Department of Energy, and clean energy/EV contractors. Attendees traveled to the nearby Colusa reservation for a tour of its energy plant and microgrid. Tribal guest speakers from across the country shared details on tribal energy sovereignty goals and projects. CALSTART allowed attendees to test drive several electric vehicles, ranging from a street sweeper to a full-sized refuse truck. With more than 300 in attendance, the Summit was a huge success.

7.9.4 Advancing Inclusive Energy Transition

In 2025, PG&E's Gas RD&D program strengthened its commitment to inclusion and belonging by supporting two groundbreaking research initiatives under the CEC grant GFO-24-501, "Paving the Way for California's Gas Transition." During the application process, Gas RD&D provided letters of support to both recipients, helping secure funding for projects that address the unique challenges and opportunities faced by rural, tribal, and diverse communities in California's energy transition.

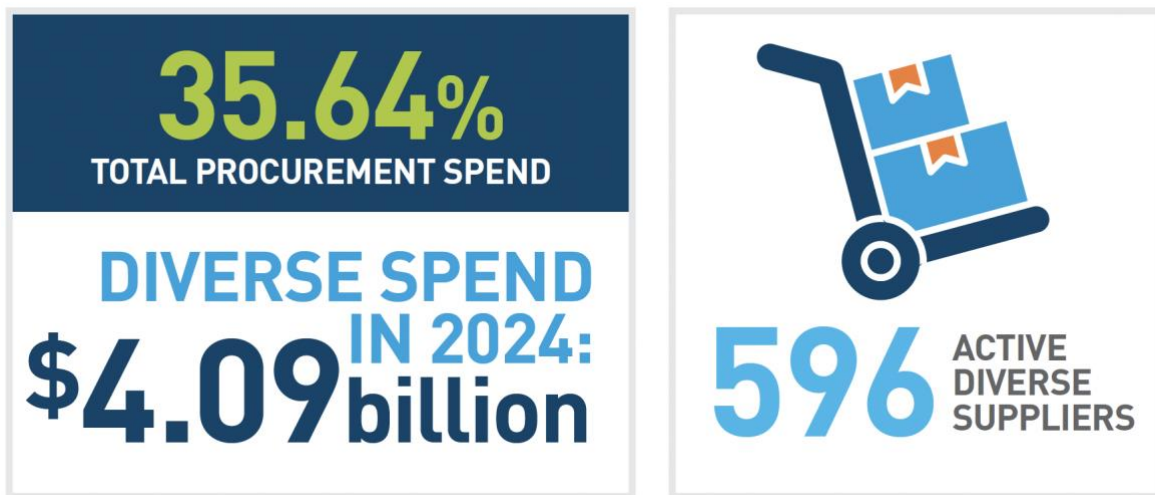
- **Sonoma Clean Power Authority** was awarded a grant for their project, "A Community-based Assessment of Energy Transition Barriers in Rural and Tribal Areas." This research investigates the conversion from fossil gas to electricity or other low-carbon alternatives for residential and commercial applications, focusing on local social practices, energy system conditions, socioeconomic impacts, and supply chain ecosystems. The project will deliver actionable insights into the frictions and opportunities for decarbonization, ensuring that the transition delivers tangible benefits and minimizes negative impacts for rural and tribal communities.
- **Gridworks** received funding for "A Social Feasibility Framework for California's Gas Transition." This project conducts empirical research across the value chain for gas end uses, examining practical decision-making, stakeholder experiences, and workforce conditions. By identifying building and user niches, analyzing supply chain and workforce needs, and studying real-world electrification experiences, Gridworks will provide recommendations to

inform programs, planning, and technology development that support energy affordability, resilience, and safety.

PG&E's Gas RD&D program is proud to have played a pivotal role in supporting these projects, which will help ensure California's energy transition is equitable, locally beneficial, and informed by the lived experiences of diverse communities.

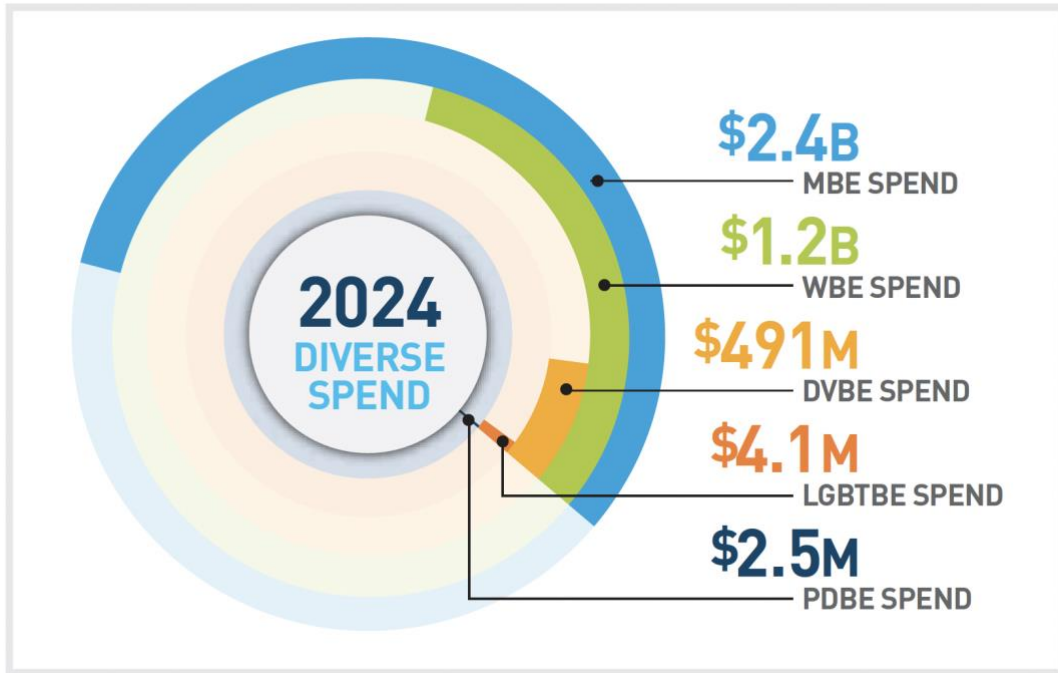
7.9.5 Supplier Diversity

PG&E achieved \$4.09 billion in diversity spend or 35.64% of our net procurement spending in 2024.¹⁹ 2024 marked 19 consecutive years of exceeding the 21.50% CPUC goal and the seventh consecutive year of PG&E achieving over \$3 billion in spending with diverse suppliers.



PG&E is committed to diversity in our supply chain. PG&E's spending with diverse suppliers not only provides a positive economic impact, but also helps the company live our purpose, virtues and stands which include delivering for our hometowns.

¹⁹ Latest year for which PG&E has data.



7.10 Appendix 10—Project Selection Process

7.10.1 PG&E 2024 R&D Strategy Report

To select the projects and technologies that receive funding, Gas RD&D 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 2023 R&D Strategy Report. As a part of this process, PG&E's R&D teams worked closely with company operations staff to identify key technology gaps—including 32 directly related to gas RD&D—that stood in the way of PG&E achieving its objectives for its energy system.

In 2024, PG&E updated the report, detailing 67 problem statements, including 50 that appeared in the 2023 R&D Strategy Report. In addition to updating and refining these 50 problem statements, PG&E also added 17 new problem statements that reflect emerging areas for R&D across its energy system.

The 2024 R&D Strategy Report includes 22 problem statements directly related to Gas RD&D, as well as an additional six related to the role of RNG and clean hydrogen in net-zero energy systems.

To address these problem statements, Gas RD&D has organized its efforts into two main investment themes: Gas System Integrity and Decarbonization. These high-level themes and associated technology gaps serve as the framework that Gas RD&D staff use when identifying potential projects to support, evaluating them, and making final selections.

7.10.2 RD&D Problem Statements

Gas System Integrity Problem Statements	
Eliminating methane emissions from transmission pipeline blowdowns	Increasing accuracy of geohazard risk assessment and monitoring
Enabling corrosion inspections for difficult to access spans	Reducing cost of pipeline integrity inspection and monitoring
Enabling remote meter set corrosion inspections	Reducing cost of well inspection and monitoring
Enhancing scalability of aboveground leak detection and monitoring	Reducing the cost of T&D leak detection
Improving accuracy of well life estimations	Reducing false positives on leak detection surveys
Improving emissions calculation methodologies	Streamlining aboveground leak repairs
Improving pipeline crack assessment technologies	Verifying material properties for existing pipeline cost-effectively
Improving pipeline locating technologies	

Decarbonization Problem Statements	
Eliminating 100% of carbon emissions cost-effectively	Increasing availability of operational data for hydrogen effects on gas system
Eliminating gas appliance combustion emissions	Mitigating hydrogen embrittlement at scale
Enhancing gas quality analysis	Reducing costs of interconnection skids
Ensuring compatibility of customer applications with mixed gas	Reducing uncertainty of storage facility performance for hydrogen blends
Facilitating cost-effective and safe debinding	Understanding risks and impacts from trace RNG chemicals
Identifying cost-effective and scalable sources for RNG production	Understanding safety risks of hydrogen blend leaks
Improving metering accuracy with hydrogen mixtures	

7.10.3 RD&D Project Selection Process

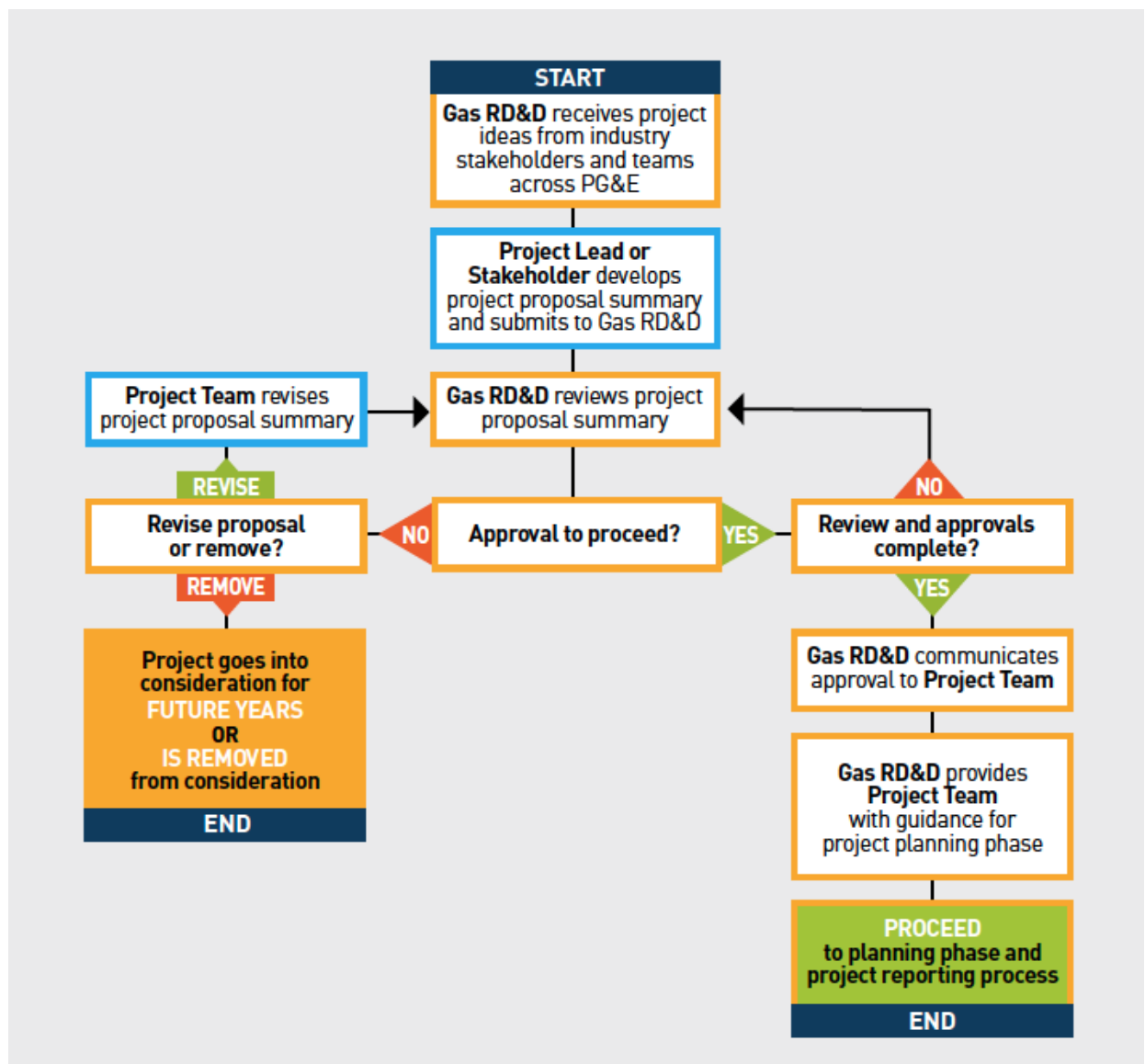
Prior to initiating new projects, the Gas RD&D team leads an ideation effort to define and select ideal projects for its portfolio. Gas RD&D first assesses strategic and industry-related opportunities and gaps. Then, the team develops a plan for ideation in coordination with “top-down” guidance, which includes direction to prioritize projects that address identified technology gaps and contribute to the achievement of California energy policies and company strategies.

Next, Gas RD&D informally reaches out to internal and external stakeholders to gather project ideas in line with the company’s overall TNS and climate strategies. 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 RD&D team may conduct benchmarking, industry outreach, and vetting with internal/external entities.

Once the Gas RD&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 a 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 RD&D staff communicate the approval to the project team.



7.11 Appendix 11: Problem Statements

[see attached spreadsheet]

Appendix 1—Sheet 1 Plan Balance Reporting

[Year] Gas RD&D Plan (AL #X)	Disposition Status Closed or Active	Total Approved Plan Funding Annual + Supplemental	Total Encumbered Plan Funds (in reporting year)	Total Spent Plan Funds (in reporting year)	Total Unspent Plan Funds (in reporting year)	Investment Theme	Initiative Title	Total Approved Initiative Funding Annual + Supplemental	Total Encumbered Plan Funds (in reporting year)	Spent in [Prior Year(s)]	Spent in Reporting Year	Total Spent Initiative Funds (Prior Year(s) + Reporting Year)	Total Encumbered Initiative Funds (in reporting year)	Unspent Initiative Funds (in reporting year)	Pending Funds Intended for approved Initiative	Reallocated Funds To new Initiatives	Justification for Reallocation of Funds	Gas RD&D Plan Funds Reallocated To	Initiative Funds Reallocated To	Funds to be Reallocated To future Initiatives	Funding Expiration Date
2024 Gas RD&D Plan (AL # 5077-G -A)	Closed	0	\$2,570,452	\$1,136,755	\$1,433,697	Gas System Integrity	Advanced Leak Detection and Repair	\$0	\$845,393	\$39,234	\$61,615	\$100,849	\$845,393	\$783,778	\$0	\$0	N/A	Rate Payer	Rate Payer	\$0	12/31/25
						Gas System Integrity	Innovative and Cost-Effective Integrity Management	\$0	\$1,523,907	\$327,844	\$893,988	\$1,221,832	\$1,523,907	\$629,919	\$0	\$0	N/A	Rate Payer	Rate Payer	\$0	12/31/25
						Decarbonization	Clean Fuels Integration	\$0	\$201,152	\$0	\$181,152	\$181,152	\$201,152	\$20,000	\$0	\$0	N/A	Rate Payer	Rate Payer	\$0	12/31/25

Appendix 2—Sheet 2 Project Reporting

[Year] Gas RMD Plan (AL #)	Investment Theme	Initiative Title	Project Title (Agreement #)	Requested Funding from 24 Plan Reauthorization	Approved Initiative Funding	Lead Administrator or Consortium	Status (Active/Completed/Cancelled)	Encumbered Project Funds (Prior Year(s))	Encumbered Project Funds (2025)	Spent in (Prior Year(s))	Spent in Reporting Year (2025)	Spent Project Funds (Prior Year(s) + 2025)	Unspent Project Funds (2025)	Total Match Amount if applicable	Spent Match Amount if applicable	Match Source if applicable	Partners if applicable	Project Need Addressed	Project Solution	Progress Made Previous Years if applicable	Reporting Year Progress (Progress made in 2025 and expectation in 2026)	Delivered Outputs i.e. Study, Pilot	Quantified Impacts To date	Coordination and Pathways to Scale (Technology Readiness Level)
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Advanced Leak Detection and Repair	RD17-054 PH3 Methane Oxidation Catalysts to Replace Flaring	\$4,358	\$0	Consortium	Completed	\$31,451	\$39,155	\$31,451	\$34,358	\$80,809	\$4,797	\$0	N/A	N/A	NYSEARCH	PG&E is still on the road to net-zero. We have made significant progress in reducing emissions, yet further innovation is needed to reduce emissions, improve reliability, and enhance safety.	To help reduce methane emissions by ensuring the solution is effective for PG&E's specific needs	The Project seeks to develop materials that oxidize hydrocarbons at low temperatures via a catalytic process. If a proof-of-concept device could be processed, 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 achievement of relatively small volumes of reduced gas is needed. In Phase 1, Stanford University improved the activity of palladium (Pd) catalysts by ten times relative to commercial Pt-based catalysts and explained the influence of water on catalytic 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 methane catalyst system's performance. Phase 3a focused on large-scale feasibility, combined analysis, unit fabrication, and performance verification. NYSEARCH, the Quarter team, and the Stanford professor who pioneered this research presented a status report in March 2024 that updated the earlier prototype design.	Prototype was finalized in 2023. In 2025, Nysearch will perform a demo of the prototype.	prototype creation	Enhanced Safety, less risk climate impacts related to GHG emissions	TL 1 - Basic principles observed
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Advanced Leak Detection and Repair	Cross compression / pipeline purging demonstration	\$18,218	\$0	Administrator	Completed	\$0	\$17,500	\$0	\$18,218	\$18,218	\$718	\$0	N/A	N/A	ZEAC	PG&E is still on the road to net-zero. We have made significant progress in reducing emissions, yet further innovation is needed to reduce emissions, improve reliability, and enhance safety.	To help reduce methane emissions by confirming it performs as marketed within PG&E's territory	develop a modified to purge pipelines into service with no or minimal venting. In 2023, Field Administrators with operations in 6, and PR proved the purging system and method without reducing purging costs from \$82 to \$30 per mile (approx. 40% cost reduction). Final report and start of vendor engagement for commercialization in 2024.	A demo of the technology was completed in 2023 and is now in questions hands.	demonstration	Enhanced Safety, less risk climate impacts related to GHG emissions	TL 5 - Actual system proven through full operation in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Advanced Leak Detection and Repair	Pilot Eval LFLA Tape on Gas Meters	\$9,305	\$0	Administrator	Completed	\$88,738	\$88,738	\$7,763	\$9,305	\$16,138	\$80,383	\$0	N/A	N/A	GRI	PG&E is still on the road to net-zero. We have made significant progress in reducing emissions, yet further innovation is needed to reduce emissions, improve reliability, and enhance safety.	To help reduce methane emissions by confirming it performs as marketed within PG&E's territory	The LFLA tape solution for replacing non-hazardous meter seal tanks. In 2024 (ph1), we conducted a mini internal pilot of 8 day area controlled meter seals.	A pilot was completed in 2023. A new project that will incorporate the LFLA pilot product in conjunction with the LFLA tape to reduce installation failure will be started in 2026.	pilot	Reduced GHG Emissions: Reducing/eliminating leaks quicker reduces GHG emissions	TL 6 - System prototype demonstration in a relevant environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Advanced Leak Detection and Repair	Demonstration at Los Medanos of continuous emission monitoring at UGS Ph. 2	\$684	\$0	Administrator	Completed	\$0	\$700,000	\$0	\$684	\$684	\$699,316	\$0	N/A	N/A	N/A	New technology are emerging to expedite LDAR	Align with the 26 best practices via continued investigation of new technologies with respect to leak detection and repair	In 2024 (ph 1), the probability of detection was lower than expected due to various factors, including message array placement and the controlled gas release techniques, which will be corrected and incorporated, respectively, into phase 2 to enhance the probability of detection.	A pilot was completed in 2023 that tested the technical aspects of the sensor. The implementation process has started and will be completed in 2025.	pilot	TL 7 - System prototype demonstration in a relevant environment	TL 7 - System prototype demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	Emerging 3D Underground Mapping Field Trial: 1	\$551,039	\$0	Administrator	Completed	\$0	\$550,339	\$0	\$551,039	\$551,039	\$709	\$0	N/A	N/A	Belland Firms Construction	Real-time daily detection	3D Mapping and Real-Time Impact Detection for Underground Assets (continuing and expansion, new: more sites and applications, new technologies/ventures)	The objective of the proposed project is to demonstrate underground mapping technologies and identify any NAD gaps to further advance 3D mapping solutions. The proposed work will conduct structural field visits of three advanced underground survey and mapping technologies, beginning at PG&E's Wilcox Trapping Assembly which will serve as the initial proving ground. Following this baseline evaluation, the technology will be tested across progressively more complex environments such as residential streets, areas with high water tables, dense water coverage, and dense urban corridors. The proposed approach is intended to evaluate the speed and limits of each technology's applications. The study will evaluate each vendor's capabilities across key metrics, including the technology's ability to: 1) accurately measure depth of cover, 2) precisely locate horizontal gas position, 3) differentiate between plastic and steel pipelines, 4) maintain accuracy in congested and varied subsurface conditions. Additional criteria may be added based on member feedback and on the study develops. The outcomes of the proposed project will be a comprehensive final report, including GIS-compatible survey deliverables, and a comparative report summarizing strengths, limitations, and identified gas-utility applications for each technology.	Kick-off meeting completed in Q4 2023. 1st field work with one of the 3 vendors to start in middle March 2026. Expect to complete the project by Q3 2026.	Field survey reports will be delivered after completion	Improved Reliability & Safety: Reduced service interruptions due to pipeline operation incidents and monitored by both frequency and duration	TL 7 - System prototype demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	MS200-007 Phase 2C Four-Inch-with NDE-Sensor Robotic System for the Inspection of Plastic Pipe	\$237,503	\$0	Consortium	Completed	\$0	\$237,503	\$0	\$237,503	\$237,503	\$0	\$0	N/A	N/A	NYSEARCH	Existing inspection methods for small-diameter plastic distribution mains are limited in range, costly to deploy, and can risk damage to the internal pipe surface. These constraints limit PG&E's ability to efficiently assess pipe condition and identify features or anomalies in long segments of unspigable plastic pipe.	Develop and validate a four-inch robotic in-pipe inspection system capable of: 1) non-destructive evaluation and internal visual inspection of plastic distribution mains. The system is designed to efficiently assess pipe condition and identify features or anomalies in long segments of unspigable plastic pipe.	Phase 2C completed the detailed engineering design of the Alpha prototype, including manufacturing Alpha system design package and confirming technical readiness for subsequent fabrication and laboratory testing. Future work beyond Phase 2C would proceed only if authorized under an approved plan and funding cycle.	In 2025, Phase 2C activities were completed, finalizing the Alpha system design package and confirming technical readiness for subsequent fabrication and laboratory testing. Future work beyond Phase 2C would proceed only if authorized under an approved plan and funding cycle.	Detailed engineering design package for the Alpha prototype. Manufacturing drawings and fabrication specifications. Preliminary Beta system design concepts. Design validation documentation	Affordability: Lower engineering repair and remediation costs through improved maintenance strategies	TL 7 - System prototype demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	MS201-011 PH3 Extending Energizing/venting	\$138,545	\$0	Consortium	Completed	\$0	\$138,545	\$0	\$138,545	\$138,545	\$0	\$0	N/A	N/A	NYSEARCH	Corrosion, crack, dent	Unspigable Pipeline Live Inspection	Completed feasibility study on the ability to scale-up the existing Explorer 2026 energizing heat-verifying system to other platforms, greater than 10" and to determine the performance envelope for each of these robots (Explorer 10"14, 16"18, 30"38) in 2024.	Kicked off in Q3/25. Conducted the overall system concept design for new Gas 1 robot. Expect completion in Q4 2026	To deliver preliminary design of the new energizing heat-verifier for the Explorer 16"18 robot.	Affordability: Decreased maintenance costs from compliance efforts and proactive management strategies.	TL 6 - System prototype demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	Field Trial of EPRI's Technology for Inspecting Pipeline Exposed at Sacramento River Bottom	\$80,511	\$0	Administrator	Completed	\$0	\$200,000	\$142,049	\$80,511	\$222,560	\$19,469	\$0	N/A	N/A	EPRI	Corrosion, crack, dent	Non-intrusive (above-ground) assessment of pipeline coating and corrosion integrity (continuing data analytics, possible more sites)	This Project is to address a recent field request for the safety concerns from the California Land Commission on 2 concrete coated unspigable pipelines L-402 & 194-02 exposed at the Sacramento River bottom in that bluff, CA, due to increasing erosion in recent years. The routing via HDD is not feasible geologically. Live pipe inline inspection using bathymetric robot L-82 & 2-286 and/or cut-of-service reformed live tool full inspection (BPM) are very costly and cannot be executed in the near term. Others field trials in the past and could not even perform the coating inspection due to strong water stream. There is a lack of techno-economically viable commercial sonar monitoring solutions that can be implemented now in this new crusting case, especially to serve the advanced offshore inspection solutions for subsea control be implemented due to insufficient water depth in the river. Before the costly high-resolution inline inspection can be conducted, if possible in a few years later, a non-intrusive, low-cost sensing/monitoring solution that can be implemented quickly is really needed to address the safety concerns. After a comprehensive engineering and search for creative solutions, the non-intrusive, low-cost active magnetometry technology (EPRI's Current Magnetometry Inspection Technology) on a boat platform has been identified as the only available techno-economically viable solution that may help be able to address this challenging case. The field trial is to conduct: 1) Non-intrusive inspection & assessment of the pipeline coating and corrosion; 2) 3D mapping of the pipeline with the depth of cover measurement; 3) bending stress assessment. The closure for pipeline L-402 line with available LiDAR data is used as a reference to help evaluate the EPRI's performance. In Q4 2024, the 1st field trial collected some preliminary data on the river portions of the pipeline and was planned due to harsh weather conditions. The preliminary analysis of the collected 3D mapping data of L401 presented a few weeks after above data promising, and further analysis will be conducted in Q1 2025. The proposed feedback will be submitted in the June-July 2025 timeframe when there are no weather concerns, plus higher water levels to avoid possible hit by rock close to the northeast bank. The delivery of the final Project report is expected by Q4 2025. The success of this work will provide PG&E with a techno-economically viable tool-kit solution for inspection/monitoring and assessment of pipeline integrity under challenging water crossing conditions.	Completed the project and the outcome was immediately used to help design the mitigation solution that was implemented to address the emergency case in Q4 2025.	Field report of the field survey plus comparison to the LiDAR data	Affordability: Decreased maintenance costs from compliance efforts and proactive management strategies.	TL 5 - Actual system proven through full operation in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	MS201-006 PH3 Explorer Wireless Range Extender	\$48,304	\$0	Consortium	Completed	\$0	\$48,304	\$0	\$48,304	\$48,304	\$0	\$0	N/A	N/A	NYSEARCH	Corrosion, crack, dent	Unspigable Pipeline Live Inspection	Development of a non-form factor - compliant prototype W- extender system and initial laboratory testing of extended communication range in 2024.	Progress in developing/testing non-form factor compliant system (Hardware testing of Electrical Systems to get the best non-software development/testing to determine the best means of communications). Expect completion in Q2 or Q3 2025.	To deliver an engineering prototype of software-defined radio communication system	Affordability: Decreased maintenance costs from compliance efforts and proactive management strategies.	TL 6 - Actual system qualified through completed limited test and demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	ICAS-G1 Pipeline Integrity Tool Cloud-Based Assessment Software 2025-2028 Extension	\$25,000	\$0	Consortium	Completed	\$0	\$47,245	\$0	\$25,000	\$25,000	\$22,245	\$0	N/A	N/A	PRG	Corrosion, crack, dent	Probabilistic Crack Assessment	Delivery of cloud-based probabilistic assessment framework implementing enhanced PRG MAT model, including core fracture mechanics algorithms and baseline database in 2024.	In 2025, completed 1) Herard CTOD and 1 integral toughness data into a single Excel file 2) 2023 scope on concrete modeling. 2028 scope are in progress stage. If budget is allowed, will support the continuous improvement	Software with added functions	Affordability: Decreased maintenance costs from compliance efforts and proactive management strategies.	TL 5 - Actual system proven through full operation in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	Field Trial of Dresser Coupling Locating Technologies with Rosen LSH-1	\$13,290	\$0	Administrator	Completed	\$0	\$100,000	\$0	\$13,290	\$13,290	\$86,710	\$0	N/A	N/A	Rosen	Corrosion, crack, dent	3D mapping of Pipeline Components	Initial field trial at selected PG&E sites to validate the ability of Rosen LSH technology to detect and locate Dresser couplings.	Completed the 1st record field trial at 2 sites with some locate Dresser couplings.	Report based on field testing	Improved Reliability & Safety: Reduced service interruptions due to pipeline operation incidents and monitored by both frequency and duration	TL 7 - System prototype demonstration in PG&E production environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	MS201-011 PH2 Battery Feasibility Study	\$9,153	\$0	Consortium	Completed	\$0	\$9,153	\$0	\$9,153	\$9,153	\$0	\$0	N/A	N/A	NYSEARCH	Corrosion, crack, dent	Unspigable Pipeline Live Inspection	Completed feasibility study on the ability to scale-up the existing Explorer 2026 energizing heat-verifying system to other platforms, greater than 10" and to determine the performance envelope for each of these robots (Explorer 10"14, 16"18, 30"38) in 2024.	Kicked off in Q3/2025. Started review of the related state-of-the-art battery technologies for the Robotic Robot platform. Expect completion by Q4 2026	To deliver final report detailing the research and evaluation results including a recommended battery in Explorer Robot	Affordability: Decreased maintenance costs from compliance efforts and proactive management strategies.	TL 6 - System prototype demonstration in a relevant environment
2024 Gas RMD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	Edify's x3x Entry Current NDE Tool for Hard Spots	\$2,335	\$0	Administrator	Completed	\$81,000	\$81,000	\$86,232	\$2,335	\$89,167	\$78,085	\$0	N/A	N/A	N/A	Corrosion, crack, dent	In-situ Non-destructive Exam	This work is to develop hard spot screening as part of standard H-form process at PG&E, including rapid detection of pipeline hard spots at integrity inspection sites. The project is conducted by non-destructive exam (NDE) team at PG&E Advanced Technology Service (ATS) Center using the existing Edify's entry Current tools with strong technical support from a PG&E's contractor who has been conducting hard spot inspection and management program for PG&E Transmission Pipeline Integrity Management Program. This work aligns with PG&E's decarbonization goals, as hydrogen can easily cause cracking at hard spots. Detection and characterization of all the hard spots in the pipeline is an important task to make sure the risk of H2 cracking is minimized. By Q4 2024, the Edify's field implementation Procedure draft as well as TO-4810P-18 TWP Direct Examination Procedure draft have been completed and approval for field deployment is expected by Q1 2025 to support the scheduled Li Dig-in Q1 2025.	Completed the project and started field deployment in Q1 2025.	Final report with Procedure of NDE test steps in a PG&E standard H-form Process	Improved Reliability & Safety: Reduced service interruptions due to PG&E maintenance incidents and monitored by both frequency and duration	TL 5 - Actual system proven through full operation in PG&E production environment

Appendix 2—Sheet 2 Project Reporting (Cont.)

[Year] Gas R&MD Plan (AL #)	Investment Theme	Initiative Title	Project Title (Agreement #)	Requested Funding from 24 Plan Reallocatioin	Approved Initiative Funding	Lead Administrator or Consortium	Status (Actual/Completed /Cancelled)	Encumbered Project Funds (Prior Year(s))	Encumbered Project Funds (2025)	Spent in (Prior Year(s))	Spent in Reporting Year (2025)	Spent Project Funds (Prior Year(s) + 2025)	Unspent Project Funds (2025)	Total Match Amount if applicable	Spent Match Amount if applicable	Match Source if applicable	Partners if applicable	Project Need Addressed	Project Solution	Progress Made Previous Years if applicable	Reporting Year Progress (Progress made in 2025 and expectation in 2026)	Delivered Outputs i.e. Study, Pilot	Quantified Impacts To date	Coordination and Pathways to Scale (Technology Readiness Level)
2024 Gas R&MD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	5.24m Field Plot of Real-Time Pipeline Threat Detection System (SPADE System)	\$551	\$0	Consortium	Completed	\$324,627	\$324,627	\$46,625	\$551	\$46,176	\$324,276	\$0	N/A	N/A	SPADE	Third-party damage	3D Mapping and Real-Time Impact Detection for Underground Assets (continuing and expansion, new: more sites and applications, new technologies/equipment)	This Operation Technology Development (OTD) project aims to assess and validate the SPADE technology for detecting and locating mechanical impacts through pilot use at 3 field sites w/ PG&E service territory. This is a pre-commercialization effort following the successful completion of 2023 Pipeline Research Council Internal (PRCI) ROW-CIS technology feasibility study. In addition, the work will increase the precision of locating/mechanical defects from the distance between rectifiers to the distance between engineering test stations. The project kicked off in Q1 2024, completed field site survey in Q3 2024 and shortly afterwards added the extra requirement on US Safety Certification from PG&E Conversion Engineering/Field Operations. By Q4 2024, US Safety Testing was successfully passed, the field installation was completed and the monitoring devices have started the initial remote real-time continuous monitoring configuration testing. The project was delayed for about 6 months due to the addition of US Safety Certification beyond the original project scopes. Now it is targeted for completion in Q4 2025 and possibly will be extended for one more year to further assessment the pilot trial. Upon successful completion of the project, PG&E and other operators will be able to use, maintain, and manage the SPADE systems as state-of-the-art technology for enhancing pipeline reliability, energy deliverability, public safety, and environmental protection – and do it all cost-effectively.	Completed draft final report in Q4 2025. Expected project completion by March 2026. If/when available, will conduct the final phase of developing & field testing the enhanced localization algorithm.	Improved tool hardware & software including user cloud-based real-time monitoring, and final report of field testing/monitoring	Improved Reliability & Safety/Reduced service interruptions due to pipeline operation incidents and monitored by both frequency and duration	RL 9 - Actual system proven through full operation in PG&E production environment
2024 Gas R&MD Plan (AL # 5077 -G-A)	Gas System Integrity	Innovative and Cost-Effective Integrity Management	ADN/Accum Lab Verification Study on Non-Destructive Residual Stress Measurement	\$0	\$0	Consortium	Completed	\$50,000	\$0	\$20,938	\$157	\$71,095	-\$157	\$0	N/A	N/A	Accum	Field-visible non-destructive stress measurement is a nascent technology needed for in-ditch validation of UJ-detectable hard spots. No commercially available quantitative stress measurement solution exists in the North American pipeline industry. Success will benefit the active THP Inspection & Management program.	Conduct state-of-the-art review of in-ditch residual stress technologies and lab verification of indentation-based NDE stress measurement tools for potential deployment as in-ditch validation tools.	Project kicked off in December 2024 to review state-of-the-art in-ditch residual stress technologies and initiate lab verification of indentation-based stress measurement tools. ADN Integrity (an Accum company) began coordinating with technology providers Frotexis (France) and Plastimeter (UK) to test their indentation-based NDE tools for in-ditch steel pipe stress measurement applications.	Lab verification completed in 2025. Final report delivered with comprehensive technology search and indicates testing results. Findings support THP Hard Spot Inspection & Management program for in-ditch validation of UJ reported hard spots.	Final report summarizing state-of-the-art review and subsequent testing of indentation-based NDE stress measurement	Eliminates unnecessary UJ dig for cost savings. Safety: Validates hard spots reducing existing risk for emerging leaks including hydrogen blends.	RL 5 - Actual system proven through full operation in PG&E production environment
2024 Gas R&MD Plan (AL # 5077 -G-A)	Decarbonization	Clean Fuels Integration	C-ZERO Feasibility Study Program	\$105,000	\$0	Consortium	Completed	\$25,182	\$100,000	\$0	\$105,000	\$105,000	\$0	\$0	N/A	N/A	CZERO	Evaluate existing infrastructure and its longevity with hydrogen in use, to understand the impact of hydrogen on the gas system	Integrating low- to zero-carbon fuels like RNG, clean renewable hydrogen, and synthetic methane	This builds on prior efforts in which the project team completed a technology survey of options for distributed methane pyrolysis technology, did a preliminary techno-economic assessment (TEA) over a range of applications, with treatment of the underlying conversion process, hydrogen and uses, and handling of carbon outputs, and performed a screening of distributed pyrolysis solutions with a gas-to-heat/rate approach, including multiple end use and carbon utilization scenarios. In 2024, the phase is the initial evaluation of C-Zero methanol pyrolysis technology, including review of process fundamentals, emissions profile, and potential utility – near-term applications.	N/A; project cancelled in 2025	Comprehensive demo review and performance assessment	Energy Supply & Resiliency: reduced power outage impact by leveraging clean fuels for load balancing	RL 6 - System prototype demonstration in a relevant environment
2024 Gas R&MD Plan (AL # 5077 -G-A)	Decarbonization	Clean Fuels Integration	PD021-005 F2 Odor Detection Study	\$61,152	\$0	Consortium	Completed	\$0	\$61,152	\$0	\$61,152	\$61,152	\$0	\$0	N/A	N/A	HYSEARCH	Increasing availability of operational data for hydrogen effects on the gas system	Integrating low- to zero-carbon fuels like RNG, clean renewable hydrogen, and synthetic methane	Phase 2 in 2024: To build on phase 1, phase 2 will determine the detectability and recognizability of the primary H2 odorant, H2S, and odorant blends in the presence of odorant concentrations of hydrogen greater than 20%. More specifically, Hovrel will investigate the impact of odor detection and recognition in 40%, 60%, 80% blends and pure 100% hydrogen. This will result in 16 test conditions (4 odorants & 4 background) to be completed on multiple trials by each panelist. There will be 16 panelists whose threshold for detection and recognition will enable the creation of a report showing the detection and recognition performance for each odorant blend averaged across the panelists as a function of hydrogen concentration.	As of December 2025, project teams struggled to find a green hydrogen producer who can supply the amount they needed (one supplier deemed the value too little and another supplier couldn't meet the demand) for testing. They will be sourcing the H2 from AirLiquide instead and are expected to begin work in April 2026.	Final report delivery	Safety: safe delivery of clean fuels that enhance air quality	N/A
2024 Gas R&MD Plan (AL # 5077 -G-A)	Decarbonization	Clean Fuels Integration	G4 Insights PCH Process Confirmation Project	\$20,000	\$0	Administrator	Completed	\$40,000	\$40,000	\$0	\$20,000	\$20,000	\$20,000	\$0	N/A	N/A	G4 Insights	RNG has feedstock limitations and trace constituent implications	Integrating low- to zero-carbon fuels like RNG, clean renewable hydrogen, and synthetic methane	The Project leverages the latest iteration of the process testing apparatus built by G4 Insights Inc. (G4) for its \$2.2M AFCCO Gas demonstration project. The Project will benefit from the baseline data and operating experience acquired on the AFCCO project. G4 PyroCatalytic Hydrogenation (PCH) is a proprietary thermochemical process to convert tertiary 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 17-day continuous operation run. During 2023, G4 continued to scale-up PCH Reactor project to achieve 3 tonne/day biomass. G4 also began to focus on government and industry grants to supplement current funding, continued to seek 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. In October 2024, G4 Insights noted issues with the biomass feed, pyrolysis, and conversion substreams, worked on the catalyst regeneration subsystem, and made instrumentation changes.	The Project team intended to collect, analyze, and share data with PG&E in a final report by Q4 2025. However, there will be no deployment, the project ended inconclusive.	Final report with quantitative benefits defined	Energy Storage: Capacity-enhanced energy storage by leveraging clean fuels	RL 5 - Individual component validation in a relevant environment

Problem Statement	Problem Statement (Extended)	Why is this Important?	Current State and Primary Limitations	Desired outcomes from RD&D
Streamlining above ground leak repairs	Current technologies to repair meter set leaks (typically smaller “fuzz” leaks) are time consuming and require a full breakdown of the meter set, at times resulting in a backlog of repairs and contributing to system emissions and operational costs.	Meter set leaks contribute approximately 11% of total baseline emissions from PG&E’s gas system. Many meter sets are added to the repair queue during the course of the year, potentially resulting in a backlog awaiting service at any given time. Existing time-consuming repair technologies impede progress against the backlog and delay addressing associated emissions.	The current state leak repair technologies require shutting off service to the meter and fully breaking down the meter set in order to complete repair. The process can be extremely time consuming to complete and may pose a safety risk to coworkers completing repairs in the field, as well as disrupt customer service. Primary limitations include: The lengthy process to repair meter set leaks requiring temporary service shutoff and full meter set disassembly and reassembly takes an average of 45 minutes Increased potential for necessary return service trips due to the invasive nature of existing repair method	Novel technologies, including AI/ML, to: Shorten leak repair time for meter set leaks on the high and low side Reduce likelihood of need for follow-up service visit Ensure high quality seal that can maintain pressure at 60 psi Allow for subsequent parts replacements and repairs Promote coworker safety while assessing meter set and completing repairs

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Improving pipeline crack assessment technologies	Existing technologies used to locate and size cracks across PG&E’s network of natural gas pipelines are costly, time intensive, and not well suited to all use cases across PG&E’s system, especially for smaller diameter pipes (6" or less), making compliance with regulations to complete crack assessments very costly.	PG&E utilizes crack detection technologies across vast sections of our natural gas transmission network. These periodic safety assessments and maintenance routines, as required by the Pipeline and Hazardous Materials Safety Administration’s (PHMSA) Mega Rule, are intended to identify and assess the size of any cracks in the walls of existing pipes. Completing these surveys with a high degree of accuracy and fidelity is critical to PG&E’s ability to proactively address developing issues and maintain overall system safety; however, no economical solution to perform these assessment processes on small-diameter pipes (6” or less) currently exists. Additionally, given the size and scope of PG&E’s transmission network, identifying methods for completing these inspections in a timely and cost-efficient manner could result in significant O&M savings across the system.	PG&E currently utilizes a range of technologies to perform periodic crack assessment surveys across our 6,500-mile transmission network. PG&E’s system includes 1,271 miles of pipelines with diameters of 6 inches and smaller in our integrity assessment plan. Of these, currently 39 miles have crack threats and are located in medium or high consequence areas. While existing crack assessment methods exist for larger-diameter pipelines, no known time- and cost-effective methods exist for smaller-diameter pipelines. Improving the accuracy, efficiency, and cost profile of these processes for pipelines of all diameters could greatly increase overall system safety while reducing maintenance costs. Primary limitations include: Costly and resource-intensive nature of existing processes for smaller diameter pipes Inability to cost-effectively perform crack assessments on smaller diameter pipes Segments of smaller-diameter pipelines must be taken out of service for crack assessments, sometimes for extended periods	Novel technologies, including AI/ML, to: Locate and size cracks in steel pipes 6” or smaller in diameter Reduce the cost and time associated with performing crack assessments on pipelines of all diameters in compliance with regulation Improve the accuracy of crack detection and sizing Eliminate customer impacts or significantly reduce impact’s scope and duration Identify which anomalies should be assessed through “learning” from Electromagnetic Acoustic Transducer (EMAT) runs

Verifying material properties for existing pipeline cost-effectively	New regulations require that PG&E verify grade and establish populations of pipelines across our existing network of installed underground assets; however, existing field in situ and laboratory-based technologies are costly, disruptive, and can result in excessive GHG emissions.	Requirements for the Pipeline and Hazardous Materials Safety Administration’s 2019 Mega Rule require that PG&E expand the scope of many existing inspection and monitoring processes across our transmission pipeline system and deploy entirely new processes across many of our assets. As part of these new regulations, PG&E must measure or verify and record several different material properties across our pipeline network, including grade, and establish populations of pipelines with similar material properties. While compliance is relatively straightforward for new pipes installed going forward, PG&E has thousands of miles of existing pipeline in place for which these properties must be verified. Completing this effort across the entire system utilizing existing technology would be cost prohibitive and extremely disruptive. This data is critical to PG&E’s management of our assets in a cost-effective manner since it directly feeds into repair decisions and integrity management programs. Further, compliance with this mandate for the installed base of assets requires either (1) the verification of actual laboratory strength and composition measurement, (2) utilizing in-situ nondestructive strength and chemical composition measurements performed opportunistically during an excavation, or (3) updating existing models used to drive maintenance and repair decisions with extremely conservative strength and material toughness values, decreasing estimates of remaining useful life and increasing the likelihood of a repair or pipe replacement.	Currently, in-ditch non-destructive testing methods have started deployment, but the associated field operation efficiency and cost leaves room for further innovation. If required, destructive testing methods are still the only option available to verify material toughness for installed transmission pipelines, which requires excavating and cutting out the existing pipes, and sending them to the lab for testing. Performing this process requires shutting down the impacted section, releases GHG emissions into the atmosphere, and disrupts customers. One alternative option for strength and toughness verification requires the use of conservative values in Fitness for Service calculations in models used to predict the failure behavior of pipes where cracks have been detected. The use of conservative toughness values will drive unnecessary repairs and/or pipe replacements. Primary limitations include: Lack of nondestructive testing methods capable of verifying toughness Costly and resource intensive nature of existing process Lack of accurate, repeatable and highly efficient in-line testing methods Environmental and customer impacts inherent to destructive testing methods	Novel technologies, including AI/ML, to: Verify strength/grade and establish different populations of pipeline material types using in-line methods Verify populations of pipe within PG&E’s existing pipeline network using in-line methods Evaluate material toughness for existing pipes via nondestructive methods that are accurate, repeatable, and reliable Significantly reduce costs and timelines associated with verification process Avoid negative environmental and customer impacts
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Reducing cost of well inspection and monitoring	Current technologies for required periodic inspections and continuous monitoring of storage wells are very costly (up to \$3M per well for in-line methods), creating a large cost burden to maintain compliance with current regulations.	Well intervention activities to perform conventional casing inspections introduce risk to our operations, often imposing damage to the wells being inspected and reducing reliability with the need to temporarily take wells out of service. These methods are also costly, ranging up to \$3M per well. Current regulations require performing well interventions frequently if an alternative frequency is not approved. Continuous monitoring solutions that could help reduce the risk of these more intensive inspections are not presently cost-effective and/or technically mature enough to deploy. Identifying more cost-effective and technically mature options for meeting these requirements could yield considerable savings across the system.	PG&E currently utilizes various technologies to inspect the condition of the steel casings that serve as a protective barrier for the well. Given that these steel casings may extend more than a mile below ground, gathering comprehensive data for the full expanse of the system is operationally impactful and costly. High resolution in-line technologies are incredibly costly. The current process requires that operations be shut down and tubing be pulled out to complete inspections. Medium-resolution in-line thru-tubing inspection can avoid the extremely costly tubing pull-out, though sacrifices some degree of accuracy and still requires operations be shut down. PG&E is exploring continuous monitoring solutions, such as distributed fiber optic sensors, to gather and transmit data on an ongoing basis to provide a better real-time understanding of well conditions. While this technology has the potential to reduce the necessary frequency of more intensive in-line inspections, installation and real-time monitoring costs of current monitoring solutions are cost-prohibitive to utilization at scale at the current stage. Primary limitations include: High costs of high-resolution in-line inspection technologies Accuracy and performance gaps associated with less costly medium-resolution thru-tubing inspection technologies, relative to existing high-resolution options Installation and real-time monitoring costs for fiber optic sensor technologies • Need to shut down well operations and/or pull-out tubing to complete in-line inspections	Novel technologies, including AI/ML, to: Cost-effectively meet regulatory requirements for periodic in-line inspections that are at least as accurate as existing methods Reduce the installation and real-time monitoring costs of continuous monitoring solutions, while ensuring high-quality, continuous data transmission

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Reducing the cost of T&D leak detection	Current leak detection methods rely heavily on manual effort to complete surveys (on foot or by vehicle/air) and to identify issues and anomalies, resulting in high costs and frequent truck rolls. Any technologies that can detect T&D leaks remotely, cost-effectively, and accurately would reduce both monitoring cost and system risk.	PG&E completes leak detection surveys of transmission assets semi-annually and of distribution assets every three years. PG&E uses a variety of methods to complete these surveys, ultimately relying on foot patrols in many areas. Given the size of PG&E’s transmission (nearly 7,000 miles) and distribution systems (42,000 miles), completing these leak surveys requires a massive mobilization of resources and adds significant cost to operating the system.	PG&E currently performs leak surveys on transmission assets via helicopter and foot patrol and distribution assets via a combination of foot patrols and on-road vehicles. While helicopters and vehicles quicken the process, completing these surveys over thousands of miles of pipeline requires a tremendous number of resources. Further, additional foot patrol resources must be deployed to any areas where leak indications were identified during initial surveys. Primary limitations include: Costliness and labor-intensiveness of current initial survey methods Inability to determine the exact location of below ground leaks with current instruments, which causes time consuming leak investigations to grade and later repair	Novel technologies, including AI/ML, to: Survey leaks with advanced tools that reduce costs and foot patrols necessary to maintain compliance with leak detection survey regulatory requirements, whether the technology is handheld, aerial, or Advanced Mobile Leak Detection (AMLDD) Increase the accuracy and reliability of leak detection technologies to direct deeper inspection efforts more precisely
Reducing false positives on leak detection surveys	False positives are common when conducting leak surveys on both transmission and distribution assets due to difficulty in distinguishing between methane leaks from the gas system and naturally occurring methane, resulting in the unnecessary deployment of resources.	Leak detection surveys of PG&E’s expansive network of transmission and distribution pipelines are resource-intensive processes that must be completed regularly to maintain the safety of the system. Any issues detected during these initial surveys must be investigated more deeply following initial inspection, requiring the deployment of additional resources (e.g., truck rolls) across the system. Given the scale of these efforts, it is critical that the information gathered during inspection surveys is as accurate as possible in order to most effectively direct PG&E’s resources for addressing actual safety concerns.	Current leak detection technologies utilized during foot patrol surveys are not capable of adequately distinguishing between naturally occurring methane and methane emitted from gas pipelines. As a result, these technologies may falsely identify a pipeline leak if methane from other naturally occurring sources (e.g., cows, wastewater treatment, etc.) is detected in the vicinity of the survey. Primary limitations include: Inability to distinguish between methane released from the gas system as result of a leak and methane from other naturally occurring sources Unnecessary deployment of additional resources to complete deeper field inspections and surveys resulting from inaccurate readings	Novel technologies, including AI/ML, to: Enable personnel completing initial foot patrol surveys to accurately distinguish between methane leaks and naturally occurring methane (e.g., based on the presence of other trace gasses only present in pipelines) Otherwise reduce false positives that result in the needless deployment of additional survey and inspection resources

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Enabling corrosion inspections for difficult to access spans	Intentionally exposed pipeline spans occur in remote locations where the pipeline needs to exit the ground. These can be both difficult and time consuming to access and potentially dangerous to inspect. The spans can go out of compliance due to the difficulty in both inspection and remediation.	PG&E’s gas transmission system includes approximately 1,000 exposed spans that must be inspected for signs of corrosion every three years. Given that many of these exposed spans are located in remote and difficult-to-access areas (often at water crossings and wash-outs), completing these inspections can be time- consuming, costly, and potentially dangerous for inspectors operating in hazardous conditions on-site.	Currently, PG&E coworkers travel to exposed spans, often in remote locations, to visually inspect and assess corrosion and coating conditions. These visits are completed every three years on each span, resulting in approximately 300 inspections per year. Primary limitations include: Difficulties and safety concerns traveling to and accessing exposed spans in remote locations and in difficult or even hazardous terrain Necessity for PG&E coworkers to contend with hazardous conditions in order to reach and visually inspect exposed spans High-cost burden associated with maintaining compliance for inspection requirements	Novel technologies, including AI/ML, to: Reduce costs associated with corrosion inspections on exposed spans Limit the need for coworkers to physically travel to remote sites to perform inspections, thereby reducing safety concerns Shorten timelines associated with completing corrosion inspections, particularly in challenging terrain
Improving accuracy of well life estimations	Current technologies and methodologies to estimate the safe and useful remaining life of existing wells are unable to produce highly accurate and reliable estimates, which can result in the early retirement of useful wells and the incurrence of substantial avoidable cost to construct new wells.	PG&E and other utilities across the industry periodically receive requests from regulators to provide information on the remaining safe and useful life of their existing storage wells. The current understanding of the key determinants of a well’s lifetime are not well understood, especially in the absence of any identifiable defects, limiting the ability of utilities to accurately forecast remaining useful life of existing wells. Developing the ability to understand and more accurately predict the remaining life of existing wells would enable utilities to provide better information to regulators, avoid early retirement of existing wells, and more optimally manage their portfolio of storage assets given better visibility into the remaining lifespans of individual wells.	There is limited understanding across the industry of how to accurately estimate the remaining useful life of a storage well, especially if there are no observable defects that can serve as the basis for forward-looking predictions of degradation. Primary limitations include: Lack of baseline understanding of the most critical factors in determining the useful remaining life of a well Difficulty modeling how various factors or conditions may evolve over time and/or interact with each other to produce different outcomes for existing wells Heterogeneity of well depths, locations, geological formations, etc. make the development of a generalizable model difficult	Novel technologies, including AI/ML, to: Identify the critical determinants of well longevity Model how those critical determinants will evolve over time, taking into consideration well-specific characteristics, use profile, etc., and how those changes and interaction effects will impact the longevity of the well Provide better substantiated estimates of remaining useful life for existing wells

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Increasing accuracy of geohazard risk assessment and monitoring	There is a lack of available technologies to enable the accurate assessment and cost- effective monitoring of pipeline assets subject to geohazards.	Significant portions of PG&E’s gas pipelines are subject to enhanced geohazard risk due to unique geological and topographical features that naturally occur across our service area. While these assets are subject to annual inspection cycles, as well as emergency inspections in cases of detectable increases in risk, 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. As a result, PG&E invests significant resources in completing annual inspections and emergency inspections but is unable to effectively mitigate geohazard risks off-cycle, as evolving geological conditions can be difficult to monitor and their impacts difficult to predict.	There are many water-crossings across PG&E’s gas system that are subject to annual geohazard risk surveys, which are completed via visual inspection during on-site visits. Additionally, in the event of a detectable geohazard event (e.g., large landslide, earthquake, etc.), PG&E personnel make emergency, off-cycle site visits to assess the condition of the asset and its surrounding environment. In some cases, frequent return visits are made in the aftermath of an event to continue to monitor evolving risks. Each of these geohazard projects can cost well into the millions of dollars. Emerging threats resulting from subtler or more gradual changes to the local topography can be more difficult to proactively identify before a problem develops. PG&E has tested multiple methods of remote monitoring, including satellite imagery and strain attachments, but more research and testing is needed to improve the accuracy, reliability, and costs of these methods. Primary limitations include: Lack of comprehensive visibility into the integrity of assets subject to enhanced geohazard risk between periodic inspection cycles Resource intensive nature of existing geohazard inspection processes Inability to more effectively target geohazard risk resources given limited understanding of how assets tolerate different geohazards	Novel technologies, including AI/ML, to: Remotely identify, track, and monitor geohazards affecting pipeline assets 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 Increase ability to optimize the deployment of geohazard monitoring resources

Problem Statement	Problem Statement (Extended)	Why is this Important?	Current State and Primary Limitations	Desired outcomes from RD&D
Improving pipeline locating technologies	Best-in-class technologies are unable to cost effectively locate pipelines and other third- party utilities under the full spectrum of conditions relevant to PG&E’s system. Even advanced options, such as ground penetrating radar, are limited in their usefulness based on the burial depth of pipes and surrounding soil conditions, sometimes necessitating the disassembly of nearby meter sets to use costly in-line technologies.	PG&E is required to locate and mark existing pipelines whenever subsurface work (i.e., digging) is conducted near our assets. The process must be completed frequently across the system and can be time-consuming and costly depending on the burial depth, soil conditions, and congestion of the underground area being mapped. While superior technologies to complete this process can provide significant efficiency gains, the accuracy of these locating and marking processes are critical to avoid utility strikes, which can pose considerable safety risks.	PG&E utilizes a range of technologies to complete subsurface surveys today, including electromagnetic scanning and ground penetrating radar (GPR). In cases where these best-in-class methods are unable to provide sufficiently accurate readings, meter sets may be disassembled to insert in-line locating devices into the pipeline. Primary limitations include: High cost-and resource-intensive approach in order to provide most accurate readings Difficulty obtaining accurate information across the full range of conditions locators encounter across PG&E’s system, notably at depths greater than 9–10 feet, in soil with high moisture content, and non-metallic pipelines (e.g., MDPE) Inability to accurately assess the location of assets on the vertical plane (i.e., pipeline depth) Inability to distinguish between multiple facilities (e.g., which pipelines are owned by PG&E and which assets are still in service)	Novel technologies, including AI/ML, to: Quickly, accurately, and/or cost-effectively provide intelligence on subterranean assets, including MDPE and other non-metallic materials Enable fast and accurate readings across a wider range of circumstances with little need for advanced interpretive capabilities to understand output from the locating device
Enabling remote meter set corrosion inspections	Current methods for completing mandatory meter set inspections for corrosion are performed via in-person visual inspection every three years, requiring a large investment of manual effort.	PG&E currently conducts visual inspections for atmospheric corrosion of meter sets every three years; however, this visual inspection is time consuming, costly, and requires significant labor to complete. Alternative techniques for carrying out meter set corrosion inspections have the potential to both reduce costs and enhance safety and reliability by more effectively and proactively addressing atmospheric corrosion.	PG&E’s inspection of atmospheric corrosion of meter sets involves a PG&E technician traveling to all customer sites and visually inspecting meter sets every three years. Primary limitations include: Costly and inefficient current meter set corrosion inspection techniques Challenges accessing customer premises	Novel technologies, including AI/ML, to: • Reduce the necessity of in-person, visual inspections of meter sets Monitor meter sets remotely or proactively detect and alert on corrosion Introduce situational awareness at the meter set to alert when elevated corrosion risk is detected or automatically shut off if failure is imminent

Problem Statement	Problem Statement (Extended)	Why is this Important?	Current State and Primary Limitations	Desired outcomes from RD&D
Reducing cost of pipeline integrity inspection and monitoring	The current inspection practice is mainly based on intrusive, costly in-line and/or direct assessment technologies, which are not techno-economically suited for periodic inspection and monitoring in the long run, especially with the high percentage of unpiggable or difficult-to-inspect pipelines at PG&E.	Current regulations require that in-line inspections or direct assessments or pressure tests be completed as frequently as every 7 years. Maintaining compliance with these requirements is costly and even disruptive if the operations must be shut down in order to complete the process. In addition, lack of cost-effective monitoring that can be frequently implemented is still a safety concern. Identifying more cost-effective and field-proven options for meeting these requirements could yield considerable savings while enhancing safety across the system.	Currently, intrusive or disruptive methods are the only options available to conduct high-resolution integrity assessment of installed pipelines. This approach requires excavation, line upgrades, and/or out-of-service for intensive inspection and also is not a viable monitoring solution, especially for unpiggable or difficult-to-inspect pipelines. Non-intrusive or less-intrusive inspection and/or monitoring solutions that could complement and help reduce the frequency of these intrusive inspections, or eliminate pressure tests, and/or further improve safety are not presently fully ready or field validated to deploy. Additionally, electrical interference (primarily in the Bay Area) due to overhead utility lines, BART, and other transit systems create signals that interfere with traditional Indirect Inspection tools (IIT). Some research is being performed to improve the quality of IIT surveys within the Bay Area and other vicinities affected by DC and other electric interferences. Primary limitations include: The need to upgrade pipelines, shut down impacted sections, releasing GHG emissions into the atmosphere and/or disrupting customers. Electromagnetic interference makes it challenging to obtain accurate measurements in ECDA/SCCDA assessments	Novel technologies, including AI/ML, to: Non-destructively inspect and/or monitor existing pipelines via non-intrusive or less-intrusive methods that are repeatable, reliable, and of sufficient usable accuracy to at least complement the current practice Significantly reduce costs and timelines associated with inspection, monitoring, and integrity assessment processes Reduce the deployment costs of continuous or on-demand monitoring solutions, while ensuring high quality and ongoing data transmission Avoid negative environmental and customer impacts Eliminate and/or minimize the impact of electrical interference caused by BART and other electromagnetic sources for “Indirect Inspection” surveys in ECDA/ SCCDA assessments

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Understanding risks and impacts from trace RNG chemicals	There is an incomplete understanding of (1) the exact chemical composition of RNG, especially trace chemicals, and (2) the impacts of these various trace chemicals on health and safety, gas system components, and end use applications. This lack of certainty limits the ability to adequately adapt the system to minimize the effects of these impacts.	Currently, the chemical properties of RNG are not universally well understood as different feedstocks result in variations in composition. The incomplete understanding of the chemical composition of RNG creates multiple potential risks for increased adoption, including potential negative effects to human health and the environment, compromised pipeline integrity, and negative impacts to gas system components creating operational issues and customer end use impacts. In order for PG&E to expand our procurement of RNG to decarbonize the gas system, these risks must be better understood so that they can be effectively managed or avoided altogether.	The industry’s current understanding of the varying trace constituents present in RNG based on different feedstocks is incomplete. Further, the potential impacts of these constituents and how those impacts differ based on variable concentrations is limited. Potential areas of impact may include gas system operations and longevity, environmental considerations, and human health and safety.	Identification and deeper understanding of all chemical components of RNG and how they vary by feedstock Determination of long-term impacts and effects of trace constituents across a wide range of dimensions, including environment, human health, system components, etc.

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Increasing availability of operational data for hydrogen effects on gas system	Although studies of the chemical and physical properties of hydrogen-methane blends in controlled lab settings are informative, understanding how these mixtures behave in the pipeline system is critical to enabling decarbonization. PG&E lacks operational data on how factors such as temperature, humidity, pressure and volume fluctuations due to changing supply and demand dynamics, and true gas quality representations affect how hydrogen blends perform in an actual pipeline setting.	Laboratory studies of the effects of hydrogen on natural gas system components are critical to building a foundational understanding of how our system may tolerate the introduction of increasing partial pressures of hydrogen. However, data collected in small-scale and controlled environments are unable to capture how the full range of environmental and system conditions present in a true operational setting may alter the range of expected outcomes. Several field demonstrations are presently underway, but the focus is largely on the low-pressure gas distribution networks and the scale of these types of field demonstrations must be greatly expanded in order to provide a dataset of sufficient size to begin to inform our operational understanding of the impacts of hydrogen blending on the gas system. To address this gap, PG&E announced our plans to build a gas transmission hydrogen blending testing facility, known as Hydrogen to Infinity, with an estimated cost of \$94M. The goal of the facility is to provide the information necessary to support a future hydrogen injection standard for blending into our transmission and distribution networks and share this information with national and international gas utilities, industry, and research associations.	Currently, PG&E has analytical data from computational and laboratory studies, providing a theoretical basis for understanding the science and impacts of hydrogen’s properties and phenomena. Primary limitations include: Lack of field studies and demonstrations in a high-pressure gas transmission system and at higher hydrogen partial pressures that capture the effects of fluctuations in a broad range of critical variables that may impact real, operational systems over time Lack of real-world data to analyze gas properties, dynamics, composition, and quality under different blends and supply and demand conditions	Engagement with stakeholders and partners in industry and government to gain financial support and offset the cost of design, construction, and testing of real-world hydrogen blending effects Gas transmission field demonstrations to provide operational data from real-life environments to inform a future hydrogen injection standard for California

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Mitigating hydrogen embrittlement at scale	Introducing hydrogen to the gas supply may cause pipelines, especially steel, to become embrittled, decreasing their structural integrity and increasing susceptibility to cracks, ultimately leading to higher O&M costs and posing major safety risks. Various materials and methods exist for mitigating embrittlement, but these can be costly at scale.	PG&E is exploring the introduction of hydrogen into its existing gas infrastructure and assets in an effort to decarbonize the gas system. Hydrogen’s chemical behavior, however, varies greatly from that of methane and must be understood to avoid the safety risks and increased O&M costs. Hydrogen can easily migrate into the crystal structure of most metals; therefore, steel pipes, particularly steel welds, used for transmission can suffer from embrittlement after continuous exposure to hydrogen. To ensure that pipelines retain their structural integrity, any pipe transporting hydrogen (or any metal exposed to hydrogen) must be resistant to cracking. The embrittlement of pipelines and other issues relating to structural integrity pose major safety risks and associated O&M costs, thus must be addressed at scale for existing pipes before hydrogen can be introduced to the gas system.	While the phenomenon of hydrogen embrittlement is well understood in theory, gaps in knowledge remain around the impacts on pipeline integrity from variables including hydrogen blend rate, pressure and pressure cycling, temperature, and other conditions. Current solutions to avoid pipeline embrittlement with the addition of hydrogen exist; however, they are expensive, time consuming, and difficult to implement at scale. While there are new pipeline technologies on the market that are not susceptible to embrittlement, such as fiber reinforced polymer (FRP) pipelines, these solutions do not allow PG&E to reuse existing infrastructure and avoid stranded assets. Additionally, recent technological advancements include pipeline crawling mechanisms that can be used to apply coatings to the inside of existing pipelines but have yet to be commercialized specifically for anti-embrittlement purposes. Primary limitations include: Limited understanding of how different levels of hydrogen blending may affect levels of observed embrittlement over time High capital costs for deployment of existing solutions to hydrogen embrittlement for existing pipes	Cost effective and scalable solution to protect existing pipelines from embrittlement Research to determine the relationship between hydrogen partial pressure and structural effects of embrittlement Research to investigate how other gas additives could prevent hydrogen from migrating into crystal structure of metals and avoid embrittlement A cost effective and scalable pipeline that is embrittlement-resistant for deployment in new projects

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Understanding safety risks of hydrogen blend leaks	Different blends of hydrogen-methane will have different safety-related properties (e.g., explosivity, flammability, dispersion, etc.) that may require adjustments to existing leak detection methods and safety protocols in order to ensure personnel and customer safety; however, the particular nuances of these qualities are not well understood.	As PG&E prepares to introduce blending of hydrogen into natural gas pipelines to decarbonize the gas system, safety risks associated with different blend rates must be investigated and understood. Based on the partial pressure of the hydrogen in the blend, various mixtures of hydrogen and natural gas will have different safety-related properties, such as explosivity, dispersion behavior, ignition, and flammability. Effectiveness of odorants is also of concern for detecting and repairing leaks and failures, particularly those in residential or commercial end-use buildings. These risks must be defined and understood in order to maximize system readiness for hydrogen blending and to determine whether safety protocols and equipment need to be modified for various gaseous mixtures.	The explosive characteristics of hydrogen mixing in natural gas are fairly well understood for a range of blend percentages up to 50%; however, further modeling may be beneficial for evaluating safety zone classifications for the full range of hydrogen blending and for defining the blending parameters. The industry’s understanding of other safety related properties, including the effectiveness of odorants in different blends needs to be more fully developed before introducing blending at scale across the system. Primary limitations include: Incomplete understanding of how varying partial pressures of hydrogen affect explosivity Additional risk associated with the largely invisible nature of hydrogen flames to the human eye Lack of sufficient data across a range of other safety parameters, including odorant effectiveness, dispersion behavior, etc., to inform updates to safety protocols	Deeper understanding of safe hydrogen blend rates to mitigate safety risks and any associated impacts to customers or coworkers Determination whether the safety zones for natural gas need to be modified for a mixture of hydrogen, RNG, and natural gas Investigation of effectiveness and safety of odorants for detecting and repairing leaks of various gaseous mixtures

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Improving metering accuracy with hydrogen mixtures	Hydrogen blending changes the physical properties of gas, such as pressure, flow rates, and calorific value, which may require changes to existing metering equipment to maintain proper operation, accounting, and billing across the gas system; however, the precise impacts of these changes are unknown.	Increased hydrogen blending in the natural gas system will alter the physical properties of the gaseous mixture, potentially necessitating updates in current metering systems and technology to ensure accurate measurements of gas composition and flow rates. Measuring the calorific value of natural gas serves several purposes, including determining the transaction value of natural gas, quality control based on heating value standards for the injection of hydrogen, controlling plant combustion equipment for stable operation, and controlling air-fuel ratios for gas turbine generators that require precise combustion control. Technology that accurately measures hydrogen flow will be key to governing and predicting gas behavior and properties in the pipeline system.	While technology to accurately meter hydrogen exists, further research, development, and validation is required to provide more rigorous and systematic understanding of the impacts of hydrogen blending at various levels on a wide range of equipment and metering components. Initial lab research has provided some initial insight; however, current state understanding of how actual operational conditions may affect these findings is also limited. Primary limitations include: The effectiveness of analyzers measuring the calorific value of blended gas above 10% hydrogen by volume Effects of hydrogen blending across different meter types, at different hydrogen blend levels, and under conditions better reflecting actual operations Impacts to durability of various system components, including adhesives, lubricants, and fasteners How impacts vary across different industrial end uses and equipment components	Better understanding of the properties associated with different blends of hydrogen and natural gas Additional research to test, model, and assess blending and injection methods for optimal homogeneity, O&M, and cost Accurate metering equipment compatible with various hydrogen and natural gas mixtures Standardized method to test metering equipment for accuracy when measuring hydrogen and hydrogen blended gas flow rates

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Ensuring compatibility of customer applications with mixed gas	Existing customer end uses are designed for conventional natural gas, and the effects of introducing gas blends on the safety, efficiency, and reliability of their operation is unknown, introducing a significant barrier to meaningful decarbonization of the gas system.	In order to introduce hydrogen and other renewable gasses into the gas system, it is crucial to understand the impacts on existing equipment, appliances, and industrial processes that use natural gas as fuel or feedstock. Numerous appliances, such as cookers, ovens, stovetops, boilers, and furnaces, were designed to run on conventional natural gas, and their functionality may be limited if they are fueled by mixed gas. Additionally, many industrial processes rely on very specialized equipment that may be impacted with the introduction of gas blends. The lack of mixed gas compatibility for gas-powered industrial, residential, and commercial equipment presents a significant bottleneck for the decarbonization of the gas system, and research must be done to best prepare existing and future equipment for the transition.	Currently, PG&E is focused on developing customer appliances and industrial processes that are compatible with low blends of hydrogen (up to 30%) eventually moving to 100%. These projects include the development of appliances and gas-fired heat pumps that can operate with varying levels of natural gas and hydrogen while eliminating common problems such as flash-back. PG&E is also investigating the use of hydrogen in industrial burners and developing burners that are fuel flexible; however, these technologies may be decades away from being commercialized in residential settings. Primary limitations include: Incomplete understanding of how hydrogen blending at different levels affects the full range of impacted customer ends uses Lack of commercially available customer end uses designed for hydrogen blend compatibility Lack of commercially available options to retrofit the range of existing end uses and appliances for hydrogen blend compatibility	Better understanding of the effects of mixed gas on existing appliances Research on the adaptation of residential and commercial appliances for use with hydrogen-methane blends, particularly for hard to electrify customer equipment Investigate how industrial equipment and processes can safely and effectively be adapted to run on gaseous mixtures

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Reducing uncertainty of storage facility performance for hydrogen blends	Hydrogen blends will need to be stored in existing underground gas facilities; however, much is unknown about how these facilities will perform with the introduction of hydrogen, including sealability, microbial response, and overall well integrity.	Hydrogen must be stored across seasons in order to balance the load of the electric and gas systems and maintain seasonal price stability. Given the high costs of new underground storage facilities, the ability to store hydrogen in existing underground storage wells (e.g., depleted gas reservoirs) will be critical to cost-effectively decarbonizing the gas system. The performance of existing storage facilities in terms of integrity, sealability, and losses through various system components is largely unknown. Understanding these performance impacts, and the ability to mitigate any negative consequences identified, will be critical to enabling the decarbonization of the gas system.	There is a limited body of existing literature on the impacts of hydrogen on underground storage facilities; however, the limited nature of these studies does not provide a sufficiently comprehensive understanding of possible outcomes. PG&E is engaging in a small number of studies to help broaden this knowledge base. Primary limitations include: Lack of comprehensive understanding of how the introduction of hydrogen into existing underground storage facilities impacts sealability, well integrity, and microbial response Inability to accurately anticipate losses over time through cap rock or storage formations or threaded connections in the well bore	Identification of components, interaction effects, and operational risks that pose the largest challenges to seasonal storage of hydrogen Field demonstrations to provide operational data from real-life environments on the impacts of hydrogen on underground storage facilities (e.g., depleted gas reservoirs)
Eliminating gas appliance combustion emissions	Emerging regulations will require the elimination of oxides of nitrogen (NOx) emissions from gas appliances by 2030 across parts of California. Solutions that will enable compliance for existing end uses powered by natural gas or future gaseous mixtures are not widely commercially available.	Methane and NOx emissions from gas appliances, particularly cookers, stovetops, and ovens can lead to negative climate and human health impacts and pose a potential risk to customer trust in the gas system. Eliminating NOx emissions from gas-based end uses is critical to ensuring compliance with recently approved regulation issued by the Bay Area Air Quality Management District that will take effect by 2030.	Existing appliances emit NOx when burning natural gas, RNG, and/or hydrogen. Based on new regulations that will take effect in the latter part of this decade, these emissions must be eliminated across a range of customer appliances. Primary limitations include: Inability for existing end uses and appliances covered by new regulations to meet zero-NOx standard Limited existing research into gaseous mixture end uses that would comply with zero-NOx standard	Novel technologies, including AI/ML, to: Retrofit of existing appliances to enable compliance with zero-NOx standard Comprehensive research into the sources and impacts of natural gas appliance emissions Research into zero-NOx emissions designs for clean fuels compatible appliances

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Facilitating cost-effective and safe debblending	Various end use applications may require pure natural gas or hydrogen to operate, requiring the debblending of methane-hydrogen mixtures at the point of demand. Technologies to facilitate this process are not commercially available.	The future pipeline blend of gases may not be suitable for all existing end use applications, as some may instead require pure hydrogen or methane to operate. For example, hydrogen ignites at a wider range of temperatures than methane, which may impact the safety and reliability of some gas-based equipment operated by customers. Before hydrogen blending can be introduced to the gas supply, separation technologies must be deployed at these sites where debblending is necessary to provide pure hydrogen or methane to ensure compatibility with end uses applications.	PG&E does not currently have solutions to support debblending at customer sites that meets desired technical and economic requirements. Primary limitations include: Lack of cost-effective debblending technologies scalable across PG&E’s gas system	Novel technologies, including AI/ML, to: Cost-effectively separate hydrogen-methane blends into component streams at the point of demand with a small physical footprint Debblending even at very low concentrations of hydrogen

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Enhancing gas quality analysis	Gas quality analysis is a key parameter for all gas operators. However, the analytical solutions provided by suppliers are not always consistent with the needs of the gas industry, particularly for RNG analysis, which has additional constituents not typically found in traditional natural gas.	Gas quality analysis is crucial for ensuring that gas meets the specific quality standard needed for health, safety, integrity, and environmental compliance. It is also crucial for pipeline integrity, pipeline operations, and effective performance of end user equipment.	Gas analyzers continuously monitor and measure concentrations of natural gas constituents and the BTU value throughout the system. Renewable Natural Gas (RNG) contains several additional constituents. The constituents of concern (COC) are included in the RNG tariff (GR 29) Table 1. Additional on-line analyzers, as well as typical gas chromatograph (gas analyzers), are located on the RNG interconnection facility. These analyzers continuously measure H2S, H2O, O2, CO2, BTU, and are programmed to shut-in the flow of RNG into PG&E’s pipeline system should an exceedance event occur. PG&E’s existing natural gas analyzers are installed at various locations on the system. The data collected by the analyzers is monitored by gas control to ensure that the quality of natural gas meets the tariffs (e.g., Gas Rule 21) requirements. Primary limitations include: Number of gas parameters assessed in a single unit, portability, and total cost of ownership Ability to detect trace constituents (e.g., siloxanes, hydrogen, mercaptans etc.), particularly found in RNG	Novel technologies, including AI/ML, to: Understand and define the requirements and needs for online and portable gas quality analysis (used for monitoring) Accurately detect trace impurities in RNG Cost-effectively analyze gas composition at various RNG interconnection points in the gas system

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Reducing costs of interconnection skids	Interconnection skids for biomethane projects are costly and can materially impact overall project economics.	Interconnection skids connect RNG from distributed production plants to the natural gas system. These mechanisms contain complex equipment for metering, gas quality analysis, and odorization to enable the safe introduction of biomethane into PG&E’s gas system. PG&E currently utilizes an in-house standard design gas interconnection skid, as the commercially available options did not meet PG&E’s specifications. PG&E’s current design covers the material fabrication, inspection, testing, and documentation requirements for the pre-fabricated skid. Novel solutions to reduce cost could therefore materially reduce the overall project cost of providing clean and reliable energy service to gas customers.	Interconnection skids contain a range of complex equipment, including meters and analyzers to measure the volume and the quality of the gas, odorization, and other technologies to ensure biomethane is compliant with a range of standards specific to PG&E’s gas system. PG&E currently utilizes skids based on in-house designs that are calibrated to our system’s unique specifications. Primary limitations include: Current in-house design biomethane interconnection skid costs over \$800,000 High cost of skid components that are approved for utility use	Novel technologies to: Significantly reduce costs relative to current levels (\$800k today) Increase available options in metering and analyzers approved for utility use

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Identifying cost-effective and scalable sources for RNG production	Traditional RNG production feedstocks do not exist in sufficient volume to replace the entire throughput of PG&E’s gas system at a reasonable cost, making it critical to identify new cost-effective and scalable methods of gaseous fuel production in order to achieve climate commitments.	PG&E aims to source 15% of gas throughput for core customers from RNG by 2030 as part of our efforts to achieve a net zero energy system by 2040. However, RNG production has not been scaled to levels sufficient to meaningfully impact PG&E’s nearly one trillion cubic feet of natural gas provided per year. Current sources of RNG alone, which include landfills, wastewater treatment plants, and byproducts from the agricultural sector, will not be nearly enough to supply the needed production capacity to meet this goal at a reasonable cost. Due to the limited number of landfills and farms that can cost-effectively produce RNG directly from biogas, alternative cost-effective sources are needed to fill this gap and meet decarbonization goals while minimizing costs to ratepayers for gas supply procurement.	According to NREL, methane potential from biomass sources in the entire US is roughly 420 billion cubic feet per year, which is less than half of our annual natural gas throughput. Given the inherent limits of biomass’ potential to supplant natural gas in the gas supply, it is critical to identify alternative sources of RNG that would be able to account for the balance of our needs. Further, today’s sources of RNG are significantly more expensive to procure than equivalent volumes of fossil gas. Primary limitations include: High cost of RNG based on current production methods Low throughput and scale of RNG at production plants Limited availability of feedstock located near pipeline infrastructure to support current methods of RNG production Utility procurement competitiveness with other markets	Research and quantify the potential of alternative RNG production sources in California, such as woody (or other) biomass, wastewater treatment plants, and Power-to-Methane Accelerate development of the Power-to-Methane solution utilizing already captured CO2 at RNG production plants to create green methane Novel technologies to reduce the costs of producing RNG from traditional sources Novel technologies to produce RNG from nontraditional feedstocks such as woody biomass to greatly accelerate progress towards PG&E’s goals of achieving 15% of core gas throughput from RNG by 2030