PUBLIC UTILITIES COMMISSION
505 Van Ness Avenue
San Francisco CA 94102-3298

Southern California Gas Company
GAS (Corp ID 904)
Status of Advice Letter 5991G
As of February 1, 2024

Subject: Southern California Gas Company 2023 Research Development and Demonstration Plan in Compliance with Ordering Paragraph 30 of Decision 19-09-051

Division Assigned: Energy

Date Filed: 06-15-2022

Date to Calendar: 06-17-2022

Authorizing Documents: D1909051

Authorizing Documents: G-3586

Disposition:	**Signed**
Effective Date:	**11-30-2023**

Resolution Required: Yes

Resolution Number: **G-3601**

Commission Meeting Date: 11-30-2023

CPUC Contact Information:

edtariffunit@cpuc.ca.gov

AL Certificate Contact Information:

Gary Lenart
(213) 244-2424
GLenart@socalgas.com

PUBLIC UTILITIES COMMISSION
505 Van Ness Avenue
San Francisco CA 94102-3298

To: Energy Company Filing Advice Letter

From: Energy Division PAL Coordinator

Subject: Your Advice Letter Filing

The Energy Division of the California Public Utilities Commission has processed your recent Advice Letter (AL) filing and is returning an AL status certificate for your records.

The AL status certificate indicates:

Advice Letter Number
Name of Filer
CPUC Corporate ID number of Filer
Subject of Filing
Date Filed
Disposition of Filing (Accepted, Rejected, Withdrawn, etc.)
Effective Date of Filing
Other Miscellaneous Information (e.g., Resolution, if applicable, etc.)

The Energy Division has made no changes to your copy of the Advice Letter Filing; please review your Advice Letter Filing with the information contained in the AL status certificate, and update your Advice Letter and tariff records accordingly.

All inquiries to the California Public Utilities Commission on the status of your Advice Letter Filing will be answered by Energy Division staff based on the information contained in the Energy Division's PAL database from which the AL status certificate is generated. If you have any questions on this matter please contact the:

Energy Division's Tariff Unit by e-mail to
edtariffunit@cpuc.ca.gov

Joseph Mock
Director
Regulatory Affairs

555 W. Fifth Street, GT14D6
Los Angeles, CA 90013-1011
Tel: 213.244.3718
Fax: 213.244.4957
JMock@socalgas.com

June 15, 2022

Advice No. 5991
(U 904 G)

Public Utilities Commission of the State of California

Subject: Southern California Gas Company 2023 Research Development and Demonstration Plan in Compliance with Ordering Paragraph 30 of Decision 19-09-051

Purpose

Southern California Gas Company (SoCalGas) hereby submits this Tier 3 Advice Letter pursuant to Ordering Paragraph (OP) 30 of Decision (D.) 19-09-051 requesting approval from the California Public Utilities Commission (Commission or CPUC) to record 2023 Research Development and Demonstration (RD&D) expenses to the Research, Development, and Demonstration Expense Account (RDDEA).[1]

Background

California Public Utilities Code Section 740.1 provides for the Commission to authorize utility RD&D activities that benefit ratepayers through improved reliability and safety, environmental benefits, or operational efficiencies provided that achieving those benefits is reasonably probable and the focus is not unnecessarily duplicative of efforts by other research organizations. In Application (A.) 17-10-008, SoCalGas requested to continue its RD&D program for the 2019 GRC cycle, forecasted an average annual funding level of $14.329 million, and proposed to continue to record RD&D expenses in a one-way balancing account.[2]

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[1] D.19-09-051 (2019 GRC Decision), addresses the Test Year (TY) 2019 General Rate Cases (GRC) of San Diego Gas & Electric Company and SoCalGas.
[2] A.17-10-008, Application of Southern California Gas Company for Authority, Among Other Things, to Update its Gas Revenue Requirement and Base Rates Effective on January 1, 2019 (October 6, 2017), Exhibit (Ex.) SCG-21 Direct Testimony of Lisa L. Alexander at LLA-9 - LLA-20.

In the 2019 GRC Decision, the Commission found that SoCalGas's RD&D programs were both complementary and supplementary to other natural gas research and development programs[3] and authorized continuing the program through the TY 2019 GRC cycle at the average annual funding level requested by SoCalGas.[4] In addition, the 2019 GRC Decision ordered that SoCalGas:

> *[ ]host an annual workshop during the second quarter of 2020 and 2021 under supervision of the Commission's Energy Division. At these workshops, SoCalGas shall present the result of the previous year's Research, Development, and Demonstration (RD&D) program and obtain input regarding its intended spending for the following calendar year. Prior to the workshop, SoCalGas shall:*
>
> *a. Submit a report to Energy Division staff describing prior years' RD&D program including a summary of ongoing and completed projects; funds expended, funding recipients, and leveraged funding; and an explanation of the process used for selecting RD&D project areas as well as the structure of SoCalGas' RD&D portfolio;*
>
> *b. Provide Energy Division staff with the workshop presentation materials as well as documentation of stakeholders consulted in the development of RD&D projects, both at least one week before the workshop; and*
>
> *c. Engage relevant stakeholders to encourage their attendance at the workshop, such as the California Energy Commission, Gas Technology Institute, the U.S. Department of Energy, and other organizations engaged in gas research and development.*
>
> *SoCalGas must also present its budget broken down by research projects, request for proposals, and funding amounts. Other specific details concerning the workshops must be coordinated with the Commission's Energy Division staff.*[5]

The Commission also required that prior to SoCalGas recording 2021 RD&D expenses to the RDDEA memorandum account, it should submit a Tier 3 Advice Letter and include a Research Plan for the following calendar year that would:

> *(1) detail budgets broken down by research sub-program area,*

[3] D.19-09-051 at 745-746 (Findings of Fact (FOF) 169-171).
[4] *Id.* at 381, 775 (OP 2).
[5] *Id.* at 783 (OP 30).

(2) explain how the projects help improve reliability, safety, environmental benefits, or operational efficiencies, and

(3) discuss how SoCalGas incorporated feedback from workshop stakeholders and Commission staff.[6]

In addition to the requirements outlined in the 2019 GRC Decision, the Commission provided guidance earlier this year for future RD&D Research Plans in OP 5 of Resolution (Res.) G-3586. In developing subsequent Research Plans, SoCalGas was requested to:

- Describe how SoCalGas is engaging with diverse academic populations at universities and colleges to foster new researchers.
- Explain how SoCalGas incorporates into its Research Plan feedback received in pre-workshop stakeholder interviews with community-based organizations (CBOs).
- Describe, with Energy Division staff guidance, how to ensure energy efficiency RD&D projects for gas-powered appliances align with the State's transportation and building decarbonization goals.
- Provide detail quantifying the amount of program funds already committed and the quantity of program funds that are for projects under development in following years.
- Provide project-level detail about Research Plans with the 16 data fields described in the Discussion sub-section titled *Detailed budgets broken down by research subprogram.*
- Provide detail about how research projects supplement and coordinate with similar projects conducted by the CEC and the other IOUs.
- Provide detail about administrative budgets using allowable cost categories that will be developed in a process launched by D.21-11-028 defining allowable EPIC administrative costs.
- Develop sufficient quantitative estimates of potential safety, reliability, operational efficiency, improved affordability, and environmental-related benefits or numeric targets, or a specified numeric range of potential benefits for projects.
- Provide detail quantifying research funding allocations by research consortium, as well as project costs related to each consortium.
- Provide quantitative detail, in consultation with Energy Division staff, measuring the impact of RD&D projects on disadvantaged and low-income communities in terms of job creation and other economic development impacts and in terms of energy cost, greenhouse gas emissions, and energy reliability.
- Provide specific rather than general detail in subprogram equity descriptions about how the research areas benefit underserved communities.

[6] *Id.* at 379.

Discussion

In accordance with the 2019 GRC Decision and Res. G-3586, SoCalGas's RD&D staff completed the below activities to develop the 2021 Annual Report and 2023 Research Plan.

A. Consistency with D.19-09-051 Annual Workshop and Report Requirements

- *Submit a report to Energy Division staff describing prior years' RD&D program including a summary of ongoing and completed projects; funds expended, funding recipients, and leveraged funding; and an explanation of the process used for selecting RD&D project areas as well as the structure of SoCalGas' RD&D portfolio;* [7]

On April 20, 2022, SoCalGas submitted its 2021 RD&D Annual Report (2021 Annual Report) to CPUC Energy Division staff for review.[8] The report includes a summary of ongoing and completed projects;[9] funds expended,[10] funding recipients,[11] and leveraged funding;[12] and an explanation of the process used for selecting RD&D project areas,[13] as well as the structure of SoCalGas's RD&D portfolio.[14]

- *Provide Energy Division staff with the workshop presentation materials as well as documentation of stakeholders consulted in the development of RD&D projects, both at least one week before the workshop;* [15]

  Engage relevant stakeholders to encourage their attendance at the workshop, such as the California Energy Commission, Gas Technology Institute, the U.S. Department of Energy, and other organizations engaged in gas research and development.[16]

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[7] D.19-09-051 at 783 (OP 30).
[8] SoCalGas, *Research and Development, Renewal: Research, Development, and Demonstration Program 2021 Annual Report*, *available at:* https://www.socalgas.com/sustainability/research-development-demonstration-rdd-annual-report.
[9] *Id.* at 67 (Appendix: 2021 Summary of Ongoing and Completed Projects).
[10] *Id*. at 11.
[11] *Id.* at 42 (Appendix: 2021 Funding Recipients).
[12] *Id.* at 11.
[13] *Id.* at 49 (Appendix: Project Selection Process and Evaluation Criteria).
[14] *Id.* at 20.
[15] D.19-09-051 at 783 (OP 30).
[16] *Id.*

On April 20, 2022, SoCalGas submitted its workshop presentation materials to CPUC Energy Division staff for review. The presentation included documentation of the stakeholders consulted in the development of the workshop presentation.[17]
In the first quarter of 2022, RD&D Program staff conducted a series of targeted interviews with 15 people from 11 different organizations including California Energy Commission, GTI Energy (formerly Gas Technology Institute), and the U.S. Department of Energy. During these interviews, these SMEs and industry stakeholders were asked a series of standard questions and then engaged in a freeform discussion about the industry and its RD&D needs.[18]

- *[ ] host an annual workshop during the second quarter of 2020 and 2021 under supervision of the Commission's Energy Division. At these workshops, SoCalGas shall present the result of the previous year's Research, Development, and Demonstration (RD&D) program and obtain input regarding its intended spending for the following calendar year.*[19]

While the language in D.19-09-051 only requires SoCalGas to hold a workshop in the second quarter of 2020 and 2021, SoCalGas recognizes that the GRC cycle was extended from 3 years to 5 years after this decision was issued.[20] In the spirit of transparency and cooperation with the Commission, our research stakeholders, and the public, SoCalGas has committed to fulfilling these requirements through the end of the GRC cycle.

On April 27, 2022, RD&D staff hosted a public workshop via an online platform.[21] In consultation with Energy Division staff, SoCalGas extended invitations to and encouraged participation from 170 stakeholders representing Disadvantaged Communities (DACs) within SoCalGas's service territory. SoCalGas also sent notification of the workshop to several relevant Service Lists.[22] Registrations for the workshop totaled 248 individuals representing more than 90 organizations, including the CPUC, CEC, GTI, EPRI, four Department of Energy National Labs, Greater Ontario Business Council, Mar Vista Family Center, Northridge East Neighborhood Council, and California State University, Los Angeles.

During the five-hour workshop, RD&D team members presented results from the 2021 RD&D activities and proposed spending and activities for 2023. At the end of each

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[17] SoCalGas reached out to various stakeholders, including CEC, U.S. DOE, GTI, Stanford Natural Gas Initiative, Cal State LA, Cal State Long Beach, Pipeline Research Council Int., NYSEARCH, Bakersfield College, Kern Oil, and National Renewable Energy Laboratory.
[18] SoCalGas Research Development and Demonstration 2023 Research Plan (2023 Research Plan) which is attached to this Advice Letter as Attachment A, Section 3.1 Stakeholder Outreach.
[19] D.19-09-051 at 783 (OP 30).
[20] *See* D.20-01-002.
[21] *SoCalGas RD&D 2023 Research Plan – Public Workshop* (April 27, 2022), *available at:* https://youtu.be/ClYqalEv4mc.
[22] A.17-10-008, R.19-10-005, R.20-01-007, R.19-01-011, and R.13-11-005.

section of the presentation, the RD&D team accepted questions and comments. SoCalGas encouraged attendees to submit written comments after the workshop regarding the proposed spending and activities for 2023. A complete list of questions and comments received during and after the workshop are included in the 2023 Research Plan.[23]

- *detail budgets broken down by research sub-program area,*

A detailed budget for 2023 RD&D activities, broken down by Sub-program are included in section 6 of the Research Plan, "Proposed 2023 Funding Allocations."

- *explain how the projects help improve reliability, safety, environmental benefits, or operational efficiencies, and*

SoCalGas RD&D tracks six standard ratepayer benefits: (1) Environmental: Reduced GHG Emissions, (2) Environmental: Improved Air Quality, (3) Safety, (4) Improved Affordability, (5) Operational Efficiency, and (6) Reliability. Each sub-program section in the 2023 Research Plan explains how projects within that Sub-program help provide ratepayer benefits. For example, section 7.2.4 describes the benefits associated with projects in the Low Carbon Resources Program, Carbon Capture, Utilization, and Sequestration Sub-program.

- *discuss how SoCalGas incorporated feedback from workshop stakeholders and Commission staff.*[24]

RD&D staff compiled and incorporated into the Research Plan input from stakeholder interviews, input from the workshop, and comments submitted by e-mail after the workshop. Section 5.1 of the 2023 Research Plan outlines how SoCalGas incorporated feedback from stakeholders.

B. Consistency with Resolution G-3586 Requirements

- *Describe how SoCalGas is engaging with diverse academic populations at universities and colleges to foster new researchers.*[25]

Section 4.3 of the 2023 Research Plan, "Equity in SoCalGas RD&D," describes how SoCalGas RD&D also regularly engages with diverse academic populations at universities and colleges to foster new researchers. Examples include support of the Cal State LA Senior Design Program, community outreach sessions to diverse academic communities, and participation in the Horizon High School Hydrogen Grand Prix program.

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[23] 2023 Research Plan at Appendix B: Public Workshop Questions & Comments and Appendix C: Post-Workshop Stakeholder Input.
[24] D. 19-09-051 at 379.
[25] Res. G-3586 at 25 (OP 5).

- *Explain how SoCalGas incorporates into its Research Plan feedback received in pre-workshop stakeholder interviews with community-based organizations (CBOs).*[26]

Section 4.3 also describes how SoCalGas solicited input from CBOs to aid in Research Plan development. Feedback from a number of CBOs highlighted the importance of energy affordability. That feedback was incorporated into the 2023 Research Plan as described in section 5.1, "Response to Stakeholder Input."

- *Describe, with Energy Division staff guidance, how to ensure energy efficiency RD&D projects for gas-powered appliances align with the State's transportation and building decarbonization goals.*[27]

Section 5.2 of the 2023 Research Plan, Alignment with California's Decarbonization Goals, describes how a diversified decarbonization pathway that includes improved energy efficiency, building retrofits, and fuel-switching will enable California to achieve its short- and long-term building decarbonization goals more cost-effectively and expeditiously.

- *Provide detail quantifying the amount of program funds already committed and the quantity of program funds that are for projects under development in following years.*[28]

Each sub-program section of the 2023 Research Plan includes a funding table that lists the committed funds for 2023, the funds for projects under development for 2023, the total sub-program funding for 2023, and the sub-program funding as a percentage of the Program funding. For example, section 7.2.6 includes funding detail for the Low Carbon Resources Program, Carbon Capture, Utilization, and Sequestration Sub-program.

- *Provide project-level detail about Research Plans with the 16 data fields described in the Discussion sub-section titled Detailed budgets broken down by research subprogram.*[29]

Detailed information about active, contracted projects for 2023, including the 16 data fields listed in Res. G-3586, are included as Attachment B to this Advice Letter.

- *Provide detail about how research projects supplement and coordinate with similar projects conducted by the CEC and the other IOUs.*[30]

Section 5.3 of the 2023 Research Plan, "Coordination with CEC and other IOUs," describes how SoCalGas RD&D collaborate and coordinates with the CEC, California utilities, and utilities across North America. Coordination occurs through the public

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[26] *Id*.
[27] *Id.*
[28] *Id.*
[29] *Id.*
[30] *Id.* at 26 (OP 5).

workshop process, participation in research consortium, and through project level collaboration.

- *Provide detail about administrative budgets using allowable cost categories that will be developed in a process launched by D.21-11-028 defining allowable EPIC administrative costs.*[31]

Section 6.1 of the Research Plan, "Proposed Funding Allocations," provides a breakdown of the Program Administration budget based on categories developed for the EPIC program.

- *Develop sufficient quantitative estimates of potential safety, reliability, operational efficiency, improved affordability, and environmental-related benefits or numeric targets, or a specified numeric range of potential benefits for projects.*[32]

  Provide quantitative detail, in consultation with Energy Division staff, measuring the impact of RD&D projects on disadvantaged and low-income communities in terms of job creation and other economic development impacts and in terms of energy cost, greenhouse gas emissions, and energy reliability.[33]

In early May 2022, SoCalGas began conversations with ED staff to discuss "a framework for collecting and reporting sufficient quantitative estimates of potential safety, reliability, operational efficiency, improved affordability, environmental-related benefits (including NOx and GHG emission reductions), benefits to underserved communities, and numeric targets or a specified numeric range of potential benefits for projects," also referred to as the "benefits analysis framework".

During the May meeting, ED staff informed SoCalGas that they would like to make sure the benefits analysis framework for SoCalGas's RD&D projects are consistent with work to develop similar frameworks for other R&D programs overseen by the CPUC. ED staff recommended submitting a letter requesting an extension of time to comply with OP 4 to allow for further discussions with the subject matter experts on ED staff working to address benefits quantification. On May 26, 2022, SoCalGas submitted a letter to the Executive Director, formally requesting an extension of time from June 15, 2022, to July 29, 2022, to submit the requirements of OP 4 of Res.G-3586.

On June 6, 2022, the Executive Director approved of the extension.

- *Provide detail quantifying research funding allocations by research consortium, as well as project costs related to each consortium.*[34]

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[31] *Id.*
[32] *Id.*
[33] *Id.*
[34] *Id.*

Section 6.2 of the Research Plan, “Funding Allocations by Research Consortium,” provides detail regarding the allocation of funds to the various research consortia with which SoCalGas RD&D collaborates.

- *Provide specific rather than general detail in subprogram equity descriptions about how the research areas benefit underserved communities.*[35]

Section 4 of the 2023 Research Plan, “Equity,” describes in detail SoCalGas’s consideration of equity and disadvantaged communities in preparing the plan. This section includes a description of Diversity, Equity, & Inclusion programs within SoCalGas at large, details about SoCalGas RD&D efforts to engage diverse academic communities, and update on the development of the RD&D Equity Engagement Roadmap. Furthermore, within each sub-program description,[36] RD&D staff endeavored to provide an explanation of how projects within a sub-program could benefit under-resourced communities.

C. Summary of 2023 Research Plan

The 2023 Research Plan describes in detail the project selection process and criteria.[37] Input from stakeholders[38] led to a continued focus on hydrogen technologies to decarbonize the gas supply, workforce development and education, carbon capture, utilization, & sequestration demonstration, increasing equity considerations at the project level, and the need to improve the affordability of energy.[39]

The RD&D Program is divided into five program areas:

- Low Carbon Resources – The primary goal of the Low Carbon Resources program area is to decarbonize the gas supply while maintaining its affordability and reliability. To achieve this goal, program staff members develop, promote, and advance new technologies aimed at increasing and expanding the production and use of hydrogen and renewable natural gas—displacing conventionally sourced pipeline gas—and capturing and permanently removing or utilizing greenhouse gases (GHG).

- Gas Operations – The Gas Operations RD&D Program area supports pipeline transportation and storage operations through innovations that enhance pipeline and employee safety, maintain system reliability, increase operational efficiency, and minimize GHG and operational impacts to the environment. The program also supports technology development driven by emerging regulatory requirements. Its primary goal is to develop, test, and introduce new gas

[35] *Id.*
[36] For example, Section 7.2.5 describes the equity considerations for the Low Carbon Resource Program, CCUS Sub-program.
[37] 2023 Research Plan at Appendix D: Project Selection Process.
[38] *Id.* at Section 5.1: Response to Stakeholder Input.
[39] *Id.*

operations technologies that are beneficial to ratepayers, public safety, and the environment.

- Clean Transportation – The Clean Transportation RD&D Program area supports activities that minimize environmental impacts related to the transportation sector through the development of low-carbon fuels, zero-emissions drivetrains, fueling infrastructure, and on-board storage technologies.

- Clean Generation – The Clean Generation RD&D Program area targets the development and demonstration of high-efficiency products and technologies associated with the generation of power for the residential, commercial, and industrial market segments to reduce emissions, lower customer costs, integrate renewable fuels, and improve energy reliability and resiliency.

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

Each program area is further divided into multiple sub-program areas. The 2023 Research Plan describes how projects in each sub-program area help improve reliability, safety, environmental benefits, or operational efficiencies. A description of how RD&D proposals "align with the State's transportation and building decarbonization goals" is identified generally in the key policy drivers for the RD&D program,[40] and specifically with respect to energy efficiency projects for gas-powered appliances.[41]

RD&D Program staff consider a variety of factors in determining how to allocate funding, including regulatory and policy drivers, input from knowledgeable stakeholders, input from CPUC Energy Division staff, and other interested parties at an annual workshop.

The total authorized funding for the RD&D program was established by escalating the 2019 funding level authorized by the TY2019 GRC decision to 2023 dollars. For 2023, the escalated, authorized funding amount is $16.874 million. This funding may be adjusted in 2023 to incorporate overspend or underspend in 2022.

To allocate the 2023 budget, first, the Program Administration costs were forecasted at 10% of total funding. Activities in the Program Administration Budget were organized to align with allowable EPIC administration cost categories developed in the process launched by D.21-11-028. Next, each subprogram identified the level of funding that will be spent in 2023, taking into consideration projects that are currently under contract, projects that are under development for 2023, and stakeholder input. Then, for each subprogram, key research areas, with examples of potential interest that could be

[40] *Id.* at Section 2: Regulatory and Policy Drivers.
[41] *Id.* at Section 5.2: Alignment with California's Decarbonization Goals.

funded if the appropriate projects are developed, are described. Funds may also be directed to other research areas that arise during the plan year. Table A below provides a summary of the 2023 RD&D budget by research sub-program area.

Table A

Program	Program Funding	Sub-program	Sub-program Funding
Low Carbon Resources	$5,619,042	Renewable Gas Production	$2,809,521
		Carbon Capture, Utilization, & Sequestration	$2,809,521
Gas Operations	$3,644,784	Environmental & Safety	$728,957
		Operations Technology	$546,718
		System Design & Materials	$1,457,913
		System Inspection & Monitoring	$911,196
Clean Transportation	$2,126,124	Off-Road	$637,837
		Onboard Storage	$425,225
		On-Road	$637,837
		Refueling Stations	$425,225
Clean Generation	$1,670,526	Distributed Generation	$835,263
		Integration & Controls	$835,263
Customer End-Use Applications	$2,126,124	Advanced Innovation	$127,568
		Commercial Applications	$318,919
		Commercial Food Service	$148,829
		Industrial Process Heat	$850,450
		Residential Appliances	$680,359
Program Administration	$1,687,400		
Total	**$16,874,000**		

Protests

Anyone may protest this Advice Letter to the Commission. The protest must state the grounds upon which it is based, including such items as financial and service impact, and should be submitted expeditiously. The protest must be submitted electronically and must be received within 20 days after the date of this Advice Letter, which is July 5, 2022. Protests should be submitted to the attention of the Energy Division Tariff Unit at:

E-mail: EDTariffUnit@cpuc.ca.gov

In addition, protests and all other correspondence regarding this Advice Letter should also be sent electronically to the attention of:

Attn: Gary Lenart
Regulatory Tariff Manager
E-mail: GLenart@socalgas.com
E-mail: Tariffs@socalgas.com

Effective Date

OP 30 of D.19-09-051 directs SoCalGas to submit this Advice Letter as Tier 3 pursuant to General Order (GO) 96-B and, as such, requires a Resolution to be issued by the Commission. Accordingly, SoCalGas respectfully requests that it be approved by the Commission by December 1, 2022, to allow SoCalGas to timely provide funding.

Notice

A copy of this Advice Letter is being sent to SoCalGas's GO 96-B service list and the Commission's service list in A.17-10-007 and A.17-10-008. Address change requests to the GO 96-B service list should be directed via e-mail to Tariffs@socalgas.com or call 213-244-2837. For changes to all other service lists, please contact the Commission's Process Office at 415-703-2021 or via e-mail at Process_office@cpuc.ca.gov.

/s/ Joseph Mock
Joseph Mock
Director – Regulatory Affairs

Attachments

California Public Utilities Commission

ADVICE LETTER SUMMARY

ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No.:

Utility type:

☐ ELC ☐ GAS ☐ WATER

☐ PLC ☐ HEAT

Contact Person:
Phone #:
E-mail:
E-mail Disposition Notice to:

EXPLANATION OF UTILITY TYPE

ELC = Electric GAS = Gas WATER = Water
PLC = Pipeline HEAT = Heat

(Date Submitted / Received Stamp by CPUC)

Advice Letter (AL) #:

Tier Designation:

Subject of AL:

Keywords (choose from CPUC listing):

AL Type: ☐ Monthly ☐ Quarterly ☐ Annual ☐ One-Time ☐ Other:

If AL submitted in compliance with a Commission order, indicate relevant Decision/Resolution #:

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL:

Summarize differences between the AL and the prior withdrawn or rejected AL:

Confidential treatment requested? ☐ Yes ☐ No

If yes, specification of confidential information:
Confidential information will be made available to appropriate parties who execute a nondisclosure agreement. Name and contact information to request nondisclosure agreement/ access to confidential information:

Resolution required? ☐ Yes ☐ No

Requested effective date:

No. of tariff sheets:

Estimated system annual revenue effect (%):

Estimated system average rate effect (%):

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected:

Service affected and changes proposed[1]:

Pending advice letters that revise the same tariff sheets:

[1]Discuss in AL if more space is needed.

Protests and all other correspondence regarding this AL are due no later than 20 days after the date of this submittal, unless otherwise authorized by the Commission, and shall be sent to:

CPUC, Energy Division Attention: Tariff Unit 505 Van Ness Avenue San Francisco, CA 94102 Email: EDTariffUnit@cpuc.ca.gov	Name: Title: Utility Name: Address: City: State: Zip: Telephone (xxx) xxx-xxxx: Facsimile (xxx) xxx-xxxx: Email:
	Name: Title: Utility Name: Address: City: State: Zip: Telephone (xxx) xxx-xxxx: Facsimile (xxx) xxx-xxxx: Email:

ATTACHMENT A

Advice No. 5991

2023 SoCalGas Research Development and Demonstration Research Plan

SoCalGas

RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM

2023 RESEARCH PLAN

SUBMISSION: JUNE 15, 2022

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“The future is very bright. Humanity has important problems to solve but we are better positioned to solve them than at any other time in history. To help build a decarbonized energy system for California, SoCalGas is overcoming challenges, implementing solutions, and collaborating with innovative partners so every Californian can have access to clean, reliable, and affordable energy.”

—Maryam Brown
President
SoCalGas

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TABLE OF CONTENTS

ACRONYMS

Acronym	Description
AB	Assembly Bill
AI	Artificial Intelligence
ARPA-E	Advanced Research Projects Agency-Energy
BETO	Bioenergy Technologies Office
BTU	British Thermal Unit
CARB	California Air Resources Board
CAV	Connected and Autonomous Vehicle
CBO	Community-based Organizations
CCS	Carbon Capture and Sequestration
CCST	California Council on Science and Technology
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization, and Sequestration
CEC	California Energy Commission
CFR	Code of Federal Regulations
CFS	Commercial Food Service
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CNTP	Catalytic Non-Thermal Plasma
CO_2	Carbon Dioxide
CPUC	California Public Utilities Commission
CSP	Concentrated Solar Power
CSU	California State University
CTP	Clean Transportation Program
DAC	Disadvantaged Community
DBE	Diverse Business Enterprise
DG	Distributed Generation
DME	Dimethyl Ether
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EERE	Energy Efficiency and Renewable Energy
EMAT	Electromagnetic Acoustic Transducer
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPIC	Electric Program Investment Charge
ESJ	Environmental and Social Justice
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FCTO	Fuel Cell Technologies Office
GHG	Greenhouse Gas
GRC	General Rate Case

GTI	GTI Energy (formerly Gas Technology Institute)
HFCV	Hydrogen Fuel Cell Vehicle
IoT	Internet of Things
IOU	Investor-Owned Utility
IPCC	Intergovernmental Panel on Climate Change
LCFS	Low Carbon Fuel Standard
LIC	Low-Income Community
MHD	Medium- and Heavy-Duty
MSS	Mobile and Stationary Source
NAACP	National Association for the Advancement of Colored People
NDE	Nondestructive Examination
NETL	National Energy Technology Laboratory
NGA	Northeast Gas Association
NGRP	Natural Gas Research Program
NGV	Natural Gas Vehicle
NREL	National Renewable Energy Laboratory
OIR	Order Instituting Rulemaking
OTD	Operations Technology Development
PE	Polyethylene
PM	Particulate Matter
PNNL	Pacific Northwest National Laboratory
PRCI	Pipeline Research Council International
PSPS	Public Safety Power Shutoff
R&D	Research and Development
RD&D Program	SoCalGas' Research, Development, and Demonstration Program
RNG	Renewable Natural Gas
RPA	Regional Public Affairs
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SCF	Standard Cubic Foot
SJVAPCD	San Joaquin Valley Air Pollution Control District
SME	Subject Matter Expert
SMP	Sustaining Membership Program
SMR	Steam Methane Reforming
SoCalGas	Southern California Gas Company
SOFCS	Solid Oxide Fuel Cells
T&D	Transmission and Distribution
TAP	Technology Advancement Program
TCO	Total Cost of Ownership
TRL	Technology Readiness Level
UC	University of California
UTD	Utilization Technology Development

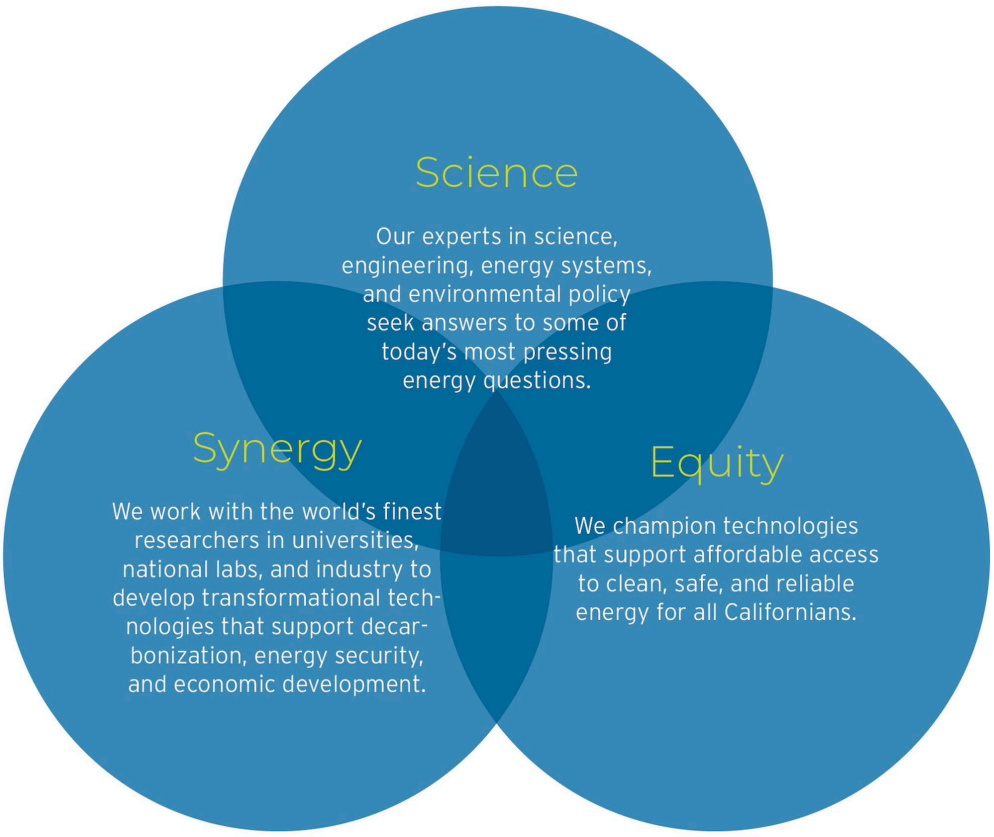
VOC	Volatile Organic Compound
ZEV	Zero-Emission Vehicle

1 Overview

SoCalGas Research, Development, and Demonstration (RD&D) plays a key role in the company's efforts to achieve net zero greenhouse gas (GHG) emissions in its operations and delivery of energy by 2045. In collaboration with professionals from the world's top institutions, RD&D staff develop and demonstrate transformational products and technologies that promote decarbonization across the natural gas value chain and a diversified portfolio of clean, reliable, safe, and affordable energy sources.

Table 1: The vision, mission, and values of the RD&D Program align with the SoCalGas mission to build the cleanest, safest, and most innovative energy company in America.

VISION	MISSION
Advancing innovative technologies for safer, cleaner, and more reliable energy.	Identify transformational energy solutions. Build them. Share them with the world.
VALUES	



SoCalGas RD&D is staffed with subject matter experts (SME) in science, engineering, industrial process technology, and environmental policy. Every year, RD&D staff support hundreds of projects along the commercialization pathway—from lab-scale research and development (R&D) to multi-year precommercial demonstrations—with the ultimate goals of saving energy, reducing GHG emissions, improving air quality, and increasing the safety, reliability, and affordability of energy.

In 2021, SoCalGas RD&D provided technical assistance, outreach, strategic guidance, and almost $17 million in funding to 379 projects throughout California and around the nation. In 2023, RD&D Program staff anticipate spending a total of $16,874,000 supporting hundreds of projects.

1.1 RD&D Program Goals and Structure

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

SoCalGas RD&D is divided into five programs, each of which is focused on products and technologies united by a broad theme such as transportation or end-use applications. Programs remain constant from year to year.

Each program is, in turn, broken into multiple subprograms. Each subprogram focuses on a subset of the program theme. Subprograms remain relatively constant but can change in response to industry developments, guidance from the California Public Utilities Commission (CPUC), or stakeholder input

Each subprogram includes several research areas. These forward-looking categories suggest the types of projects RD&D hopes to fund. Staff evaluate research areas annually. Research areas are non-exhaustive; RD&D can and does fund or otherwise support projects that do not fall within a defined research area.

In 2023, SoCalGas RD&D intends to allocate funding across five programs—Low Carbon Resources, Gas Operations, Clean Transportation, Clean Generation, and Customer End-Use Applications—and multiple associated subprograms.

Table 2: The RD&D Program is divided into five programs and 17 subprograms.

Programs	Subprograms
Low Carbon Resources	Carbon Capture, Utilization, & Sequestration
	Renewable Gas Production
Gas Operations	Environmental & Safety
	Operations Technology
	System Design & Materials
	System Inspection & Monitoring
Clean Transportation	Off-Road
	Onboard Storage
	On-Road
	Refueling Stations
Clean Generation	Distributed Generation

	Integration & Controls
Customer End-Use Applications	Advanced Innovation
	Commercial Applications
	Commercial Food Service
	Industrial Process Heat
	Residential Appliances

Within each sub-program, RD&D Program staff take a comprehensive yet flexible approach when identifying promising projects and evaluating them for potential funding. This approach enables them to 1) identify potential projects most in alignment with RD&D Program goals, state and federal environmental policy, and industry demand; 2) accurately assess the likelihood of potential projects to succeed; 3) work with proven partners and technologies over time; and 4) respond nimbly to changing market, technology, and policy drivers. More details about the Project Selection Process and Evaluation Criteria can be found in Appendix D of this document.

2 Regulatory and Policy Drivers

RD&D staff consider a variety of factors in determining how to broadly allocate funding. These factors include regulatory and policy drivers, input from knowledgeable stakeholders, input from the California Public Utilities Commission (CPUC) Energy Division staff and other interested parties at an annual workshop, and the potential impact of research on environmental and social justice (ESJ) communities. The process is designed to optimize subprogram-level funding allocations, to provide an opportunity for stakeholder input, and to maximize progress toward overarching program goals and objectives.

Table 3: Key state and federal policies and regulations impacting SoCalGas RD&D.

Category	Regulations and Policy Drivers
GHG Emissions	**AB 32:** Reduce carbon dioxide (CO_2) emissions 40% below 1990 levels by 2030 **SB 100:** Zero-carbon electricity by 2045 **EO B-55-18:** Carbon-neutral California economy by 2045 **AB 3232:** Reduce GHG emissions from residential and commercial buildings by 40 below 1990 levels by 2030 **SB 1101:** Carbon Sequestration: Pore Space Ownership and Carbon Capture, Utilization, and Storage Program
Pipeline Safety	**CPUC General Order 112F:** Rules governing design, testing, operation, and maintenance of gas transmission and distribution (T&D) systems **U.S. Department of Transportation (DOT) 49 Code of Federal Regulations (CFR) Part 192:** Federal pipeline safety regulations **AB 1900:** Biomethane quality standards **Order Institute Rulemaking (OIR) R.13-02-008, Phase 4:** Addresses injection of renewable hydrogen into gas pipelines
Local Air Quality	**Clean Air Act:** Air quality standards for nitrogen oxides (NOx) and particulate matter (PM) **AB 617:** Nonvehicular air pollution: criteria air pollutants and toxic air contaminants
Clean Transportation	**ARB Implementation Plan:** Low-NOx standard for trucks **AB 8:** Development of 100 hydrogen fueling stations in California **EO B32-15:** Sustainable freight action plan **EO B48-18:** 200 hydrogen refueling stations by 2025 **EO N-79-20:** 100% of MHDs be zero emission by 2045 for all operations where feasible **Low Carbon Fuel Standard (LCFS):** Reduce carbon intensity of fuels by 10% by 2020 **SB 1275:** One million zero-emission and near-zero-emission vehicles by 2023

Equity	**General Order 156:** Encourages investor-owned utilities (IOUs) to procure or contract goods and services from women-, minority-, disabled veteran- and/or LGBTQ-owned business enterprises **CPUC ESJ Action Plan:** Increase investment in clean energy resources to benefit ESJ communities, especially to improve local air quality and public health
Methane Emissions	**SB 1383:** Reduces methane emissions from decomposition of organic wastes **SB 1440:** Authorizes a state procurement program for biomethane **CARB Oil and Gas Rules:** Requires new monitoring and repairs to reduce methane emissions **Natural Gas STAR Program:** Encourages adoption of methane-reducing technologies and practices **EPA Methane Challenge Program:** Recognizes oil and gas companies that take comprehensive action to reduce methane emissions

3 Stakeholder Input

3.1 Stakeholder Outreach

SoCalGas RD&D works closely with industry professionals and SMEs at universities, national labs, public agencies, businesses, and industry research consortia to maximize the impact of its funding of promising technologies and products focused on producing or delivering cleaner, safer, affordable, and more reliable energy. These relationships enable SoCalGas to engage with science and technology experts, other utilities, and industry stakeholders to effectively identify and close knowledge and research gaps, avoid duplication of previous and ongoing research, and reduce technology and commercialization risks to achieve the goals of SoCalGas RD&D.

Conversations with these stakeholders and SMEs are ongoing throughout the year, but in preparation for the 2023 funding allocations, RD&D Program staff also conducted a series of targeted interviews with 15 people from 11 different organizations in the first quarter of 2022. During these interviews, the SMEs and industry stakeholders were asked a series of standard questions and then engaged in a freeform discussion about the industry and its RD&D needs. See Appendix A for a summary of responses.

Table 4: RD&D Program staff conducted stakeholder interviews with 15 individuals from 11 different organizations in early 2022.

2022 Stakeholder Organizations Interviewed	
Bakersfield College	National Renewable Energy Laboratory
California Energy Commission	Northeast Gas Association/NYSEARCH
California State University, Long Beach	Pipeline Research Council International
California State University, Los Angeles	Stanford Natural Gas Institute
GTI Energy	U.S. Department of Energy

3.2 Annual Stakeholder Workshop

On April 27, 2022, SoCalGas RD&D hosted an online workshop to present the results of the previous year's program and obtain input regarding proposed spending allocations for 2023. SoCalGas RD&D staff publicly announced the workshop on the SoCalGas RD&D website and LinkedIn page and by email to members of the A.17-10-008, R.19-10-005, R.20-01-007, R.19-01-011, and R.13-11-005 service lists.

248 individuals from a wide variety of organizations attended the workshop. Organizations sending attendees included four national laboratories, four public agencies, and numerous industry organizations, universities, community-based organizations (CBOs), and private companies.[1]

2022 Annual Stakeholder Workshop Attendee List

Accenture	Global Water Advisors, Inc.
Agility	Greater Ontario Business Council
Air Products and Chemicals, Inc.	Green Impact Partners
Alexander Talks	Gregori Consulting LLC
Allawos & Company	Gridworks
Alliance North America	GTI Energy
American Gas Association	H2 Energy Group, Inc.
ANGI Energy Systems	H2U Technologies
Argonne National Laboratory	Heliogen
AISIN Corporation	Hermandad Mexicana Nacional
Aspen	Home Energy Analytics, Inc.
ATCO Ltd.	Hy Stor Energy
Berokoff Energy Solutions	Hyperlight Energy
BEST LLC	Hyteon, Inc.
Brubaker & Associates, Inc.	Immaterial Ltd.
Burns & McDonnell	InterAct PTMI
California Energy Commission	Jay Luboff Consulting LLC
California Fuel Cell Partnership	Los Angeles Department of Water and Power
California Institute of Technology	Mar Vista Family Center
California League of Food Producers	Massachusetts Hydrogen Coalition
California Public Utilities Commission	MCE Clean Energy
California State University, Los Angeles	Mehta Associates
Calpine Corporation	Middle River Power LLC
Capgemini	Momentum
Capstone Green Energy	NASA Jet Propulsion Laboratory
Chevron	National Grid
Clean Energy	National Renewable Energy Laboratory
Custom Alloy Sales, Inc.	Nel Hydrogen
DAC	New Jersey Natural Gas

[1] To encourage participation by CBOs, RD&D provided stipends to several to cover their time attending the workshop.

Del Rey Consultancy	New York State Electric & Gas Corporation
Department of Energy, Hydrogen & Fuel Cell Technologies	NGVAmerica
E2 Consulting Engineers, Inc.	Northridge East Neighborhood Council
EEG Energy Gas	Northwest Energy Efficiency Alliance
Electric Power Research Institute, Inc.	NW Natural Gas Co.
Energy Capital Ventures	NYSEARCH/Northeast Gas Association
ENGIE	Oak Ridge National Laboratory
Florence Firestone Merchants Association	OMC Hydrogen, Inc.
FM Global Holdings	Osaka Gas USA
Frontier Energy	Pacific Gas & Electric
FuelCell Energy, Inc.	Pacific Northwest National Laboratory
Galileo Technologies	Palo Alto Research Center
Gazomat	Peoples Gas
GenCell Energy	Plains Midstream Canada
General Motors	Quaise Energy Limited
GKN Hydrogen	RealEnergy

3.3 Stakeholder Input

During the five-hour workshop, RD&D team members presented the following topics:

- 2021 in Review
- Program Status and Updates for 2022
- Draft Research Plan for 2023

At the end of each section of the presentation, the RD&D team fielded questions and comments from attendees. SoCalGas also posted a link to the workshop recording on the SoCalGas RD&D web page.[2] A complete list of the questions received during and following the workshop, along with answers from appropriate SoCalGas personnel, is included in Appendix B and Appendix C. See also Section 5.1 for more information about the response of SoCalGas RD&D to stakeholder input.

[2] https://www.socalgas.com/sustainability/research-development-demonstration-rdd

4 Equity

4.1 Environmental and Social Justice Communities and Climate Change

In California, millions of people live and work in areas categorized as ESJ communities, a designation that includes disadvantaged communities (DACs), tribal lands, and low-income households and census tracts. All too often, people from ESJ communities suffer disproportionate environmental and socioeconomic impacts, including poverty, high unemployment, air and water pollution, and high incidences of asthma and heart disease. In many cases, ESJ community residents also suffer from reduced or less reliable access to energy. What energy they can access often represents a burdensome percentage of their household incomes.[3]

Critically, members of ESJ communities are at greater risk from the negative impacts of climate change. According to the Fourth National Climate Assessment:

> *Climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth.*[4]

Further:

> *Impacts within and across regions will not be distributed equally. People who are already vulnerable, including lower-income and other marginalized communities, have lower capacity to prepare for and cope with extreme weather and climate-related events and are expected to experience greater impacts. Prioritizing adaptation actions for the most vulnerable populations would contribute to a more equitable future within and across communities. Global action to significantly cut greenhouse gas emissions can substantially reduce climate-related risks and increase opportunities for these populations in the longer term.*[5]

4.2 Diversity, Equity, and Inclusion at SoCalGas

SoCalGas is committed to equity, diversity, and inclusion. SoCalGas is an Affirmative Action and Equal Employment Opportunity employer and considers all applicants for employment without regard to race, color, religion, sex, gender identity, gender expression, sexual orientation, national origin, age, handicap or disability status, or status as a protected veteran under state and federal law.

In 2021, the company awarded $972.6 million in SoCalGas contracts—a 10% increase over 2020 and the highest total in SoCalGas history—to 577 certified Diverse Business Enterprises (DBEs). This represents 42.42% of the company's total purchases with suppliers.[6] Importantly, this total marks the 29th consecutive time that SoCalGas

[3] https://www.energy.gov/sites/prod/files/2019/01/f58/WIP-Energy-Burden_final.pdf
[4] https://nca2018.globalchange.gov/#
[5] https://nca2018.globalchange.gov/#
[6] https://www.socalgas.com/for-your-business/supplier-diversity

exceeded the CPUC's goal of 21.5% of total procurement of goods and services from women, minority, service-disabled veteran, and LGBTQ-owned businesses.

The company is also actively fulfilling the commitments of the CEO Action for Diversity & Inclusion, a pledge by more than 900 companies worldwide to advance diversity and inclusion in the workplace. To reinforce the SoCalGas vision of a workplace where everyone feels like they belong and are able to thrive, the company's Diversity & Inclusion department offers several ways for employees to be involved, including:

- Five Diversity & Inclusion Councils
- A Diversity & Inclusion Mentoring Program
- An Annual Diversity & Inclusion Summit
- Affinity groups for Black and Latino employees
- The VALOR program that helps provide a smooth transition for newly hired SoCalGas veteran/active military employees

SoCalGas believes in not only lending a hand, but also empowering people with a hand up, so they can further develop, grow, and subsequently empower others. The company's goal is to focus on charitable giving initiatives that create positive ripple effects throughout the community we serve and truly make a better world. Recently, the SoCalGas Charitable Giving Report was converted into a quarterly video and magazine series entitled *Empower*,[7] where stakeholders can learn more about the diverse personal human impacts that our charitable initiatives create.

4.3 Equity in SoCalGas RD&D

Equity is one of the program's core values and a factor it considers in every funding allocation decision. SoCalGas RD&D seeks to advance and champion technologies that support widespread access to clean, affordable, and reliable energy for all Californians, including those living and working in ESJ communities. To achieve these goals, SoCalGas RD&D:

- Seeks to locate projects in under-resourced communities
- Supports diverse research teams that include members from disadvantaged and underrepresented groups
- Shares the results from RD&D projects to inform and educate the public
- Reports its progress in diversity and inclusion efforts in its Annual Report

SoCalGas RD&D also regularly engages with diverse academic populations at universities and colleges to foster new researchers. Examples of this activity include:

- **Cal State LA Engineering, Computer Science, & Technology Capstone Senior Design Program**
  Cal State LA is a public university known for serving numerous Hispanic, Asian American, Pacific Islander, and minority students. Many are from low-income families and are the first in their families to attend college. The university is ranked number one in the nation for upward mobility, in part due to programs such as its Engineering, Computer Science, & Technology Capstone Senior Design

[7] https://www.socalgas.com/our-community/empower

Program. Each year, funded by corporate and university sponsorships, the program gives students open-ended, real-world problems to solve. Working in small groups, the students meet with faculty advisors and project sponsors, work collaboratively, learn new skills, and present their results to faculty and sponsors. SoCalGas RD&D has provided and continues to provide financial and technical support to the program since [YEAR]. See page 17 of the SoCalGas RD&D 2021 Annual Report for a relevant case study.

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

- H2GP: Horizon Hydrogen Grand Prix
  With support from numerous corporate sponsors, Horizon Educational conducts a global competition among high school students seeking to design and build a hybrid car powered by a hydrogen fuel cell. Representatives from SoCalGas RD&D have served as judges for the competition in the past. In 2022, SoCalGas plans to sponsor teams, with a particular focus on schools located in under-resourced communities.

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

4.4 Equity Engagement Roadmap Update

Disenfranchised communities are often left out of the decision-making process. This can result in ill-fated policy and implementation efforts that do not address their actual needs. To effectively engage with historically underserved communities, better understand their needs, and improve its operational response to these needs, SoCalGas RD&D began development of a multi-year public-facing Equity Engagement Roadmap in 2021. To develop this plan, SoCalGas RD&D has completed the following activities:

- Engaged with 2020Vet, a woman- and veteran-owned consulting firm to help develop the roadmap.

- Conducted a literature review of more than 50 ESJ documents, NGO publications, and academic reports produced by federal, state, and local government, private industry, and utilities. Among these documents was the CPUC's ESJ Action Plan.
- Identified general themes and industry best practices.
- Developed three key themes for the roadmap:
    - Obtain situational awareness
    - Increase community engagement
    - Institutionalize equity engagement
- Developed a draft plan with RD&D action items to address the key themes.
- Coordinated with 2020Vet to seek input from ESJ and diversity, equity, and inclusion (DE&I) experts and incorporated feedback into the draft plan.

Moving forward, SoCalGas RD&D will pursue the following next steps:

- Complete internal review of the draft plan
- Seek public stakeholder input for the draft plan and incorporate feedback
- Finalize the plan and share it with public stakeholders

SoCalGas RD&D anticipates finalizing the Equity Engagement Roadmap in 2022.

To better measure the impact of RD&D projects on disadvantaged and low-income communities in terms of job creation and other economic development, SoCalGas RD&D is working closely with the Energy Division of the California Public Utilities Commission to develop suitable metrics and an evaluation framework (see Section 5.2).

5 New in 2023

5.1 Response to Stakeholder Input

Through ongoing conversations throughout the past year and an intensive outreach process conducted during the first quarter of 2022, RD&D staff identified many key issues important to stakeholders. These issues are summarized in:

- Appendix A: Stakeholder Input
- Appendix B: Public Workshop Questions & Comments
- Appendix C: Post-Workshop Stakeholder Input

Generally, RD&D staff confirmed that program areas, subprograms, and research areas were in alignment with how key stakeholders from relevant universities, national labs, research consortia, and businesses view the needs of the industry. When appropriate, SoCalGas RD&D incorporates input received into its research plans.

Figure 1: The SoCalGas RD&D Annual Outreach Program revealed numerous themes.

In 2022, several key themes emerged from stakeholder input. SoCalGas RD&D staff carefully reviewed this year's input (Appendices A, B, and C) and considered them against RD&D project selection criteria (Appendix D). Foremost among the identified themes were:

Outreach Takeaway	SoCalGas RD&D Strategy
Hydrogen is a key technology for decarbonization.	Across all of its program areas, SoCalGas RD&D is exploring the role of hydrogen in

A majority of outreach targets (Section 3.1) stressed the importance of exploring the role of hydrogen in the decarbonization of energy production, delivery, and end-use applications. From leveraging existing gas infrastructure and developing refueling options for heavy-duty trucks to exploring new ways to produce hydrogen that minimize water consumption, the consensus was that hydrogen is a key technology for decarbonization.	the decarbonization of energy. See Sections 7.3.3 (Areas 1, 3, 4), 8.5.3 (Areas 1, 3), 9.2.3 (Areas 1, 2, 3, 4), 9.3.3 (Area 1), 9.4.3 (Areas 1, 2), 9.5.3 (Areas 1, 2), 10.2.3 (Areas 1, 2), 11.3.3 (Area 2), 11.4.3 (Area 1), 11.5.3 (Area 2), and 11.6.3 (Area 1).
Support Carbon Capture, Utilization, and Storage (CCUS) projects. Many respondents indicated support for CCUS technologies—including direct air capture—and some stressed the need for developing commercial-scale projects to demonstrate that the technologies actually work.	SoCalGas RD&D supports CCUS projects through its Low Carbon Resources program. See Section 7.2.
Increase project equity. Some respondents recommended increasing the diversity of SoCalGas RD&D through greater engagement with student programs, locating projects in areas categorized as disadvantaged or low-income, and adding people from underrepresented groups to project teams.	Equity is a core and growing focus of SoCalGas RD&D. See Sections 4.3, 4.4, 7.2.5, 7.3.5, 8.2.1, 9.2.5, 9.3.5, 9.4.5, 10.2.5, 10.3.5, 11.2.5, 11.3.5, 11.4.5, 11.5.5, and 11.6.5.
Focus on improving the affordability of energy. Some respondents stressed the importance of pursuing technologies and projects that reduce energy costs for members of ESJ communities.	SoCalGas RD&D is keenly interested in improving the affordability of energy. Of the 379 projects it supported in 2021, 107 of them directly or indirectly would improve energy affordability. See Sections 7.3.4, 8.2, 9.2.4, 9.3.4, 9.5.4, 10.2.4, 10.3.4, 11.2.4, 11.3.4 11.4.4, 11.5.4, and 11.6.4.
Support development of RNG and low-carbon fuels. RNG and other low-carbon fuels came up frequently in discussions with stakeholders.	SoCalGas RD&D explores and supports development of RNG and other low-carbon fuels. See Sections 7.2.3 (Areas 1, 2), 7.3.3 (Areas 2, 3, 5), 8.5.3 (Areas 1, 3), 9.2.3 (Area 3), 9.3.3 (Area 1), 9.5.3 (Area 1), 10.2.3 (Area 3), 10.3.3 (Area 2), 10.4.3 (Area 1), and 11.6.3 (Area 1).
Focus on system integrity. Stakeholders expressed interest in continuing research on how to support existing gas infrastructure through artificial intelligence (AI), data standards, and inspection technologies.	System integrity is a key focus of several RD&D research areas. See Sections 8.4.3 (Areas 1, 2), 8.5.3 (Areas 1, 2, 3), and 8.6.3 (Areas 1, 2, 3, 4).
Workforce development and education are vital to the energy transition. Numerous outreach respondents expressed a need for workforce development and training for students,	SoCalGas RD&D actively supports workforce development and education efforts in the projects it supports. In many cases, RD&D projects set the stage for future workforce development and

technicians, first responders, and engineers in hydrogen and other new technologies. Some also spoke of the importance of educating policy makers and legislators about the safety and reliability of natural gas, hydrogen, and RNG, as well as realistic timelines for the energy transition.	education activities. See Sections 4.3, 8.3.3 (Area 3), and 8.4.1.

5.2 Alignment with California's Decarbonization Goals

AB3232 requires California residential and commercial building stock to reduce their GHG emissions level by at least 40% below 1990 emissions levels (23.6 MMTCO2e) by 2030. According to a 2019 study by the Energy Future Initiative, even if the state enacted aggressive electrification policies and electrified 22% of residential buildings and all new construction by 2030, this would only equate to about 3.9 MMTCO2e in emissions reduction by 2030 or a 10% reduction from 2016 building emissions (39.4 MMTCO2e).

In comparison, energy efficiency has contributed to a decrease in the sector's emissions since 2000, despite the sector's growth since then. According to the California Energy Commission (CEC), mandatory energy efficiency codes and standards, plus programs that incentivize emissions reductions through behavioral and financial mechanisms, equates to a reduction of 8.4 MMTCO2e by 2030. Technology development that improves the energy efficiency of end-use gas appliances would only further drive emissions reduction potential. Therefore, a diversified pathway that includes improved energy efficiency, building retrofits, and fuel-switching (i.e., RNG, hydrogen, and electrification) will enable California to achieve its short- and long-term building decarbonization goal more cost-effectively and expeditiously.

While there is strong technical potential for each of these measures to play a role in reducing emissions, it is important to consider the impacts to buildings and homeowners involving costs, consumer preferences, and potential for disruption. It is critical to acknowledge that electricity and gas complement each other—both are needed and can reinforce each other. Taking a systemwide view of energy infrastructure that recognizes the value and coordinates the gas and electric systems to manage decarbonization affordability and resiliency provides the greatest overall benefits. One of the gas system's main strengths is its ability to meet extreme peaks. It can store, quickly ramp up, and deliver high volumes of energy on short notice and can handle large changes in volumes over time without operational, reliability, or financial strain. Without the inherent benefit of the gas system, the electricity system would be overburdened during the most crucial moments when our ratepayers need energy. For example, the electricity system currently struggles to meet peak summer loads. While these scenarios do not generally create a human life crisis, the complete removal of the gas system may create a winter seasonal peak demand for the electricity system. The gas system's seasonal peak is in the winter when heating load is the highest. Without the natural gas resiliency in the winter, a completely electrified energy infrastructure could pose a significant concern for heating loads resulting in loss of life. Therefore, a diversified energy system gives us the versatility to meet peak energy demand seasonally.

5.3 Coordination with CEC and Other IOUs

SoCalGas RD&D is committed to coordinating with the CEC, other government agencies including the California Air Resources Board (CARB), the South Coast Air Quality Management District (SCAQMD), and the U.S. Department of Energy (DOE), and other IOUs and municipal owned utilities.

One way that SoCalGas RD&D coordinates with others in the research community is through its annual public workshop. This year, the workshop was attended by representatives from the CEC and IOUs from across North America, including ATCO, ENGIE, Los Angeles Department of Water and Power (LADWP), National Grid, New Jersey Natural Gas, New York State Electric & Gas Corporation, NW Natural Gas Co., Pacific Gas & Electric Company (PG&E), and Peoples Gas (Section 3.2).

On January 31, 2022, SoCalGas submitted comments on the January 19, 2022, CEC Gas R&D Workshop. The comments addressed the CEC's research initiative to study hydrogen blending in power generation applications and included citations for the following SoCalGas RD&D projects:

- UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing
- UCI Fuel Flexible Microturbine Generator Development
- UCI Fuel Flexible Rotary Engine MicroCHP Development

In response, CEC staff commented that they will track these SoCalGas RD&D projects, since the results from these projects may inform future CEC solicitation development. CEC staff has subsequently contacted RD&D staff to discuss these projects in detail.

SoCalGas RD&D also engages and coordinates with other IOUs through involvement with national research consortia. These consortia are made up of IOUs and other researchers. Their intent is to leverage funding, expertise, and collaboration to maximize the value of research projects and avoid duplication of R&D efforts. In addition, the research consortiums meet with other organizations and agencies to discuss on-going and future research plans to avoid duplication[8], publish public Annual Reports[9] which summarize their work, and develop project proposals in response to agency funding opportunities. For example, CEC funding typically requires cost share to win an award. The OTD and UTD research consortiums monitor CEC solicitations as a mechanism to further leverage critical research dollars. Industry-led research consortiums such as UTD and OTD not only provide cost-share to projects, but also provide industry technical representation and input. See Section 6.2 for more detail about SoCalGas RD&D's participation in research consortia.

SoCalGas RD&D also works directly with other utilities to advance technologies that will benefit all Californians. SoCalGas RD&D recently collaborated with PG&E to support the

[8] For examples of research consortium affiliate organizations, please see: https://www.prci.org/About/PartnersAffiliates.aspx, https://www.utd-co.org/members/, and https://primis.phmsa.dot.gov/rd/workshops.htm.

[9] For examples of research consortium annual reports, please see: https://www.utd-co.org/wp-content/uploads/2021/12/UTD_Annual_Report_Research_Project_Summaries_2020-21.pdf, https://www.otd.org/wp-content/uploads/2021/10/OTD-Research-Project-Summaries-2020.pdf, https://www.nysearch.org/tech-brief-pdfs/2NYSearchBookUPDATEDFINALWEBFILE.pdf.

development of Brimstone Energy's low-cost, low-energy hydrogen and sulfuric acid co-production via electrolysis technology.[10] SoCalGas RD&D is currently working with LADWP and the DOE's Advanced Research Projects Agency-Energy to support a rapid temperature swing adsorption system for CO2 capture.[11]

SoCalGas RD&D regularly participates in CEC funding solicitations and is working with the CEC on a number of co-funded projects. In April 2022, the CEC announced proposed award funding for three hydrogen production technology projects supported by RD&D. The CEC is providing nearly $5 million to the awardees, with $1.9 million awarded to the University of Southern California for catalytic reformer development and $750,000 each to the University of California, Los Angeles and Susteon for hydrogen production technology development. To support these projects, SoCalGas RD&D committed a total of $700,000 to these projects. Also in April 2022, the CEC awarded GTI Energy and the University of California, Irvine $1.8 million to study the cost-performance-safety implications and emissions benefits of adopting up to 100% hydrogen to decarbonize large commercial buildings and industrial applications. SoCalGas committed a total of $700,000 with an additional $1 million in co-funding from PG&E, UTD, EPRI, and others to support this research.

[10] Renewal: SoCalGas RD&D 2021 Annual Report, p. 81.
[11] Id. at p.74.

6 Proposed 2023 Funding Allocations

6.1 Proposed 2023 Funding Allocations

The total authorized funding for the RD&D program was set by the 2019 General Rate Case (GRC) decision, which established the authorized funding for test year 2019 and the escalation and attrition rates for each subsequent year in SoCalGas' rate case cycle, including 2023. The total authorized funding for 2023 is $16,874,000.[12] Of that total, SoCalGas RD&D will allocate approximately 10% or $1,687,400 to program administration. Activities in the Program Administration Budget were organized to align with allowable EPIC administration cost categories developed in the process launched by D.21-11-028.

Program Administration Budget Items	2023 Forecast
Investment Plan Development	$170,000
Project Initiation	$104,008
Project Oversight and Governance	$26,002
Stakeholder Communication, Engagement, and Outreach	$430,000
Regulatory Support and Compliance	$450,952
Internal Management Coordination	$62,738
Program and Process Coordination and Improvement	$156,845
Administration Activities	$130,009
Supervision and Personnel	$125,476
Training and Development	$31,370
Total	**$1,687,400**

The remaining authorized budget, approximately $15,186,600, is allocated across the subprograms. First, each sub-program identified committed funds for 2023. These are finds that will be spent in 2023 with a high degree of certainty.

Next, each sub-program identified finds for projects that are under development for 2023. Sub-program personnel identified key research areas of interest for 2023. This funding is allocated to support projects in these key research areas for which some uncertainty in timing or budget remains. For example, on some projects, certain components such as research partner, testing location, co-funding source, or timeline have not yet been determined. The key research areas are examples of research concepts that could be funded if the appropriate project is developed. Funds may also be redirected to new research areas that arise during the plan year.

Table 5: RD&D Program Proposed 2023 Funding Allocations by Program and Subprogram.

Programs	Program Funding	Subprograms	Subprogram Funding
	$5,619,042	Renewable Gas Production	$2,809,521

[12] Any over- or under-spend from 2022 will be applied to 2023 in accordance with Resolution G-3573.

Low Carbon Resources		Carbon Capture, Utilization, & Sequestration	$2,809,521
Gas Operations	$3,644,784	Environmental & Safety	$728,957
		Operations Technology	$546,718
		System Design & Materials	$1,457,913
		System Inspection & Monitoring	$911,196
Clean Transportation	$2,126,124	Off-Road	$637,837
		Onboard Storage	$425,225
		On-Road	$637,837
		Refueling Stations	$425,225
Clean Generation	$1,670,526	Distributed Generation	$835,263
		Integration & Controls	$835,263
Customer End-Use Applications	$2,126,124	Advanced Innovation	$127,568
		Commercial Applications	$318,919
		Commercial Food Service	$148,829
		Industrial Process Heat	$850,450
		Residential Appliances	$680,359
Program Administration	$1,687,400		
Total	**$16,874,000**		

After careful review and consideration of stakeholder input (Appendix A), RD&D staff identified the subprograms listed above and the key research areas described below. In response to new stakeholder input, changing market conditions, new legislation or policy drivers, or significant advances in technology, RD&D Program staff may also choose to fund projects that are in alignment with overall program goals and objectives but do not fall under the research areas listed in the Research Plan.

6.2 Funding Allocations by Research Consortium

Per Resolution G-3586, SoCalGas RD&D is instructed to:

> *Provide detail quantifying research funding allocations by research consortium, as well as project costs related to each consortium.*

The breakdown for each Research Consortium is listed in the table below.

Research Consortium	2023 Dues[13]	
	Total	Portion available for Project Allocation[14]
NYSEARCH	$72,250	$0
OTD	$750,000	$690,000
PRCI	$150,000	$100,000
UTD	$350,000	$315,000

Research Consortium	Total Consortium-related Project Costs[15]	
	Total SoCalGas Cost	Total Project Cost
NYSEARCH	$528,001	$3,465,111
OTD	$527,050	$28,320,833
PRCI	$475,028	$18,046,046
UTD	$12,711	$578,000

The utilization of consortium dues varies by organization. Dues cover administrative expenses, with the remaining portion allocated to projects.

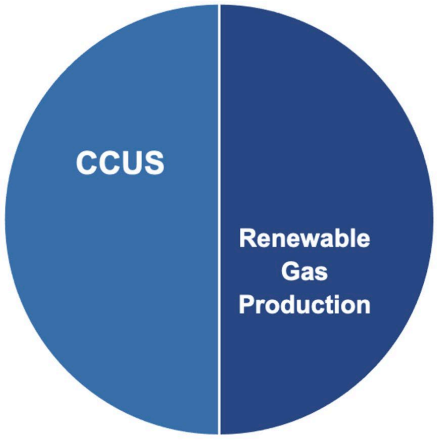
[13] Estimated dues. OTD dues offset by projects funded under the SB1371 Leakage Abatement Program. PRCI dues are calculated annually based upon miles of pipe.
[14] Estimated based upon historical trends after administrative deduction
[15] The total consortium-related project costs include 2023 "continuing projects" (projects previously initiated and spanning multiple years) based upon estimated end dates as of 5/1/2022. More details on continuing projects can be found in the Project Details section of this document Appendix E. The project selection and finding process for 2023 year will begin 4th quarter 2022.

7 LOW CARBON RESOURCES

The primary goal of the Low Carbon Resources program area is to decarbonize the gas supply while maintaining its affordability and reliability. To achieve this goal, program staff members develop, promote, and advance new technologies aimed at increasing and expanding the production and use of hydrogen and renewable natural gas (RNG), displacing conventionally sourced pipeline gas, and capturing and permanently removing atmospheric GHG emissions. RD&D Program personnel in the Low Carbon Resources program area focus their efforts on the following goals:

- Increasing the availability of renewable gas and promoting pipeline decarbonization solutions by advancing production technologies that diversify renewable gas feedstocks and pathways.
- Offsetting emissions from conventional natural gas use by capturing and permanently removing atmospheric GHG emissions through carbon capture utilization and sequestration (CCUS) technologies.

7.1 Proposed 2023 Low Carbon Resources Funding Allocation



Subprogram	Allocation
CCUS	50%
Renewable Gas Production	50%
Total	$5,619,042

Figure 2: Visual Summary of proposed 2023 Funding Allocations for Subprograms within the Low Carbon Resources Program.

7.2 Carbon Capture, Utilization, and Sequestration

7.2.1 Subprogram Overview

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

into a useful product or sequestered in solid form, methane pyrolysis will be listed as a stand-alone category under CCUS.

7.2.2 Policy Considerations

Carbon capture can help California reach its ambitious decarbonization and climate change mitigation goals more expeditiously by not only offsetting emissions from various GHG-emitting sectors, but also by creating a circular and carbon-negative economy. This subprogram can impact public policy by providing a realistic pathway for California to reach its carbon neutrality goals by 2045. The report *Getting to Neutral*, published by the Lawrence Livermore National Laboratory, indicates that California needs to remove 125 metric tons of CO_2 per year by 2045 to achieve state carbon neutrality goals. In addition, simultaneous carbon capture and hydrogen production pathways, such as biomass gasification with CCUS or methane pyrolysis, can make large-scale carbon removal solutions cost-effective in California. CCUS can support various California policies and regulations.

Policy	Description
AB 3232	Building decarbonization
EO B-55-18	2045 Carbon-neutral California economy
Clean Air Act	Air quality standards for NOx and PM
LCFS	Reduce carbon intensity of transportation fuels
AB 8	Development of 100 hydrogen refueling in California
EO B48-18	200 hydrogen refueling stations in California by 2025

7.2.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Carbon Capture
  Carbon capture explores different carbon capture pathways, techniques, and methodologies. Carbon capture technologies under consideration in this area aim to investigate and improve various CO_2 extraction and capture technologies while meeting cost and efficiency constraints needed for mass deployment. For example, CO_2 could be captured from biogenic point sources to enhance RNG yield and recovery from biodigesters, from industrial point sources to prevent release of CO_2-laden flue gas to the atmosphere, from atmospheric sources via direct air capture, and from oceanic carbon sources via CO_2 bipolar membrane electrodialyzers. All these technologies are at different stages of development and could revolutionize SoCalGas' ability to offset carbon emissions post-release.
- Area 2: Carbon Utilization and Sequestration
  Carbon utilization encompasses a wide variety of conversion technologies through which CO_2 is converted into valuable chemicals, including methanol, plastics, dimethyl ether (DME), concrete, and biofuels such as RNG. Several technologies and processes can be leveraged to convert CO_2 into useful products, including:
  - Electrochemical and electrocatalytic processes, such as plastics and biofuels production from CO_2 and water using electricity
  - Electro-methanogenesis, that is, RNG production from CO_2 and water using electricity

- Mineralization processes, such as concrete production

Alternatively, CCS involves the use of geological formations, such as active or depleted oil and gas reservoirs, as well as saline aquifers in the San Joaquin Valley to sequester CO_2. Studies by the Intergovernmental Panel on Climate Change (IPCC)[16] and the California Council on Science and Technology (CCST) have shown that CCS has the potential to reduce carbon emissions by billions of metric tons and may be an integral part of meeting California's climate goals in 2050.[17] Indeed, CCS allows for existing fossil fuel resources, such as natural gas, to be used in a way that produces far fewer carbon emissions than their use without CCS. Due to the potential importance of CCS in meeting California's long-term climate goals, CARB plans to integrate CCS into its climate programs in compliance with the AB 32 requirements that GHG emissions reductions achieved are real, permanent, quantifiable, verifiable, and enforceable. Studies have concluded that there is sufficient pore space available in California to inject tens of billions of metric tons of CO_2. CCS is already being deployed to sequester carbon emission from large-scale steam methane reforming (SMR) facilities and improve the carbon intensity of natural-gas-derived hydrogen. Projects in this research area aim at identifying and demonstrating the most economically viable CCS pathways, including co-generation of hydrogen and electricity. In addition, synergies can also exist between CCS technologies and various renewable gas production pathways, such as biomass gasification.

- Area 3: Emissions-Free Hydrogen Production via Methane Pyrolysis
  SoCalGas is investigating multiple methane pyrolysis pathways. Methane pyrolysis is a nascent but extremely interesting technology that consists of bubbling methane into a molten solution to decompose it into hydrogen and solid elemental carbon. The carbon can be used for a wide variety of applications, such as cement additives and carbon nanotubes. This technology has tremendous decarbonization potential because it does not generate any carbon emissions and can therefore reduce the cost of large-scale hydrogen generation while simultaneously offsetting carbon emissions.

7.2.4 Subprogram Benefits

Benefit	Explanation
Reliability	Leveraging synergies between renewable energy surplus/curtailment, carbon capture, and RNG production from captured CO_2 through advanced methanation processes can help improve gas system reliability and reduce reliance on out-of-state gas resources while simultaneously decarbonizing the pipeline. This benefit relates to the identical benefit under the "Renewable Gas Production" subprogram.
Environmental: Reduced GHG Emissions	CCUS systems can permanently remove CO_2 from the air, resulting in potentially negative overall carbon emissions. In addition, emissions-free hydrogen production via methane pyrolysis can further help decarbonize the pipeline and

[16] IPCC, 2014, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, page 151.
[17] CCST, 2011, California's Energy Future: The View to 2050.

	reduce its associated GHG emissions as well as offset emissions from hard-to-decarbonize industrial sectors.
Environmental: Improved Air Quality	Hydrogen produced from methane pyrolysis can improve air quality.

7.2.5 Equity Considerations

CPUC ESJ ACTION PLAN GOAL 2

Increases investment in clean energy resources to benefit ESJ communities, especially to improve local air quality and public health.

Deployment of carbon capture technologies near industrial facilities, most of which are co-located in ESJ communities, can improve the air quality in those communities. In addition, hydrogen from methane pyrolysis can be used directly to provide emissions-free energy in hard-to-decarbonize industries, such as steel and aluminum, which are also located in ESJ communities. These benefits to ESJ communities are in line with Goal 2 of the CPUC ESJ Action Plan. Equally as important, by offsetting GHG emissions, CCS technologies will reduce the negative impact of climate change on ESJ communities (Section 4.1).

7.2.6 Funding Table

Low Carbon Resources Program	
Carbon Capture, Utilization & Sequestration Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$615,000
Funds for Project Under Development for 2023	$2,194,521
Total Sub-program Funding for 2023	$2,809,521
Sub-program Percentage of Funding	50%

7.3 Renewable Gas Production

7.3.1 Subprogram Overview

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

7.3.2 Policy Considerations

Renewable gas production aligns and conforms with California's decarbonization goals through its direct relevance and applicability to several key policies. By reducing the carbon intensity of the gas grid through its gradual decarbonization, this subprogram supports the following policies:

Policy	Description
AB 3232	Building decarbonization
EO B-55-18	2045 Carbon-neutral California economy
Clean Air Act	Air quality standards for NOx and PM
SB 32	Regulating and monitoring GHG emission sources
AB 32	GHG emission reduction targets
SB 1383	Methane (CH_4) emissions from organic waste
LCFS	Reduce carbon intensity of transportation fuels

AB 8	Development of 100 hydrogen refueling stations in California
EO B48-18	200 hydrogen refueling stations in California by 2025

7.3.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Renewable Hydrogen Production via Advanced Water-Splitting
  Direct, high-efficiency sunlight/photon-driven water splitting into hydrogen and oxygen is an important research area with tremendous potential to streamline the conventional, multi-step water electrolysis process by coupling renewable electric power and water electrolysis into a one-step hydrogen-producing process. By decoupling green hydrogen production from the power grid, this technology would also eliminate intrinsic power system conversion and transmission losses, costly transmission system upgrades, and competition with electricity end users. In addition, the Low Carbon Resources Program area is also exploring ways to reduce conventional electrolysis cost and improve its efficiency by relying on earth-abundant catalysts and exploring pathways to reduce the operating cost burden imposed through electric T&D costs.
- Area 2: Renewable Methane Production via Various Methanation Pathways
  Renewable methane production from biogenic CO_2 with methanation—via conventional thermo-catalytic methanation, electrocatalytic processes, or the use of biological methanogens—is a key area of research that can be broadly deployed to capture and convert biogenic CO_2 emissions from bio-digesters, ethanol plants, landfills, and biomass gasifiers into RNG. Therefore, methanation technologies can expand the availability of renewable gas and avoid the upstream production, gathering, storage, transportation, and end-use GHG emissions associated with fossil-sourced gas; reduce net emissions; and improve air quality. Moreover, RNG produced via methanation has approximately triple the energy density of hydrogen (approximately 990 British thermal units per standard cubic foot [Btu/scf] versus 330 Btu/scf) and, most importantly, can be directly injected into the existing gas grid without the need for any system retrofit or modification.
- Area 3: Renewable Gas Production via Biomass Gasification
  Biomass is an abundant domestic resource that literally "recycles" CO_2. California has tremendous biomass resources that can be leveraged to not only produce renewable energy, but also mitigate the effects of devastating fires, which release very large quantities of GHG and criteria pollutants. Biomass gasification uses a controlled process involving heat, steam, and oxygen to convert biomass to hydrogen, RNG, and other products without combustion. Because growing biomass removes CO_2 from the atmosphere, the net carbon emissions of this method can be low, or even negative, especially if coupled with CCUS in the long term. Key challenges to hydrogen production via biomass gasification involve reducing costs associated with capital equipment and procuring continuous biomass feedstocks.
- Area 4: Distributed Hydrogen Production via Advanced Steam Methane Reforming of Biomethane
  SoCalGas is exploring different SMR technologies, including advanced catalytic non-thermal plasma (CNTP) and 3-D printed meso- and micro-channel SMR

reactors. SMR technology has progressed greatly in recent years with the development and manufacturing of a new, high-efficiency, low-cost, modular, combustion-free, solar- and/or induction-heat-driven, SMR technology for distributed hydrogen production. Originally developed by PNNL and being commercialized by STARS corporation, this technology has now reached a high technology readiness level (TRL) and is being deployed for field demonstration to support distributed hydrogen production. Incidentally, the first-ever production of oxygen on Mars was recently achieved by MOXIE (Mars OXygen In-situ utilization Experiment) onboard the NASA Mars2020 using similar 3-D printed microchannel heat exchanger technology, originally developed by PNNL, and now used in the STARS SMR reactor, which is licensed to SoCalGas.

- Area 5: Concentrated Solar Power Technology for Renewable Gas Production
  Concentrated solar power (CSP) technology can be leveraged to drive renewable gas production through seamless integration with biomass conversion processes to further reduce the carbon intensity of biomass-derived renewable gas, increase system efficiencies, and improve overall performance.

7.3.4 Subprogram Benefits

Benefit	Explanation
Reliability	Broadly, the gas grid can improve energy reliability by absorbing curtailed power and synchronizing renewable energy supply with demand by storing energy in the form of RNG/hydrogen and shifting utilization across days, weeks, and months. Specifically, surplus renewable energy from wind, solar, and organic wastes can be channeled to make hydrogen for pipeline injection and long-duration energy storage. Alternatively, renewable hydrogen can be processed with biogenic CO_2 emissions to produce RNG via methanation processes. In 2020, up to 1,586,500 megawatt hours of electricity were curtailed in California according to the California Independent System Operator. This translates to approximately 32,000 metric tons of hydrogen production from electrolysis and, correspondingly, 168,000 metric tons of CO_2 that potentially could have been recycled to methane from methanation pathways. In addition, hydrogen and RNG can be produced from biomass—a clean, reliable, locally available energy resource.
Safety	The latest hydrogen high-pressure tube trailer storage technology can allow the transport of 560–720 kilograms for on-road vehicles. Distributed hydrogen generation of similar capacity located at end-user sites and closely matching production to end-user demand eliminates the need for hydrogen transportation from centralized production points in high-pressure containers and large quantities of end-user storage, making hydrogen adoption inherently safer. In addition, small, modular on-site hydrogen generation systems contain relatively small

	amounts of hydrogen and can more easily be turned off should a plant upset occur.
Improved Affordability	The development of technologies and innovations for renewable gas production at the lowest possible cost would result in increased affordability and accessibility of renewable gas to ratepayers. Critically, a hydrogen production target price of $2 per kilogram by 2030 would allow hydrogen to become a cost-effective consumer alternative to conventional fuels.
Environmental: Reduced GHG Emissions	Hydrogen and RNG production can displace fossil-sourced hydrocarbons, thereby reducing, mitigating, or eliminating associated CO_2 and methane emissions. Carbon-negative hydrogen production cycles are now being deployed that directly remove CO_2 from the atmosphere.
Environmental: Improved Air Quality	Replacement of fossil-sourced gas with renewable hydrogen can improve air quality, especially in industrial zones, by facilitating the transition from conventional combustion technologies to electro- and thermo-catalytic processes that eliminate NO_x and PM emissions.

7.3.5 Equity Considerations

By decarbonizing the pipeline and replacing its fossil-sourced content with renewable gas, this subprogram seeks to reduce emissions and improve air quality in areas neighboring industrial facilities, most of which fall within ESJ Communities. This work is in direct alignment with Goal 2 of CPUC's ESJ Action Plan: "Increase investment in clean energy resources to benefit environmental and social justice communities, especially to improve local air quality and public health." Equally as important, by reducing GHG emissions, the development and deployment of zero-emission transportation fuels will reduce the negative impact of climate change on ESJ communities (Section 4.1).

7.3.6 Funding Table

Low Carbon Resources Program	
Renewable Gas Production Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$0
Funds for Project Under Development for 2023	$2,809,521
Total Sub-program Funding for 2023	$2,809,521
Sub-program Percentage of Funding	50%

8 GAS OPERATIONS

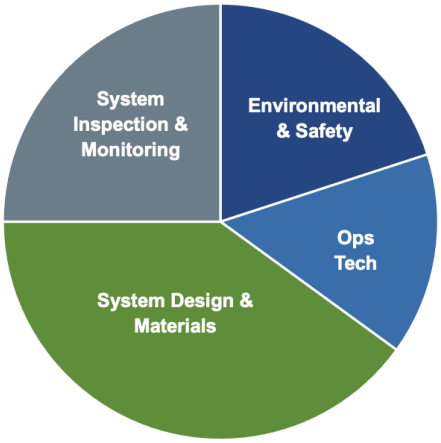
The Gas Operations Program area supports pipeline and storage operations through innovations that enhance public and employee safety, maintain system reliability, increase operational efficiency, and minimize GHG and operational impacts to the environment. The program also facilitates technology development driven by emerging regulatory requirements. Its primary goal is to develop, test, and introduce new gas operations technologies that are beneficial to ratepayers, public safety, and the environment.

More broadly, the objectives of the Gas Operations Program area are to:

- Improve gas safety and system integrity
- Improve or enhance system reliability
- Advance system design and materials
- Increase operational efficiencies and effectiveness
- Reduce system emissions

The program invests in technology development projects in the following subprograms: 1) Environmental & Safety, 2) Operations Technology, 3) System Design & Materials, and 4) System Inspection & Monitoring.

8.1 Proposed 2023 Gas Operations Funding Allocation



Subprogram	Allocation
Environmental & Safety	20%
Operations Technology	15%
System Design and Materials	40%
System Inspection & Monitoring	25%
Total	**$3,644,784**

Figure 3: Visual Summary of proposed 2023 Funding Allocations for Subprograms within the Gas Operations Program.

8.2 Program Benefits

Projects supported by the Gas Operations Program area deliver a wide range of benefits.

Benefit	Explanation
Reliability	Projects in this program focus on developing methods and technologies for more effective pipeline construction, alteration, and repair and on minimizing impacts to the public through avoidance of service

	interruptions and construction disruptions by extending the service life of the pipeline infrastructure.
Safety	Projects in this program seek to develop advanced systems to identify and mitigate threats to the pipeline system, protect pipelines from intentional and unintentional damage, and focus on various other aspects related to the safety of the public, company employees, and contractors working on or around the pipeline and system facilities.
Operational Efficiency	Projects in this program seek to identify practices that streamline processes, reduce time-on-task, leverage automation of data gathering and analytics, improve effectiveness, and develop new technologies to advance pipeline safety and regulatory compliance. Examples of such projects include developing less-invasive pipeline construction methods or more efficient operation and maintenance methods.
Improved Affordability	Projects in this program seek to drive development of technologies and innovations that reduce or avoid operational costs to increase energy affordability for ratepayers.
Environmental: Reduced GHG Emissions	Projects in this program develop technologies and best practices for reducing GHG emissions and mitigating the impacts of gas system emissions on climate change.
Environmental: Improved Air Quality	Projects in this program reduce the environmental impact of the pipeline system emissions through reducing the emissions of harmful air pollutants, such as post-combustion criteria pollutants.

8.2.1 Equity Considerations

The natural gas pipeline system serves customers regardless of their socioeconomic status. The Gas Operations Program funds a wide variety of projects applicable to all aspects of system pipeline operations. Many of this program's projects improve the efficiency of the gas pipeline and therefore its affordability. This keeps energy costs more affordable, which has a greater positive impact on ESJ community members, for which energy costs may comprise a greater share of their incomes. Importantly, many of the innovations developed by this program are adopted nationally by other utilities, which supports equity across the nation.

8.3 Environmental & Safety

8.3.1 Subprogram Overview

This subprogram seeks to advance the environmental integrity of the pipeline network and the safety of those who live and work in proximity to it. Environmental projects focus on developing technologies that also support state goals. Safety projects are concerned with protecting the pipeline from intentional and unintentional damage and improving the safety of the general public and company employees or contractors working on or around the pipeline. Projects include exploring how blending hydrogen into the pipeline

impacts the operation and maintenance of the pipeline system regarding safety, reliability, integrity, and environmental impacts.

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

8.3.2 Policy Considerations

This subprogram aligns and conforms with California's decarbonization goals through its direct relevance and applicability to several key policies, including:

Policy	Description
EO B-55-18	Carbon-neutral California economy by 2045
Clean Air Act	Air quality standards for NOx and PM
AB 32	Reduce CO2 emissions 40% below 1990 levels by 2030
SB 1383	Reduce methane emissions from decomposition of organic wastes
SB 1440	Authorizes a state procurement program for biomethane
LCFS	Reduce carbon intensity of fuels by 10% by 2020
AB 8	Development of 100 hydrogen refueling stations in California
EO B48-18	200 hydrogen refueling stations in California by 2025
Cal/OSHA Title 8 CCR	Injury and Illness Prevention Program
CPUC General Order 112F	Rules governing design, testing, operation, and maintenance of gas transmission and distribution systems
DOT 49 CFR Part 192	Federal pipeline safety regulations

8.3.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: System Emissions
  Projects in this research area seek to address post-combustion criteria air pollutants and GHG emissions. This research area supports the development of advanced technologies to detect, quantify, and provide real-time monitoring of emissions. Projects also include development of technologies or systems aimed at reduction or prevention of emissions. Projects are also needed to study diverse sources of energy and the effects on system emissions. This area supports the SoCalGas policy drivers for decarbonization, digitalization, and development of a diversified portfolio of energy sources.
- Area 2: Environment
  This area includes projects related to the impact of diversified energy and to acquiring real-time information on the impact of ground subsidence and movement caused by drought and groundwater replenishment. Environmental

projects focus on developing methods to prevent or mitigate contaminated water or hazardous waste run-off and preserve plants and endangered species during pipeline construction and repair within environmentally sensitive areas.

- Area 3: Safety
  The majority of safety incidents in the pipeline system are associated with third-party damage. Safety projects concerned with protecting the pipeline from intentional and unintentional damage include those developing 1) advanced sensors and monitoring systems to alert pipeline operators of third-party encroachment and construction activities near pipeline rights-of-way and 2) automatic shutoff systems for above- and belowground piping systems. Safety projects related to worker safety include those advancing training technologies and knowledge transfer.

8.3.4 Funding Table

Gas Operations Program	
Environmental & Safety Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$432,844
Funds for Project Under Development for 2023	$296,113
Total Sub-program Funding for 2023	$728,957
Sub-program Percentage of Funding	20%

8.4 Operations Technology

8.4.1 Subprogram Overview

This subprogram advances and develops advanced techniques for the construction, operation, maintenance, rehabilitation, and testing of gas pipelines and systems that facilitate continued safe and reliable service. It also supports technologies that improve employee training and explores how to prevent gas leaks that result from blending hydrogen into the pipeline.

8.4.2 Policy Considerations

Operations Technology projects support these key policies and regulations:

Policy	Description
DOT 49 CFR Part 192	Federal pipeline safety regulations
CPUC General Order 112F	Gas Transmission & Distribution rule
AB 32	GHG emission reduction targets
AB 1900	Biomethane quality standards
D.14-06-007	Approved SoCalGas' Pipeline Safety Enhancement Program

8.4.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Steel and Plastic Pipeline Construction, Operations, and Repair Technologies

Projects in this area would develop cost-effective polyethylene (PE) or steel pipe repair technologies that improve the efficiency of maintaining the integrity of the infrastructure. Projects in this area could also determine construction best practices for maintaining system integrity, such as how to eliminate strain on pipelines during installation. These projects improve the efficiency of maintaining the integrity of the infrastructure. Projects in the area also align with state goals to reduce GHG emissions by eliminating excessive methane emissions.

- Area 2: Mapping and Locating Technologies
  Projects in this area would improve pipeline locating and mapping technologies through, for example, further enhancement of acoustic, electromagnetic, and ground probing radar systems to produce complete accurate images of buried substructures. Other projects in this area could develop technologies for mapping underground pipelines and improving pipeline asset management. GIS mapping technologies are designed to improve the safety and integrity of underground natural gas pipelines by increasing the accuracy and availability of pipeline location information in areas where traditional methods and technology are inadequate. These technologies could help address excavation damage incidents caused by insufficient or inaccurate mapping methodologies. This research area supports the SoCalGas goal of digitalization, which includes the deployment of advanced technologies and analytics to improve planning, safety, resiliency, and the integration of real-time information to benefit participants across the energy value chain.
- Area 3: Measurement, Equipment and Tools
  Projects in this area would validate the capabilities of state-of-the-art measurement equipment and devices for both natural gas and other constituents, such as trace constituents in RNG. Through evaluation and testing of new methane hydrogen blend leak detection equipment, this research area supports the SoCalGas goals of decarbonization and diversity of energy.

8.4.4 Funding Table

Gas Operations Program	
Operations Technology Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$299,844
Funds for Project Under Development for 2023	$246,874
Total Sub-program Funding for 2023	$546,718
Sub-program Percentage of Funding	15%

8.5 System Design & Materials

8.5.1 Subprogram Overview

The objectives of this subprogram are to advance materials and materials science, materials tracking and traceability, and technical tools for designing pipeline systems and infrastructure for safety, reliability, efficiency, and maintainability throughout the life cycle of pipeline assets. Projects include research to advance engineering design standards and models, developing risk analytical tools to comply with pipeline integrity regulations, modeling operational efficiencies of gas storage and compressor station assets, and assessing the effects of incorporating gas from nontraditional sources (biogas and hydrogen-blend) on overall natural gas quality and system integrity.

Ultimately, lessons learned on these projects help SoCalGas better design, engineer, and develop its pipeline system.

8.5.2 Policy Considerations

System Design & Materials projects support key policies and regulations:

Policy	Description
AB 32	Reduce CO2 emissions 40% below 1990 levels by 2030
CPUC General Order 112F	Rules governing design, testing, operation, and maintenance of gas transmission and distribution systems
DOT 49 CFR Part 192	Federal pipeline safety regulations
AB 1900	Biomethane quality standards
Biomethane OIR Phase 3 (R.13-02-008)	Biomethane standards and requirements
ASME B31.8	Gas transmission and distribution piping systems
OIR R.13-02-008, Phase 4	Addresses injection of renewable hydrogen into gas pipelines

8.5.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Gas Composition and Quality
  Natural gas quality affects the integrity and safety of the pipeline infrastructure and end-use combustion equipment. RNG from non-conventional sources contains trace constituents that can impact pipeline integrity and customer combustion equipment performance. RNG-related research projects in this area will seek to identify trace constituents and support establishment of upper limits for accepting RNG. Hydrogen-related research projects would identify technologies that could enable the introduction and blending of 10–20% hydrogen into existing pipeline infrastructure. In addition, projects in this area could develop cost-effective, miniature online volatile organic compound (VOC) and siloxane analyzers that have the detection levels and accuracies of laboratory equipment. This research area supports the SoCalGas goals of decarbonization and the development of a diversified portfolio of clean energy sources.
- Area 2: System Design
  Projects in this research area seek to improve the understanding of the implications of potential risk factors, such as stresses due to internal gas pressure, construction procedures, and environmental factors (corrosive and geohazards). Integrating this understanding with analytics of materials that mitigate these risks enables improvements in system design that can mitigate risks prior to installation. Development of metal loss criteria for anomalies in the pipeline enables the establishment of acceptable limits for pipelines operating at various pressures, which in turn enables the redesign of pipeline specifications and repair solutions to maintain system integrity. In addition, projects that focus on external loads—such as geohazards or construction hazards—create opportunities to better understand the stresses these hazards would potentially place on the

pipeline, enabling these factors to be incorporated into the original design or retrofitted into legacy pipeline segments. Enhancing pipeline integrity addresses SoCalGas' decarbonization initiative by reducing the risk of pipeline damage that can cause methane emissions and determining impacts to the system infrastructure with the new diversified energy sources.

- Area 3: Materials
  Projects in this area will analyze state-of-the-art materials and coatings to identify those that can improve the longevity and therefore the reliability of newly installed pipeline segments over that of legacy installations. Area 3 projects could also help identify materials and coatings that are suitable for internal and external environments—knowledge that is key to maintaining a safe and reliable pipeline system. Understanding the advancements of both pipeline and weld materials will enable appropriate selections for the wide variety of environmental scenarios to which the pipeline will be exposed. With the acceptance of hydrogen and RNG as key initiatives, work is being done to understand which materials would complement the anticipated change in the internal environment of the pipeline to maintain the integrity of the legacy system as well as incorporate that information into material selection for future designs of newly constructed segments. Research efforts for tracking and traceability projects improve the data collection of materials by developing an approach to streamline the traceability of steel assets and a marking standard for pipeline components.

8.5.4 Funding Table

Gas Operations Program	
System Design & Materials Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$1,025,964
Funds for Project Under Development for 2023	$431,950
Total Sub-program Funding for 2023	$1,457,914
Sub-program Percentage of Funding	40%

8.6 System Inspection & Monitoring

8.6.1 Subprogram Overview

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

8.6.2 Policy Considerations

System Inspection & Monitoring projects support key policies and regulations:

Policy	Description
AB 32	Reduce CO2 emissions 40% below 1990 levels by 2030

CPUC General Order 112F	Rules governing design, testing, operation, and maintenance of gas transmission and distribution systems
DOT 49 CFR Part 192	Federal pipeline safety regulations
Clean Air Act	Air quality standards for NOx and PM

8.6.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Pipeline Systems Inspection Technologies
  Projects in this area improve pipeline inspection technologies such as in-line and non-destructive examination (NDE). Projects continuing for 2023 include enhancing modules or sensors detection capabilities and extending the inspection range for the Explorer robotic platform, and with developing non-destructive inspection technologies like using THz methods to interpret PE butt-fusion joint defects with 2D and 3D reconstruction imaging.
- Area 2: Remote Pipeline Monitoring Systems
  Projects in this area include the evaluation of remote inspection and monitoring systems. These non-intrusive technologies include satellite, aerial (manned and unmanned), and aboveground measurement of ground subsidence, methane emissions, distressed or dead vegetation, pipeline coating condition, and corrosion.
- Area 3: Data Analytics
  Digitalization of system information and advancing the use of data analytics are key strategies for improving system safety, reliability, and integrity in addition to being a pathway for achieving operational efficiency and emissions reductions. Leveraging machine learning, AI, image recognition, virtual and augmented reality technologies, neural networks, and advanced connectivity through social networks and IoT are examples of technologies that are being leveraged in a variety of research areas and proposals that are under development.
- Area 4: Geohazard Threat Inspection and Monitoring
  Projects in this area seek to monitor environmental threats, such as weather-related landslides and floods as well as seismic ground faults impacting pipeline integrity. This technology can provide continuous real-time measurement of strain imposed on the pipeline and alert pipeline operators to take mitigative measures to avoid pipeline failures. This research area supports the SoCalGas goal of digitalization.

8.6.4 Funding Table

Gas Operations Program	
System Inspection & Monitoring Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$686,563
Funds for Project Under Development for 2023	$224,633
Total Sub-program Funding for 2023	$911,196
Sub-program Percentage of Funding	25%

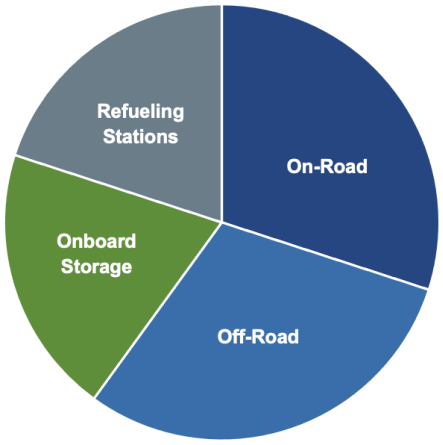
9 CLEAN TRANSPORTATION

The Clean Transportation Program area supports activities that minimize environmental impacts related to the transportation sector through the development of low-carbon fuels, zero-emissions drivetrains, fueling infrastructure, and on-board storage technologies. Other key objectives of this RD&D program area are to develop:

- Zero-emission transportation technologies
- Gaseous fueling infrastructure
- Advanced onboard storage technologies

The program invests in technology development projects in the following subprograms: 1) Off-Road, 2) On-Road, 3) Refueling Stations, and 4) Onboard Storage.

9.1 Proposed 2023 Clean Transportation Funding Allocation



Subprogram	Allocation
Off-Road	30%
Onboard Storage	20%
On-Road	30%
Refueling Stations	20%
Total	**$2,126,124**

Figure 4: Visual Summary of proposed 2023 Funding Allocations for Subprograms within the Clean Transportation Program.

9.2 Off-Road

9.2.1 Subprogram Overview

This subprogram targets emissions reductions from off-road vehicles such as rail, ocean-going vessels and commercial harbor craft, and construction and cargo handling equipment, where gaseous fuels can reduce emissions. Subprogram staff have also begun to explore aviation applications, including hydrogen fuel cell aircraft and drones. The subprogram focuses on developing zero-emission off-road transportation solutions using renewable hydrogen and RNG.

9.2.2 Policy Considerations

This subprogram aligns and conforms with several of California's decarbonization goals:

Policy	Description
EO N-79-20	100% zero-emission off-road vehicles and equipment by 2035 where feasible

CARB Clean Fleets Rule	Establishes a medium- and heavy-duty zero-emission fleet regulation with the goal of achieving a zero-emission truck and bus California fleet by 2045 where feasible
CARB At-Berth Regulations	Reduce diesel PM and NOx emissions from the auxiliary engines of ocean-going vessels while they are docked at California ports

9.2.3 2023 Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Zero-Emission Technology for Rail
  For decades, diesel fuel has been the only realistic way to meet the demanding operating requirements in rail. As the demand for zero-emission transportation increases, alternative technologies continue to be the right solution for customers around the globe. Hydrogen fuel cells are recognized as one of the innovative solutions necessary for a carbon-neutral future, generating enough energy to power passenger and cargo trains. R&D in this area will help provide emission reductions that meet or exceed regulatory requirements. Fuel cell trains will play a key role in the transition to a zero-emission economy. Hydrogen-powered trains are poised to disrupt the rail industry as a cost-effective, high-performing, zero-emission alternative to diesel.
- Area 2: Zero-Emission Technology for Marine
  Off-road mobile sources account for over 40% of NOx emissions in the South Coast Basin. The marine industry is subject to new, stringent emissions standards. In addition, hoteling and shore-power for marine applications is a significant source of emissions in the basin. R&D in this area will help provide emission reductions that are surplus to regulatory requirements.
- Area 3: Zero- and Near-Zero-Emission Technology for Construction Equipment
  New diesel engines manufactured in the United States for construction vehicles such as wheel scrapers and wheel dozers are required to meet the EPA Tier 4 off-road standard of approximately 0.3 grams per brake horsepower-hour (g/bhp-hr) for NOx. In California, regulatory and competitive pressures are motivating fleet owners to convert their older (Tier 3 or less) machines to Tier 4. Most older machines cannot be repowered (replace older engine with new one) to Tier 4 because the manufacturer does not have a Tier 4 retrofit package. Research in this area will help construction equipment and fleets meet Tier 4 standards in a cost-effective manner.
- Area 4: Zero-Emission Technology for Aviation
  Airlines have committed to carbon-neutral growth in international commercial aviation beginning in 2021. U.S. airlines have set a goal to achieve net-zero carbon emissions by 2050.[18] Although U.S. airlines have improved efficiency by 130% compared to 1978 levels, additional efficiency improvements in planes and engines are not likely to be enough. Meeting the 2050 goal will require fuels that have a lower carbon footprint. Hydrogen, with three times the energy density per mass of traditional jet fuel, is increasingly considered as one of the most promising zero-emission technologies for future aircraft.

[18] See, *for example*, Airlines for America - https://www.airlines.org/airlines-fly-green/

9.2.4 Subprogram Benefits

Benefit	Explanation
Reliability	Fuel-cell electric vehicles (FCEVs) could reduce dependence on foreign oil because hydrogen can be derived from domestic sources, including renewable sources such as water, biogas, and agricultural waste. Zero-emission vehicles (ZEVs) require less maintenance than their gasoline and diesel counterparts.
Operational Efficiency	ZEVs require less maintenance and can refuel in the same amount of time as their diesel counterparts. FCEVs operate at higher fuel efficiency (60%) than internal combustion counterparts (20–30%).
Improved Affordability	ZEVs can benefit from incentives such as the LCFS.
Environmental: Reduced GHG Emissions	RNG and hydrogen fuel significantly reduce GHG emissions compared to diesel.
Environmental: Improved Air Quality	Vehicles emit a significant fraction of the air pollutants that contribute to smog and harmful particulates in California. Zero-emissions vehicles produce no tailpipe NOx or PM emissions.

9.2.5 Equity Considerations

ESJ communities are disproportionately affected by both mobile and stationary source (MSS) pollution. MSS reductions will highly benefit ESJ communities. This subprogram seeks rapid transition to zero-emission technology in and near ESJ communities, complementing AB 617 strategies and consistent with CARB's equity goals.[19]

9.2.6 Funding Table

Clean Transportation Program	
Off-Road Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$273,949
Funds for Project Under Development for 2023	$363,888
Total Sub-program Funding for 2023	$637,837
Sub-program Percentage of Funding	30%

9.3 Onboard Storage

9.3.1 Subprogram Overview

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

[19] California Air Resources Board "2020 Mobile Source Strategy"

9.3.2 Policy Considerations

Onboard Storage projects support multiple policies and regulations. Advancements In onboard hydrogen storage tanks for on-road and off-road applications can help reduce the size, weight, and cost of hydrogen vehicles. This can also increase range and efficiency to make hydrogen more favorable in different applications.

Policy	Description
EO B-48-18	5 million ZEVS by 2030; 200 hydrogen refueling stations by 2025
EO N-79-20	Eliminate new internal combustion engine vehicles by 2035; 100% light-duty vehicles and drayage trucks sold will be zero-emission by 2035; 100% MHD vehicles sold and operated are zero-emission by 2045

9.3.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Conformable and Low-Pressure Tanks
  Projects in this area research improvements in the capacity, conformability, safety, and cost of on-board storage of gaseous fuels through development of conformable and low-pressure tanks. They will also research fueling protocols and applications to allow faster and fuller fills for RNG and renewable hydrogen.

9.3.4 Subprogram Benefits

Benefit	Explanation
Reliability	Low-pressure and advanced onboard storage tanks can provide greater cycle life and reduce required load on infrastructure.
Safety	Advanced materials can help store fuel at lower pressures and meet highest safety requirements of high-pressure storage vessels.
Operational Efficiency	Higher absorption and desorption materials can help reduce refueling times and fuller fills to maximize range and efficiency.
Improved Affordability	Low-pressure storage tanks require less compression and power needed to operate, and advanced onboard tanks help decrease costs.
Environmental: Reduced GHG Emissions	RNG and hydrogen fuel reduce GHGs given their lower carbon intensity relative to diesel.
Environmental: Improved Air Quality	Low-pressure storage tanks require less compression and power needed to operate.

9.3.5 Equity Considerations

"Investment in zero-emission transportation cannot be limited to electric cars, which are beyond the financial reach of many Californians. It must also be directed to clean transit, which will greatly benefit disadvantaged communities."[20]

9.3.6 Funding Table

Clean Transportation Program	
Onboard Storage 2023 Funding Allocation	
Committed Funds for 2023	$29,855
Funds for Project Under Development for 2023	$395,370
Total Sub-program Funding for 2023	$425,225
Sub-program Percentage of Funding	20%

9.4 On-Road

9.4.1 Subprogram Overview

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

9.4.2 Policy Considerations

On-Road research projects support multiple policies and regulations:

Policy	Description
EO B-48-18	5 million ZEVs by 2030; 200 hydrogen refueling stations by 2025
EO N-79-20	Eliminate new internal combustion engine vehicles by 2035; 100% light-duty vehicles and drayage trucks sold will be zero-emission by 2035; 100% MHD vehicles sold and operated are zero-emission by 2045
CARB Clean Truck Rule	100% ZEV where feasible for drayage, public fleets, last-mile delivery by 2045
CARB Clean Fleet Rule	100% zero-emission trucks and buses where feasible by 2045

9.4.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- **Area 1: Hydrogen Fuel Cell Development for MHD Trucks**
  Projects in this area perform research in advanced hydrogen fuel-cell electric vehicles (FCEVs) and zero-emission technologies for MHD freight and people transportation. Projects also demonstrate zero-emission vehicles (ZEVs) to encourage adoption of such technologies.
- **Area 2: Pathways for Zero-Emission Vehicles and Sustainable Transportation**

[20] https://blog.ballard.com/public-transport-access

Projects in this area perform studies on and assessments of advanced hydrogen FCEVs and zero-emission technologies for goods movement, transit, and transportation. Projects will also look at total cost of ownership, techno-economic analyses, planning, and roadmaps toward the adoption of ZEVs.

- Area 3: Advanced Innovation and Connected Vehicles
  Projects in this area perform research in state-of-the-art sustainable transportation technologies such as connected and autonomous vehicles (CAVs) to increase efficiencies in goods movement, public transportation, and ZEVs. Projects also demonstrate emissions reductions and efficiencies related to the adoption of CAVs.

9.4.4 Subprogram Benefits

Benefit	Explanation
Reliability	FCEVs could reduce U.S. dependence on foreign oil because hydrogen can be derived from domestic sources, including renewable sources such as water, biogas, and agricultural waste. ZEVs require less maintenance than their gasoline and diesel counterparts.
Operational Efficiency	ZEVs require less maintenance and can refuel in the same amount of time as their diesel counterparts. FCEVs operate at higher fuel efficiency (60%) than their internal combustion counterparts (20–30%).
Environmental: Reduced GHG Emissions	RNG and hydrogen fuel significantly reduce GHG emissions compared to diesel.
Environmental: Improved Air Quality	Vehicles emit a significant fraction of the air pollutants that contribute to smog and harmful particulates in California. Zero-emissions vehicles produce no NOx or PM emissions.

"Reducing NOx emissions is vital to public health. As a precursor to smog, NOx can cause or worsen numerous respiratory and other health ailments and is also associated with premature death. All combustion engines produce NOx, and although technology has advanced markedly over the years, California must still do more to reduce NOx emissions from mobile sources, especially trucks."

—California Air Resources Board

9.4.5 Equity Considerations

By seeking to develop zero-emissions MHD on-road vehicles, which frequently operate in ESJ communities, this subprogram will not only improve air quality, but also reduce GHG emissions—which will help reduce the impact of climate change. This program also supports development of zero-emission clean transit solutions, which typically benefit residents of ESJ communities more than other groups.

9.4.6 Funding Table

Clean Transportation Program	
On-Road Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$405,782
Funds for Project Under Development for 2023	$232,055
Total Sub-program Funding for 2023	$637,837
Sub-program Percentage of Funding	30%

9.5 Refueling Stations

9.5.1 Subprogram Overview

This subprogram targets the development, demonstration, and deployment of technologies and systems that support refueling for alternative fuels, including renewable hydrogen and RNG. The subprogram seeks to identify and manage concerns and issues arising from refueling of gaseous fuels—from storage to safety and standardization.

9.5.2 Policy Considerations

Refueling Stations projects support multiple policies and regulations:

Policy	Description
AB 8	100 Hydrogen Refueling Stations in California
EO B-48-18	5 million ZEVs by 2030; 200 hydrogen refueling stations by 2025
Low Carbon Fuel Standard	Reduce carbon intensity in transportation fuels as compared to conventional petroleum fuels, such as gasoline and diesel

9.5.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Advanced Full Fill Technologies
  Fast fill of compressed gas generates heat, which prevents full fill of the storage tank. Advanced full fill technologies help resolve this issue to provide full fills to CNG and hydrogen FCEVs. This helps alleviate range anxiety and promotes wider adoption of gaseous vehicles that significantly reduce emissions versus their liquid fuel counterparts.
- Area 2: Hydrogen Refueling Station Optimization and Safety
  Although hydrogen FCEVs have been researched and demonstrated, optimizing refueling infrastructure would enable broader adoption of these vehicles by transit and goods movement fleets. This research will look at improving hydrogen compressors, increasing the efficiency of overall refueling stations, and alternative technologies for refueling stations. Hydrogen and CNG as transportation fuel operate at high pressures: 10,000 pounds per square inch (psi) and 3,600 psi, respectively. Safety and standardization for station technologies are imperative for the successful adoption of both natural gas vehicles (NGVs) and FCEVs. Safety

of refueling stations and components is a top priority for the station and vehicle operators of ZEVs.

9.5.4 Subprogram Benefits

Benefit	Explanation
Reliability	FCEVs could reduce U.S. dependence on foreign oil because hydrogen can be derived from domestic sources, including renewable sources such as water, biogas, and agricultural waste.
Safety	Technologies to reduce and mitigate potential risks in near-zero and zero-emission infrastructure to be as safe as gasoline stations.
Operational Efficiency	Optimizing refueling stations can decrease refueling times and supplement fueling for on-road vehicles and nearby buildings through distributed energy resources.
Improved Affordability	Optimizing refueling stations can decrease needed power for compressors and other equipment to reduce costs.
Environmental: Reduced GHG Emissions	RNG and renewable hydrogen fuel reduce GHGs given their lower carbon intensity relative to diesel.
Environmental: Improved Air Quality	Optimizing refueling stations can decrease emissions from additional devices that are essential to deliver the hydrogen to customers.

9.5.5 Equity Considerations

By seeking to develop technologies that enable deployment of hydrogen fueling infrastructure, this sub-program supports a broader deployment of FCEV's in all communities. However, since the effects of transportation pollution, including higher rates of asthma, are more pronounced in low-income communities,[21] supporting the deployment of zero emission transportation could help reduce air pollution and save up to 6,000 lives per year.[22]

9.5.6 Funding Table

Clean Transportation Program	
Refueling Stations Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$29,855
Funds for Project Under Development for 2023	$395,370
Total Sub-program Funding for 2023	$425,225
Sub-program Percentage of Funding	20%

[21] https://www.uclahealth.org/news/asthma-disproportionately-affects-low-income-populations
[22] https://www.nature.com/articles/news050620-12

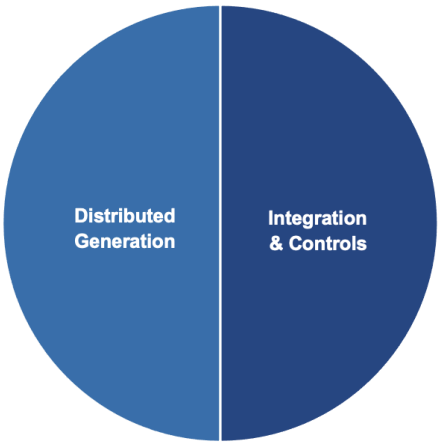
10 CLEAN GENERATION

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

- Improve energy reliability and resiliency
- Reduce emissions of distributed generation (DG) technologies
- Reduce customer costs
- Improve DG integration and microgrid controls

The program invests in technology development projects in the following subprograms: 1) Distributed Generation and 2) Integration & Controls.

10.1 Proposed 2023 Clean Generation Funding Allocation



Subprogram	Allocation
Distributed Generation	50%
Integration & Controls	50%
Total	**$1,670,526**

Figure 5: Visual Summary of proposed 2023 Funding Allocations for Subprograms within the Clean Generation Program.

10.2 Distributed Generation

10.2.1 Subprogram Overview

This subprogram seeks to develop and enhance DG technologies. New DG technologies are needed to improve energy reliability and resilience and to incorporate increasing quantities of RNG and hydrogen.

10.2.2 Policy Considerations

This subprogram develops reliable DG technologies with high efficiencies and increased RNG and hydrogen tolerance, resulting in reduced or eliminated emissions. Through these pathways, this subprogram supports several key policies.

Policy	Description
CPUC R.19-09-009	Microgrids and resiliency proceeding

AB3232	Building decarbonization
SB32	Reduce CO_2 emissions
Clean Air Act	Air quality standards for NOx and PM
SB 100	Zero-carbon electricity by 2045
EO B-55-18	Carbon-neutral California economy by 2045
SB 1298	DG regulation
SGIP	Self-Generation Incentive Program

10.2.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Commercialization of Small Scale (less than 50 kilowatt) Solid Oxide Fuel Cells (SOFCs)
  Projects in this area seek to commercialize SOFCs for residential and small commercial customers. Small-scale SOFC units are widely available in Japan and Europe and recently are becoming increasingly available in South Korea. There are currently no commercially available small SOFCs in the United States. Lab testing, field demonstrations, system optimization, and safety certifications are required to introduce these products into the U.S. market.
- Area 2: Hydrogen Integration with Existing Power Generation Technologies
  Projects in this area seek to continue to test and identify pathways for increased levels of hydrogen blending for fuel cell, engine, and turbine-based DG technologies currently operating on natural gas. Identifying and increasing hydrogen thresholds of existing DG equipment is a critical component of meeting California's building decarbonization goals.
- Area 3: Development of Low-emission CHP and Backup Generation
  Projects in this area seek to develop and demonstrate low-emissions DG technologies that can help customers maintain energy resilience year-round, including during public safety power shutoff (PSPS) events and other grid disturbances, while limiting GHG and criteria pollutant emissions.

10.2.4 Subprogram Benefits

Benefit	Explanation
Reliability	Gas-fueled DG has the ability to provide highly reliable and resilient electricity to customers by enabling them to be partially or completely independent of the electric grid, when needed.
Operational Efficiency	Combined heat and power (CHP) systems have the ability to maximize customers' operational efficiency by productively using "waste heat," often offsetting other heating- and cooling-related energy consumption.
Improved Affordability	By improving the overall efficiency of DG technologies and microgrids, customer energy costs are reduced.

Environmental: Reduced GHG Emissions	Improving the efficiency (reduced fuel utilization) and increasing hydrogen tolerance of DG technologies result in lower GHG emissions.
Environmental: Improved Air Quality	Projects in this subprogram specifically focus on developing and demonstrating technologies that can meet or exceed CARB-DG certification standards, resulting in improved air quality.

10.2.5 Equity Considerations

Low-emission, DG technologies can provide energy resilience to vulnerable populations, such as medical baseline customers, during power outages—including those resulting from PSPS events. Deployment of diesel-replacing DG within industrial areas adjacent to low-income communities (LICs) improves air quality.

10.2.6 Funding Table

Clean Generation Program	
Distributed Generation Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$137,763
Funds for Project Under Development for 2023	$697,500
Total Sub-program Funding for 2023	$835,263
Sub-program Percentage of Funding	50%

10.3 Integration & Controls

10.3.1 Subprogram Overview

This subprogram develops, enhances, and demonstrates technologies and control systems that integrate diverse DG resources and thermal loads. The focus is on enabling low-emissions, DG, and storage technologies to provide energy resilience and affordability to customers.

10.3.2 Policy Considerations

This subprogram aims to increase energy resilience and reduce customer emissions through the optimization of a "fully integrated energy system," leveraging and optimizing the utilization of low-emissions gas-fueled DG (such as fuel cells), on-site renewable generation, energy storage, and thermal systems. Integration & Controls projects support multiple policies and regulations:

Policy	Description
SB 1339	Microgrids for increased electricity reliability
CA Title 24	Buildings Energy Efficiency
CPUC R.19-09-009	Microgrids and Resiliency proceeding
AB3232	Building Decarbonization
SB 100	GHG emissions
Clean Air Act	Air quality standards for NOx and PM
EO B-55-18	Carbon neutral economy by 2045

10.3.3 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Integration and Optimization of Fuel Cells with Existing Customer Electric and Heating Systems
  Projects in this area seek to develop and demonstrate hardware and software that enable the optimal integration of fuel cells with existing electric (including solar and battery storage) and heating systems at customer sites. Microgrids are typically highly customized, which results in high implementation costs. Identifying and demonstrating off-the-shelf components to simplify installations for customers will ideally reduce cost and other Integration complications. System complexity and lack of clear hardware requirements are significant barriers to adoption.
- Area 2: Integration of Low-emissions Backup Generation with Existing Customer Electrical Systems to Provide Energy Resilience
  Projects in this area seek to demonstrate how low-emissions backup generation can be seamlessly integrated with existing customer systems to provide increased resilience. This topic is targeted toward the integration of intermittent/backup generation with existing systems. With the increasing regularity of wildfires (and resulting PSPS events), customers and agencies are looking for alternatives to diesel backup generation and clarity on how low-emissions natural gas– or hydrogen-fueled generation technologies can address this need.
- Area 3: Development of Technologies that Improve the Overall Efficiency of CHP Systems
  Projects in this area seek to develop and demonstrate new technologies that optimize the utilization of “waste heat” from combined heat and power (CHP) systems. Improving the total efficiency of a CHP system by using a CHP system's heat can improve the emissions and economics of a fully integrated energy system.
- Area 4: Development of Technologies that Improve Cybersecurity of Integrated Energy Systems
  Projects in this area seek to research the needs and opportunities associated with improving cybersecurity in connected DG and microgrid technologies as well as to develop new technologies. With emerging fuel cells and microgrid technologies being connected to the cloud for remote monitoring and control purposes, there is a growing need to address potential cybersecurity concerns and threats.

10.3.4 Subprogram Benefits

Benefit	Explanation
Reliability	Ensuring that customer energy systems are integrated and optimized improves power reliability and resilience. Improving grid interaction of DG also improves reliability on both sides of the meter.
Safety	When power reliability and resilience are increased, customer safety is improved due to the ability to keep

	critical equipment, such as HVAC or medical devices, operating during grid outages.
Operational Efficiency	Optimizing the integration of gas-fueled DG with existing customer power systems and heating technologies ultimately improves the overall energy efficiency for a customer.
Improved Affordability	Developing "off-the-shelf" solutions for DG integration can reduce installation costs. In addition, the development of improved control systems can reduce customer energy costs.
Environmental: Reduced GHG Emissions	Optimizing the integration of low-emissions DG, such as fuel cells, with solar + storage and heat-driven appliances can greatly reduce CO_2 emissions by providing on-site electricity that is cleaner than grid-sourced electricity and potentially offset gas consumption when CHP is optimally utilized.
Environmental: Improved Air Quality	Integrating low-emissions DG, such as fuel cells, with solar + storage and heat-driven appliances can greatly reduce criteria pollutants (NOx) by providing on-site electricity that is cleaner than grid-sourced electricity and potentially offset gas consumption when CHP is optimally utilized.

10.3.5 Equity Considerations

By simplifying and standardizing DG integration, installation costs will decrease, making resilience and energy efficiency more affordable. In addition, by simplifying the integration of clean generation technologies, the need for dirtier forms of backup generation decreases, resulting in improved air quality in DACs.

10.3.6 Funding Table

Clean Generation Program	
Integration & Controls Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$756,858
Funds for Project Under Development for 2023	$78,405
Total Sub-program Funding for 2023	$835,263
Sub-program Percentage of Funding	50%

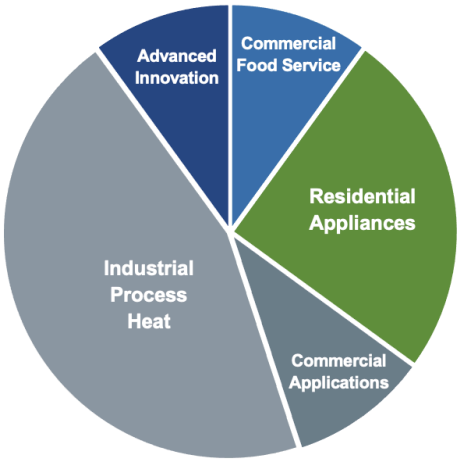
11 CUSTOMER END-USE APPLICATIONS

The Customer End-Use Applications Program area focuses on developing, demonstrating, and commercializing technologies that cost-effectively improve the efficiency and reduce the environmental impacts of gas equipment used in residential, commercial, and industrial settings. Other key objectives of this program area are to:

- Support the development and deployment of technologies that meet air emissions and energy efficiency goals
- Increase safety and performance while reducing cost

The program invests in technology development projects in the following subprogram areas: 1) Commercial Food Service, 2) Residential Appliances, 3) Commercial Applications, 4) Industrial Process Heat, and 5) Advanced Innovation.

11.1 Proposed 2023 Customer End-Use Applications Funding Allocation



Subprogram	Allocation
Advanced Innovation	6%
Commercial Applications	15%
Commercial Food Service	7%
Industrial Process Heat	40%
Residential Applications	32%
Total	**$2,126,124**

Figure 6: Visual Summary of proposed 2023 Funding Allocations for Subprograms within the Customer End-Use Applications Program

11.2 Advanced Innovation

11.2.1 Subprogram Overview

This sub-program seeks to develop new, nontraditional technologies to improve energy efficiency and decrease emissions.

11.2.2 Policy Considerations

Advanced Innovation projects support key policies and regulations:

Policy	Description
2016 Air Quality Management Plan	NOx and PM emissions regulation
CA Title 24	Buildings Energy Efficiency
CA Title 20	Appliance Energy Efficiency

Policy	Description
AB3232	Reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by 2030
AB32	Reduce CO_2 emissions 40% below 1990 levels by 2030
EO B-55-18	Carbon-neutral California economy by 2045
AB617	DACs for air quality improvements
LEED	Building sustainability and stewardship

11.2.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Smart Appliances
  Projects in this research area will investigate the use of smart technology to optimize energy efficiency and reduce gas consumption. For example, projects may explore advanced construction technologies and building materials that can improve building energy efficiency or assess new innovations—such as machine learning, blockchain, 3D multi-sensor transmitters, robotics, augmented reality, or improved cybersecurity—for applicability to emissions reduction, increased efficiency, and improved safety.
- Area 2: Advanced Materials for Building Energy Efficiency
  Projects in this research area will investigate the use of advanced construction technologies and building materials. This includes prefabricated material, vacuum insulation panels, or phase-change glass.

11.2.4 Subprogram Benefits

Benefit	Explanation
Safety	These innovations increase customer safety by monitoring for equipment failures (for example, leaks, performance degradations, emissions increases). Reduced fuel consumption, smart air monitoring, and advanced ventilation also improve local air quality.
Operational Efficiency	These innovations aim to provide operational efficiencies by directly targeting building performance and optimizing energy systems to yield the highest total efficiency.
Improved Affordability	Identifying new technologies that provide energy efficiency results in lower customer energy costs.
Environmental: Reduced GHG Emissions	By reducing energy usage, these innovations provide environmental benefit by reducing associated GHG emissions.

Environmental: Improved Air Quality	By reducing energy usage, these innovations provide environmental benefit by reducing associated NOx and PM emissions.

11.2.5 Equity Considerations

Smart technologies and advanced building techniques and materials have the ability to provide energy efficiency at lower costs than complete retrofits. This can result in meaningful energy savings without burdensome upfront capital costs for lower income households.

11.2.6 Funding Table

Customer End-use Applications Program	
Advanced Innovation Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$7,365
Funds for Project Under Development for 2023	$120,203
Total Sub-program Funding for 2023	$127,568
Sub-program Percentage of Funding	6%

11.3 Commercial Applications

11.3.1 Subprogram Overview

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

11.3.2 Policy Considerations

Commercial Applications projects support key policies and regulations:

Policy	Description
2016 Air Quality Management Plan	NOx and PM emissions regulation
CA Title 24	Buildings Energy Efficiency
CA Title 20	Appliance Energy Efficiency
AB3232	Reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by 2030
AB32	Reduce CO_2 emissions 40% below 1990 levels by 2030
EO B-55-18	Carbon-neutral California economy by 2045
AB617	DACs for air quality improvements

11.3.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- **Area 1: High-Efficiency Commercial Equipment for Building Decarbonization**

Projects in this area seek to develop a variety of high-efficiency equipment, including commercial water heating, space conditioning, and heating, cooling, and refrigeration process equipment, with the goals of increasing energy efficiency and reducing NOx emissions.

- Area 2: Hydrogen Blends in Commercial Equipment
  Projects in this area seek to investigate how hydrogen blends impact the performance of commercial equipment, with particular focus on NOx emissions and energy efficiency. Projects will identify feasible modifications to equipment to accommodate higher blends.

11.3.4 Subprogram Benefits

Benefit	Explanation
Operational Efficiency	Increasing energy efficiency and burner performance for commercial equipment also provides improved operational efficiency for customers by reducing fuel cost associated with space conditions, water heating, and other commercial operations.
Improved Affordability	Increased energy efficiency improves cost savings. This reduces overhead expenditures for businesses and delivers an attractive ROI to adopt high-efficiency technologies.
Environmental: Reduced GHG Emissions	Developing advanced end-use equipment that is compliant with RNG and hydrogen provides an environmental benefit by reducing GHG emissions from commercial buildings.
Environmental: Improved Air Quality	Increasing energy efficiency and burner performance for commercial equipment provides an environmental benefit by reducing NOx and PM emissions.

11.3.5 Equity Considerations

Buildings are part of the community. Where office buildings are located determines who will have access to the jobs they house, how much energy they use, and how much waste they produce. Therefore, the goal of this subprogram is to provide highly efficient and socially responsible technology to the built environment that improves the quality of life for all people.

11.3.6 Funding Table

Customer End-use Applications Program	
Commercial Applications Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$47,186
Funds for Project Under Development for 2023	$271,733
Total Sub-program Funding for 2023	$318,919
Sub-program Percentage of Funding	15%

11.4 Commercial Food Service

11.4.1 Subprogram Overview

This subprogram develops and enhances technologies and advancements related to commercial food service (CFS). CFS includes restaurants, catering services, and institutional kitchens that primarily rely on fuel supplied by SoCalGas for cooking and water heating. In response to the COVID-19 pandemic, this subprogram may also explore new solutions, such as adaptation to increased outdoor dining.

11.4.2 Policy Considerations

This subprogram aligns and conforms with California's decarbonization goals through its direct relevance and applicability to several key policies, including:

Policy	Description
2016 Air Quality Management Plan	NOx and PM emissions regulation
CA Title 24	Buildings Energy Efficiency
CA Title 20	Appliance Energy Efficiency
AB3232	Reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by 2030
AB32	Reduce CO_2 emissions 40% below 1990 levels by 2030
EO B-55-18	Carbon-neutral California economy by 2045
AB617	DACs for air quality improvements

11.4.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Hydrogen and RNG Blends in Commercial Food Service Equipment
  Projects in this area seek to develop highly efficient commercial food service equipment that is compatible with hydrogen and RNG blends.
- Area 2: Low-Cost, Low-Emission Commercial Food Service Equipment
  Projects in this area seek to develop safe, efficient, and effective technologies such as next-generation burners, gas heat pump water heaters, and kitchen ventilation systems. This area also supports projects that promote adoption of new high-efficiency equipment through technology development, demonstrations, webinars, conference presentations, and journal publications.

11.4.4 Subprogram Benefits

Benefit	Explanation
Operational Efficiency	Increasing energy efficiency and burner performance also provides improved operational efficiency for customers by reducing cooking time, increasing food output, and reducing fuel cost.

Improved Affordability	Increasing energy efficiency and burner performance results in energy cost savings and reduced total cost of ownership.
Environmental: Reduced GHG Emissions	Projects in this subprogram seek to increase energy efficiency and burner performance, which provides GHG benefit by reducing emissions from CFS equipment.
Environmental: Improved Air Quality	The CFS sector is a highly energy-intensive sector. Improved burner performance and energy efficiency significantly reduces GHG and NOx emissions.

11.4.5 Equity Considerations

Half of all American adults have worked in the restaurant industry. This subprogram seeks to reduce emissions, improve air quality, and increase profitability for an important sector that employs more minority workers than any other industry.[23]

11.4.6 Funding Table

Customer End-use Applications Program	
Commercial Food Service Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$102,531
Funds for Project Under Development for 2023	$46,298
Total Sub-program Funding for 2023	$148,829
Sub-program Percentage of Funding	7%

11.5 Industrial Process Equipment

11.5.1 Subprogram Overview

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

11.5.2 Policy Considerations

Industrial Process Equipment projects support key policies and regulations:

Policy	Description
2016 Air Quality Management Plan	NOx and PM emissions regulation
CA Title 24	Buildings Energy Efficiency
CA Title 20	Appliance Energy Efficiency
AB3232	Reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by 2030
SB32	Reduce CO_2 emissions 40% below 1990 levels by 2030

[23] https://restaurant.org/about/our-industry/commitment-to-diversity-equity-and-inclusion

EO B-55-18	Carbon-neutral California economy by 2045
AB617	DACs for air quality improvements

11.5.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- Area 1: Heavy Industrial Process Equipment
  This research area seeks projects that increase energy efficiency of industrial process heat applications and reduce NOx emissions. This can include high-performance burners, waste heat recovery devices, carbon capture and utilization, smart systems, and sensors.
- Area 2: Hydrogen Blends in Industrial Equipment
  Industrial processes, with high energy loads and high temperature requirements, are extremely difficult to electrify. Projects in this area will investigate how hydrogen blends impact the performance of industrial equipment, with particular focus on NOx emissions.

11.5.4 Subprogram Benefits

Benefit	Explanation
Operational Efficiency	Increasing energy efficiency and burner performance for industrial equipment improves operational efficiency for industrial customers by reducing fuel costs associated with high-temperature processes and improving throughput.
Improved Affordability	Developing solutions that can be implemented as modifications or retrofits to existing equipment allow for cost-effective and energy-efficient decarbonization of industrial end uses.
Environmental: Reduced GHG Emissions	Developing advanced industrial equipment that is compliant with RNG and hydrogen reduces GHG emissions from industrial processes, which are difficult and costly to electrify.
Environmental: Improved Air Quality	Increasing energy efficiency and burner performance for industrial equipment provides an environmental benefit by reducing NOx and PM emissions.

11.5.5 Equity Considerations

Industrial facilities typically neighbor LICs and DACs. This subprogram aims to improve energy efficiency and replace conventional fuels with RNG and hydrogen, which can significantly reduce emissions and improve air quality in these regions.

11.5.6 Funding Table

Customer End-use Applications Program	
Industrial Process Equipment Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$313,091

Funds for Project Under Development for 2023	$537,359
Total Sub-program Funding for 2023	$850,450
Sub-program Percentage of Funding	40%

11.6 Residential Appliances

11.6.1 Subprogram Overview

This subprogram develops, demonstrates, and enhances technologies and advancements related to gas-consuming appliances in residences. Subprogram staff also seek to adapt proven technologies to the California market. Relevant appliances include furnaces, hot water heaters, stoves, ovens, and dryers.

11.6.2 Policy Considerations

Residential Appliances projects support multiple policies and regulations:

Policy	Description
2016 Air Quality Management Plan	NOx and PM emissions regulation
CA Title 24	Buildings Energy Efficiency
CA Title 20	Appliance Energy Efficiency
AB3232	Building Decarbonization
AB32	Reduce CO_2 emissions 40% below 1990 levels by 2030
EO B-55-18	Carbon-neutral California economy by 2045
AB617	DACs for air quality improvements

11.6.3 2023 Key Research Areas

Based on input received during outreach activities, this subprogram will target the following key research areas with funds for projects under development:

- **Area 1: Hydrogen and RNG Blends in the Home**
  Projects in this area seek to develop highly efficient residential appliances that are compatible with hydrogen and RNG blends.

11.6.4 Subprogram Benefits

Benefit	Explanation
Operational Efficiency	Increasing energy efficiency and burner performance for residential appliances also provides improved operational efficiency for customers by reducing fuel cost associated with space conditions, water heating, and cooking.
Improved Affordability	Increased energy efficiency improves cost savings and ensures that energy is affordable and equitable.
Environmental: Reduced GHG Emissions	Developing advanced appliances that are compliant with RNG and hydrogen provides an environmental benefit by reducing GHG emissions from residential buildings.

Environmental: Improved Air Quality	Increasing energy efficiency and burner performance for residential appliances provides an environmental benefit by reducing NOx and PM emissions.

11.6.5 Equity Considerations

The introduction of hydrogen may have higher upfront costs than conventional fuels. Therefore, high-energy-efficiency appliances in the residential space will have greater importance in ensuring that clean energy is affordable and equitable.

11.6.6 Funding Table

Customer End-use Applications Program	
Residential Appliances Sub-program 2023 Funding Allocation	
Committed Funds for 2023	$616,599
Funds for Project Under Development for 2023	$63,760
Total Sub-program Funding for 2023	$680,359
Sub-program Percentage of Funding	32%

Appendix A: Stakeholder Input

In early 2022, SoCalGas RD&D conducted outreach to 11 organizations and spoke to 15 different individuals. Key takeaways from this year's outreach include:

1. Leverage existing infrastructure to decarbonize.
2. Hydrogen is a key technology for decarbonization.
3. Study the impact of transporting low-carbon fuels—RNG and hydrogen—and carbon dioxide in existing and new pipelines, as well as ways to retrofit existing pipelines.
4. Explore blending of hydrogen and natural gas in a natural gas power plant.
5. There is a need for more distributed hydrogen production at refueling stations.
6. Explore different ways to transport hydrogen, including liquid and ammonia.
7. Support development of dispensers, hoses, and other equipment for 10 kg/min hydrogen refueling for heavy-duty trucks.
8. Explore hydrogen production that does not consume water.
9. There is a need for more workforce development and training for students, technicians, first responders, and engineers in hydrogen and other new technologies.
10. Continue to support gas heat pump technology, particularly at greater than 100% efficiency.
11. Get ahead of regulation and police yourself using a variety of technologies and leak detection methods to reduce fugitive methane emissions.
12. Develop commercial-scale CCUS projects—including direct air capture—to prove that they can work.
13. Focus on developing data collection standards, artificial intelligence, and real-time sensors.
14. Develop protocols for low-carbon heavy-duty refueling processes.
15. Educate policy makers about safety, reliability of natural gas, hydrogen, and RNG, as well as realistic timelines for the energy transition.
16. Explore non-destructive evaluation technologies for pipelines, as well as ways to better predict and prevent corrosion.
17. Fuel cell technology needs a lot of investment.
18. Explore how to track green molecules in the pipeline and give credits.
19. Demonstrate use of gaseous fuels for heavy-duty transportation.
20. Study how to integrate gas and electric systems for resilience.
21. Support research into thermochemical conversion of woody biomass.
22. Pursue technologies with potential to reduce energy costs for ESJ communities.
23. Increase diversity through student programs.

Appendix B: Public Workshop Questions & Comments

B1	Submitter: Vishnu Vijayakumar, **UC Davis** (vvijayakumar@ucdavis.edu) **Q:** Are there any plans for SoCalGas to get into building hydrogen refueling stations? **A:** This question falls outside the scope of RD&D. SoCalGas' plans to develop hydrogen refueling stations are being addressed through the general rate case (GRC) process. Please refer to SoCalGas's GRC Test Year 2024 Application 22-05-015 for more information.
B2	Submitter: Paul Sandsted, **NGV America** (psandsted@ngvamerica.org) **Q:** As far as clean transportation, where RD&D is concerned, are there specific vehicle applications that your team focuses on? **A:** SoCalGas RD&D has historically focused primarily on heavy-duty on-road vehicle applications, particularly around developing and demonstrating ultra-low-NOx or near-zero-emissions compressed natural gas (CNG) heavy-duty truck engines. The focus has recently shifted toward fuel cell electric vehicles—particularly in the heavy-duty space. SoCalGas RD&D has also started exploring off-road applications, including rail, marine, and aviation. After decades of emissions reductions in the on-road sector, emissions from these off-road sectors now exceed those from on-road. Emissions reductions for off-road applications are critical to achieving decarbonization and air quality targets.
B3	Submitter: Debolina Dasgupta, **Argonne National Laboratory** (ddasgupta@anl.gov) **Q:** Can microgrid resilience be provided by CHP systems in addition to diesel? **A:** Yes, combined heat and power (CHP) systems can provide resilience like diesel backup. However, CHP systems typically operate full-time, also providing "waste heat" for heating or cooling processes—instead of only powering on for backup power. If a CHP system is sized to provide the majority of a site's power, then a customer will benefit from full/near-full energy resilience. There are also natural gas and hydrogen power generation technologies that perform similarly to diesel backup systems, only providing power when needed.
B4	Submitter: Carrie Berard, **NYSEG** (caberard@nyseg.com) **Q:** Great job Karen [McInnis]. **A:** Thank you.
B5	Submitter: Marianne Mansour, **SoCalGas** (Mmansour@socalgas.com) **Q:** Has there been research in storage of CO_2 and [the] possibility of using our underground storage facilities?

	A: SoCalGas Gas Operations RD&D does not currently have any active projects related to the underground storage of CO_2. However, projects are being developed related to carbon sequestration and storage by various research consortia. (See question B54).
B6	Submitter: Rizaldo Aldas, California Energy Commission (rizaldo.aldas@energy.ca.gov) Q: I may have missed this. Are you currently limiting your distributed generation (DG) focus on scales of below 50 kW, and, if so, what were the main drivers for that? A: The SoCalGas RD&D Distributed Gas subprogram is not limited in focus to sub-50kW technologies. RD&D is also interested in developing and advancing new technologies across various sizes, for a wide range of customer applications. However, RD&D included sub-50kW fuel cells as a research area due to an identified technology gap for smaller systems in the United States, and specifically California. There are several models of residential and small commercial-sized fuel cells available in Japan and Europe, with over 400,000 systems installed in Japan. RD&D staff believe that these technologies can provide several environmental and resiliency benefits in California.
B7	Submitter: Submitter: Rizaldo Aldas, California Energy Commission (rizaldo.aldas@energy.ca.gov) Q: It sounds like you've identified a gap in the product space for that size of fuel cell. So that is a focus for developing small-scale fuel cell products? Does that sound accurate? A: Yes, that's correct.
B8	Submitter: Kevin Uy, California Energy Commission (kevin.uy@energy.ca.gov) Q: Is there a projected level of RD&D funding for 2022-2023? A: Yes. Projected 2022 RD&D funding is discussed in the 2022 Research Plan, which was approved by the California Public Utilities Commission (CPUC) in Resolution G-3586. Projected 2023 funding is listed in Section 6.1 of this document.
B9	Submitter: Claire Becker-Castle, SoCalGas (cbecker-castle@socalgas.com) Q: The last two minutes of video were not seen on screen. A: We apologize for the inconvenience.
B10	Submitter: Cynthia Carter, SoCalGas (ccarter5@socalgas.com) Q: Only a comment. This is a great workshop! I'm excited for our future.

	A: Thank you.
B11	Submitter: Ludwig Lipp, T2M Global (llipp@t2mglobal.com) Q: Power for ships at the Los Angeles and Long Beach ports is a major source of pollution. SoCalGas should consider supporting fuels for clean power production for marine applications, including hydrogen. A: Thanks for the feedback. This is something that RD&D is interested in and will consider looking at for future projects. In fact, RD&D is currently pursuing a grant funding opportunity to provide fuel cell shore power at the ports.
B12	Submitter: Michael Slusarz, American Gas Association (mslusarz@aga.org) Q: Thank you, RD&D Team, for the great presentations. Looking forward to continuing the discussions! A: Thank you for participating in this public workshop.
B13	Submitter: Siari Sosa, SoCalGas (ssosa@socalgas.com) Q: Thanks all! Great presentation, very informative! A: Thank you for participating in this public workshop.
B14	Submitter: Bianca Tippett, Sowing Seeds for Life (receptionist@sowingseedsforlife.org) Q: This was not covered yet. How can charities better partner with the gas company to best provide services to those living food-insecure? A: RD&D is part of SoCalGas, a larger company that provides charitable giving programs, grant opportunities, scholarship funding, diversity and inclusion efforts, and supplier diversity. SoCalGas RD&D is happy to connect you with the correct group within SoCalGas to help facilitate those relationships. Please contact us by email at RDDInfo@socalgas.com.
B15	Submitter: Kaycee Chang, California Energy Commission (kaycee.chang@energy.ca.gov) Q: What target metrics would you be looking for around hydrogen-blended power generation? A: RD&D is considering several potential metrics at this time. One key metric is impact on performance, such as reduced efficiency or an increase in NOx emissions. Another key metric is impact to system durability and longevity. For example, does the hydrogen affect any components that would require shorter service intervals? Are catalysts affected? If there are any other metrics you believe that RD&D should focus on, please let us know.
B16	Submitter: Adele DiBiasio, National Grid (adele.dibiasio@nationalgrid.com)

	Q: Will your slide deck be available? A: A recording of the workshop is available on the SoCalGas RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd.
B17	Submitter: Ishita Dave, SoCalGas (Ishah1@scgcontractor.com) Q: Thanks all, presenters and Matthew, for providing all this technical info through great presentations. A: Thank you for participating in this public workshop.
B18	Submitter: SanSan Lee, SoCalGas (sslee@socalgas.com) Q: First time attending the workshop. Excellent materials. Will take a day off to attend the workshop next year so the focus can be on the workshop only. Thank you. A: Thank you for participating in this public workshop.
B19	Submitter: David Blekhman, Cal State LA (blekhman@calstatela.edu) Q: Great vision. It would be great to implement small-scale fuel cells at Cal State LA for training, research, and demo projects through senior designs. Excellent job. We appreciate all the work that went into this event. Hopefully, more to come. We look forward to future collaborations. A: Thank you for the suggestion. We will consider this for future projects.
B20	Submitter: Zhiming Gao, ORNL (gaoz@ornl.gov) Q: How can we contact SoCalGas RD&D for a collaboration? A: Please contact us by email at RDDInfo@socalgas.com. Please provide a brief description of the collaboration opportunity so that SoCalGas RD&D can make sure it gets directed to the right group.
B21	Submitter: Zhiming Gao, ORNL (gaoz@ornl.gov) Q: How about NOx control in gas combustion? A: SoCalGas RD&D considers six distinct ratepayer benefits—such as emissions reductions, cost-savings, and operational efficiency—that help guide the direction of its research. The Gas Operations program has funded and continues to fund projects that examine NOx reduction methods through air-fuel ratio controllers, catalysts, and various other mechanisms. The Customer End-Use Applications subprogram has focused on advanced combustion burners that specifically address NOx emissions as well as the implementation

	of catalysts after treatment across residential, commercial, and industrial market segments. Lastly, SoCalGas RD&D has ramped up its research into hydrogen blending to address burner performance and combustion emissions of carbon monoxide and NOx.
B22	Submitter: Bob Coleman, SoCalGas (rwcoleman@socalgas.com) Q: I understand that the goal is to get hydrogen down to $1/kg and it is currently at $2/kg, though I could have this wrong. What are the improvements that need to take place to get from where we are to the goal? A: SoCalGas RD&D would like to clarify that while costs for hydrogen may be as low as $2/kg, those prices are typically for hydrogen produced from fossil gas sources and with no greenhouse gas emissions mitigation. Renewable hydrogen production costs are typically in the range of $5-$10/kg depending on the feedstock and pathway. That said, the DOE has identified several key areas in which costs must be reduced in order to achieve a renewable hydrogen cost of $1/kg. These primarily involve capital expense and operating expense reductions. SoCalGas RD&D supports projects and technology developments that aim to address multiple technological pathways to produce renewable hydrogen, including supporting projects to de-risk and advance cutting-edge technology as well as projects that help to further develop existing technologies to improve efficiency or reduce manufacturing costs. For electrolysis, the primary driver to reduce operating expenditures (OpEx) is reducing renewable electricity costs. On the capital expenditure (CapEx) side, RD&D supports projects to decrease electrolyzer module cost by identifying earth-abundant materials that can replace the expensive and scarce platinum group metal materials typically used in electrolysis. For other technological pathways, RD&D has supported projects in many research areas that aim to reduce OpEx by increasing reactor efficiencies. For example, RD&D has supported the development of advanced, modular, and scalable steam methane reforming (SMR) reactors that can convert renewable natural gas (RNG) to renewable hydrogen. RD&D has also supported the development of methane pyrolysis technologies that produce valuable carbon byproducts that help offset the cost of hydrogen produced through this method.
B23	Submitter: Peter Chen, California Energy Commission (peter.chen@energy.ca.gov) Q: Is there flexibility with reallocating funding across subprograms? A: Yes, two key goals of the public workshop are to share the proposed allocations across subprograms for 2023 and to obtain stakeholder feedback.
B24	Submitter: Peter Chen, California Energy Commission (peter.chen@energy.ca.gov)

	Q: What applications/sectors are interested in low-pressure hydrogen storage? Are there issues with scalability considering the established 350/700 bar standards for refueling on-road hydrogen fuel cell vehicles? A: Low-pressure hydrogen storage could reduce the weight of the storage tank on the vehicles in many different transportation applications. Low-pressure storage could also to reduce the energy requirements and reliability issues that come with high-pressure hydrogen storage. Low-pressure hydrogen storage may require new fueling standards and potentially require modification of the current fueling infrastructure, which is designed to operate at high pressure.
B25	Submitter: Emily Chow, Public Utilities Commission (emily.chow@cpuc.ca.gov) Q: Regarding the Food Service subprogram, will restaurant operators receive any grants or stipends that will help them purchase high-efficiency equipment in combination with the educational opportunities mentioned? A: The SoCalGas Energy Resource Center (ERC) offers seminars, demonstrations, and consulting services to help local businesses find cost-effective, energy-efficient solutions. The webpage is located at: https://www.socalgas.com/for-your-business/education-and-training/energy-resource-center. This past year, the ERC offered customers a complete virtual experience to help them select and acquire rebates for high-efficiency equipment during the pandemic. On the rebate side, SoCalGas was able to offer a 50% deemed rebate until 12/31/2021. The ERC has also been working on offering grants for restaurant workers through the California Restaurant Foundation.
B26	Submitter: Emily Chow, Public Utilities Commission (emily.chow@cpuc.ca.gov) Q: What a fantastic workshop! Is there anywhere we can sign up to receive notifications for future SoCalGas workshops like this one? A: All attendees of the public workshop you are automatically added to the SoCalGas RD&D email list to receive notification of future workshops and webinars. Anyone interested in signing up for notification should contact us by email at RDDInfor@socalgas.com.
B27	Submitter: Michael Allawos, Allawos & Company (michael.allawos@allawosandcompany.com) Q: Was it correct that there is over $8 billion available for the production of hydrogen for local hubs? Can you please show the slide that illustrates this? A: This was slide 58 in the presentation. The bipartisan infrastructure law (BIL) has allocated $8 billion in DOE funding to support at least four regional hydrogen hubs. See [https://www.energy.gov/articles/doe-establishes-bipartisan-infrastructure-laws-95-billion-clean-hydrogen-initiatives for more information.

B28	Submitter: Michael Allawos, Allawos & Company (michael.allawos@allawosandcompany.com) Q: Would SoCalGas be interested in a partnership with San Bernardino International Airport to go after the $8 billion for a proposed hydrogen production facility to provide hydrogen for aircraft? A: The hydrogen hubs funding opportunity is primarily being handled outside of RD&D. SoCalGas RD&D will pass along the information to the team that is looking at proposed hydrogen hub activities.
B29	Submitter: Sean Anayah, California Energy Commission (sean.anayah@energy.ca.gov) Q: Public Utilities Code (PUC) 740.1(d) states that projects should not unnecessarily duplicate research undertaken by other organizations. How does SoCalGas ensure non-duplicity? Thanks. A: One of the one of the key ways SoCalGas RD&D strives to eliminate non-duplicity is by working through research consortia that will be described in more detail later in the public workshop. Research consortia tend to be organizations composed of multiple research entities and utilities across the United States and even North America. If, for example, a utility on the East Coast is conducting similar research, SoCalGas RD&D would be aware of it through working with them through its consortia efforts. In working with these research consortia, SoCalGas RD&D has the opportunity to leverage funding by pooling and coordinating funding from multiple resources. Other ways SoCalGas RD&D strives for non-duplicity are through review by subject matter experts on staff, workshops, connecting with the research community, attending conferences, and generally developing its network of researchers from across the United States and around the world. These efforts help SoCalGas RD&D stay up to date on the current state of the art and conduct research that advances technology without duplicating work that's already been done.
B30	Submitter: Sean Anayah, California Energy Commission (sean.anayah@energy.ca.gov) Q: Has the utilities' obligation to serve (CPUC 451) been considered as electrification replaces gas services? A: This question falls outside the scope of RD&D.
B31	Submitter: Sean Anayah, California Energy Commission (sean.anayah@energy.ca.gov) Q: How does SoCalGas propose to alleviate the burden to commercial food services, industry, and residents with future required installations of high-efficiency technologies?

	A: Generally speaking, SoCalGas could help alleviate the burden by improving or increasing the incentives to help reduce customer costs. SoCalGas can also help in this space by providing education on the type of technology available to the customer base. One of the major problems associated with the turnover to high-efficiency equipment is that not a lot of restaurant operators are aware that the technology exists. Thus, education and outreach will be a great resource to help address this concern. Two examples of such programs outside of SoCalGas RD&D are the customer programs that develop incentives for high-efficiency equipment and the Energy Resource Center, which includes a demonstration kitchen where customers can test out new, high-efficiency equipment and learn more about it.
B32	Submitter: Charles Sponberg, SoCalGas (csponberg@socalgas.com) Q: Are there any micro projects that would digest home food and yard clippings into methane that could then make power? A: SoCalGas RD&D has engaged with Cal State University, Los Angeles on its senior design projects over the past few years. One of the senior design projects involved operation of a Home Biogas Unit, a small anaerobic digester designed to fit into a residential backyard. The methane produced could then be used to operate a small cooking device. More information about this project is available on page 36 of the SoCalGas RD&D 2019 Annual Report.
B33	Submitter: Charles Sponberg, SoCalGas (csponberg@socalgas.com) Q: What is the longevity and reliability outlook for the fuel cells in use and for lower-cost future fuel cells? A: The fuel cells that SoCalGas RD&D is looking into have a claimed longevity of five to ten years, depending on the fuel cell technology and manufacturer. In most cases, the systems have much longer lifespans, only requiring the fuel cell stack (catalyst) to be replaced at the five-to-ten-year mark. Assessing degradation in power output is one of the goals for RD&D lab and field evaluations of new technologies. In addition, some of the systems require minimal maintenance, such as filter replacements. As for the reduction in fuel cell cost, this is something RD&D hopes to achieve through its projects—both directly through foundational research into new fuel cell technologies and indirectly through demonstrating the benefits, providing a pathway to scaled production.
B34	Submitter: Charles Sponberg, SoCalGas (csponberg@socalgas.com) Q: I may have missed it, but will this presentation be available for viewing again?

	A: A recording of the full workshop is available on the SoCalGas RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd.
B35	Submitter: David Xu, PG&E (dxx2@pge.com) Q: How does your company conduct deployment of the completed R&D projects? A: If the technology reaches commercialization, one pathway is to use the technology internally for potential deployment in SoCalGas operations. For other technologies and products, SoCalGas RD&D seeks to identify a good commercialization pathway for those technologies. Such pathways may include a commercialization partner to help a startup company or a technology provider to bring that technology to market. SoCalGas RD&D then works to advance that technology into the commercial space so that it can provide benefit to SoCalGas customers.
B36	Submitter: David Xu, PG&E (dxx2@pge.com) Q: How is your upper management's support of the R&D [projects]? [Have there been] budget increases or decreases in recent years? A: The SoCalGas RD&D program and the annual budget are authorized by the CPUC via the General Rate Case process. Budget allocations outlined in the Research Plan are submitted to the CPUC via a Tier 3 Advice Letter and approved annually by Resolution.
B37	Submitter: David Xu, PG&E (dxx2@pge.com) Q: Can the current infrastructure handle the hydrogen? If so, what [is] the supporting evidence? If not, what is the viable plan and the associated cost estimation? A: Research is being conducted to perform due diligence on all portions of the existing gas infrastructure to determine the effect of various blends of hydrogen. The status of existing projects can be found in the 2021 RD&D Annual Report, Appendix *2021 Summary of Ongoing and Completed Projects*. Since research is ongoing, publications are pending.
B38	Submitter: Arezoo Khodayari, California State University, Los Angeles (akhoday@calstatela.edu) Q: Thank you for the great update. What is the plan to sustain the collaboration and partnerships that you have established with your current university partners? A: Part of the workshop outreach effort is to engage with current SoCalGas RD&D research partners as well as new research stakeholders to help identify new technologies and research areas. RD&D looks forward to continuing to

	have those discussions with its current and potential research partners to refine the research program and the plan for 2023.
B39	Submitter: Arezoo Khodayari, California State University, Los Angeles (akhoday@calstatela.edu) Q: Will there be an update later today about the status of the hydrogen blending with natural gas and its prospects? A: Today's presentation won't cover any specific projects in great detail, as there is a lot to cover in the 2023 Research Plan, but please feel free to e-mail rddinfo@socalgas.com with a specific question.
B40	Submitter: Arezoo Khodayari, California State University, Los Angeles (akhoday@calstatela.edu) Q: How can we see the list of participants here on the dashboard? Also, how can we change the name that appears on the screen? A: Our workshop platform does not have the functionality to show all attendees during the broadcast. For a list of organizations represented at the workshop, please refer to section 3.2 of this document.
B41	Submitter: Norman Pedersen, Southern California Generation Coalition (npedersen@hanmor.com) Q: Where will you post the workshop feedback questions and other handouts on the SoCalGas website? See the Public Workshop Notice. A: A recording of the workshop is available on the SoCalGas RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd. The workshop feedback questions are included in this document in Appendix B and C.
B42	Submitter: Norman Pedersen, Southern California Generation Coalition (npedersen@hanmor.com) Q: Where will you post the slide deck on the website? A: A recording of the workshop is available on the SoCalGas RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd.
B43	Submitter: Norman Pedersen, Southern California Generation Coalition (npedersen@hanmor.com) Q: In your feedback question #2 about power generation, are you talking about fueling the power generation with blended fuel or fueling with 100% hydrogen? If the latter, how would you separate the hydrogen from the blended gas flow?

	A: For question #2, we are specifically talking about hydrogen blended fuel. However, we are also interested in achieving 100% hydrogen utilization in some cases. The ultimate goal would be for the customer to receive hydrogen (blended or pure), and for their equipment to be compatible the fuel composition received. Q: In the case of 100% hydrogen, how would the hydrogen be separated from the blended gas flow? Is the question: "In the future if there was a supply of 100% hydrogen, could we enable the power generation to be fueled along that supply?" A: Ideally, when hydrogen is delivered to the customer, whether 100% hydrogen or blended with natural gas, the customer's equipment would function normally without the need to separate the hydrogen. If the hydrogen needed to be separated from the natural gas for a specific use case, there are technologies that can facilitate this, such as the HyET hydrogen separation technology highlighted on Page 23 of the 2021 RD&D Annual Report.
B44	Submitter: Julieta Lafond, Sempra (JLafond@semprautilities.com) Q: Will you be describing more on what type of projects are part of the allocations, e.g., Low Carbon Resources, Customer End-Use Applications? A: Yes. The workshop presentation includes deep dives into each of the five programs within RD&D. The presentations describe what each program focuses on and what research areas have been identified for 2023. A recording of the workshop is available on the SoCalGas RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd.
B45	Submitter: Julieta Lafond, Sempra (JLafond@semprautilities.com) Q: Will there be collaborations with disposal companies to enable users and communities to donate their organic waste? A: Thank you for the suggestion. This type of strategy will likely be required to enable RNG at scale. In some municipalities, organic waste is already going to an anaerobic digester to make renewable natural gas, which then fuels the waste hauler's fleet. For example, CR&R Environmental is injecting renewable natural gas produced at CR&R's anaerobic digestion facility in Perris, California, into the SoCalGas pipeline. For more information, visit the SoCalGas website: https://www.socalgas.com/sustainability/renewable-gas/rng-success-stories/crr-environmental.
B46	Submitter: Lorna Holt, SoCalGas (lmholt@socalgas.com) Q: You showed a list of benefits. Is there a particular benchmark used for the overall benefits? A: Thank you for the question. SoCalGas RD&D has a rigorous project selection process. The projects are first vetted and the benefits to SoCalGas ratepayers

	identified. Then, RD&D staff conduct an internal review for funding approval before the project moves forward.
B47	Submitter: Lorna Holt, SoCalGas (lmholt@socalgas.com) Q: Do you know when other workshops will be held? Are they quarterly? A: SoCalGas RD&D holds a public workshop once a year to help prepare the following year's research plan. In addition, SoCalGas RD&D holds quarterly research webinars where RD&D staff and project research partners share details of projects that are active or have been recently completed. Recordings of past webinars and information about upcoming webinars can be found on the RD&D website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd.
B48	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: How and to what extent does SoCalGas coordinate its research projects with the Gas Research Institute? A: The Gas Research Institute (GRI) merged with Institute of Gas Technology (IGT) to become the GTI Energy in 2000. SoCalGas RD&D has maintained a close and long-standing relationship with GTI Energy and its predecessors. SoCalGas RD&D also coordinates a number of research projects through consortia. GTI Energy is an important part of the ecosystem for generating new projects, coordinating new research teams, and applying to funding solicitations. GTI Energy administers both the Operations Technology Development and Utilization Technology Development consortia.
B49	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Does the research program include analyses of alternatives to underground storage fields such as Aliso Canyon? Has SoCalGas studied means of making these underground storage fields less prone to explosions or methane releases? A: Currently, SoCalGas RD&D is not funding research in alternatives to underground storage fields. The SB1371 Leakage Abatement RD&D Program has funded research to detect, quantify, and minimize methane emissions at SoCalGas facilities including underground storage fields. For more information, see https://www.socalgas.com/regulatory/R1501008.
B50	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Has SoCalGas conducted research on preventing large-scale transmission lines from failures in the desert area? A: Yes. SoCalGas has conducted research supporting pipeline integrity, including improving inspection technologies such as inline inspection (ILI) tools to detect corrosion and mechanical damage through the research consortia Pipeline Research Council International and NYSEARCH. The status of existing

	projects can be found in the 2021 RD&D Annual Report, Appendix *2021 Summary of Ongoing and Completed Projects*.
B51	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Doesn't renewable natural gas create GHG emissions when it is burned by the end user? What are the net GHG emissions when RNG is used by regular end users? A: Burning natural gas, whether renewable natural gas (RNG) or fossil-sourced natural gas, produces GHG emissions at the point source. However, from a perspective of net GHG emissions and net carbon intensity, RNG results in reduced GHG emissions and lower carbon intensity compared to fossil-sourced natural gas. In many cases, RNG can demonstrate net-zero or net-negative carbon intensities. Please see the California Air Resources Board's (CARB) most recent GREET modeling outputs demonstrating negative carbon intensities of RNG, particularly when used as a transportation fuel, at https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation. For context, the feedstock that is used as an input to produce RNG is primarily diverted from waste streams—including dairy manure, forestry residues, organic food waste, and other biomass—that would otherwise emit large quantities of methane. Methane has a much higher carbon intensity than CO_2. By diverting those feedstocks to produce fuels such as RNG, those methane emissions are reduced or eliminated. Additionally, the RNG that is produced can displace demand for fossil-sourced natural gas, resulting in further emissions reductions and increased environmental benefits.
B52	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: How much RNG is potentially available to supply California natural gas users? Could as much as 50% of supply come from RNG sources? A: A recent CARB inventory report on GHG emissions has demonstrated that as much as 7% of California's GHG emissions comes from agricultural and forestry activities. Much of these can be diverted to produce RNG. The California legislature has passed several bills regarding expanding RNG development or procurement. For example, SB 1383 involved reduction of biogenic methane emissions and resulted in the development of large-scale anaerobic digestion as a means to divert waste streams to produce RNG. As a result of SB 1440, California will explore managing its woody biomass resources and waste forestry and agricultural residues through gasification or pyrolysis to produce biomethane, deliver RNG, and reduce short-lived climate pollutant emissions.

	SoCalGas is seeking to increase the proportion of RNG in the natural gas it delivers to its customers. Currently, SoCalGas' goal is for RNG to make up 20% of all natural gas it delivers by 2030.
B53	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Does the production of RNG produce toxic chemicals or other waste products that must be disposed of safely? A: There are multiple pathways—including biomethanation, anaerobic digestion, and gasification—that can produce RNG. In addition, multiple feedstocks can be used as inputs in these pathways. However, RNG is most often produced from biogas sources, such as the anaerobic digestion of animal and food waste, landfills, and wastewater treatment facilities. These biogas sources produce roughly a 60:40 mixture of methane and carbon dioxide, respectively, that is separated using gas separation technologies such as membranes, amine scrub, and pressure swing adsorption. Other ways to produce RNG are the conversion of carbon dioxide using hydrogen in biomethanation or thermochemical process that produce nearly pure methane. In general, production of RNG does not, by necessity, result in toxic chemicals that need to be managed, stored, or disposed of. During certain processes using specific feedstocks, some toxic compounds can be produced temporarily and often in small quantities, usually at parts-per-million (ppm) levels; these are usually destroyed, converted, or neutralized in later steps of processing. Regarding biogas sources, hydrogen sulfide is produced naturally along with carbon dioxide and methane during the decomposition of our waste streams and ranges from 50 to 5,000 ppm by volume but can reach up to 20,000 in some cases. Hydrogen sulfide is easily removed from renewable and fossil natural gas using well established technologies that are common in the oil and gas industry. In addition to hydrogen sulfide, siloxanes can be produced from landfills and may be present in landfill gas. Tars can be formed during the first stage of gasification if it is conducted at low temperatures. SoCalGas does not allow any toxic content, from RNG or otherwise, into its gas grid.
B54	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Right, and has there been research in storage of CO_2, and possibly using SoCalGas underground storage facilities? A: SoCalGas RD&D has not supported any efforts to store CO_2 at any SoCalGas' underground storage sites, however, SoCalGas RD&D have participated in a CO2 injection and storage study in the central valley with Clean Energy Systems (CES) that was completed and presented in SoCalGas' RD&D 2019 Annual

	Report. RD&D staff are open to evaluating potential research projects in this area involving geologic or other long-term sequestration. SoCalGas RD&D has supported several projects looking at utilizing CO_2 to produce fuels or durable products, such as building materials or plastics.
B55	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: The San Bruno explosion happened in part because of a power failure at a PG&E compressor station. When the power came back on, there was a surge of pressure that may have triggered the explosion. Is SoCalGas conducting research on how to prevent this type of incident in its transmission system? A: The San Bruno incident occurred in 2010. Much has transpired since then to address the issues involved. SoCalGas has pressure control systems in place to trip and prevent system over-pressurization. Basic Process Control Systems and Safety Systems are designed to have redundant sources of power supply.
B56	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Why has the repair on Line 400 taken so long and what can be done to speed up the restoration process? A: This question falls outside the scope of the SoCalGas RD&D Program.
B57	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Has SoCalGas explored the use of treated effluent water as a source of water for hydrogen electrolysis? A: Our understanding is that treated effluent water can always be further treated to reach purity levels required for existing electrolyzer technology. SoCalGas RD&D has not yet been involved in any projects that have explored directly electrolyzing low-purity water, such as brackish or effluent water.
B58	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Does SoCalGas anticipate delivering hydrogen to fueling stations via pipeline or via trucks? A: RD&D is investigating several avenues for supplying fueling stations with hydrogen, including separating hydrogen from a blend of gases delivered by pipeline[24] and modular electrolyzers for distributed hydrogen production.[25]
B59	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Are there any active research programs regarding using hydrogen in maritime settings?

[24] Renewal: SoCalGas RD&D 2021 Annual Report, p.23
[25] Renewal: SoCalGas RD&D 2021 Annual Report, p.78

	A: There are currently two such active projects. To learn more, see the SoCalGas RD&D 2021 Annual Report on pages 167 and 168. The relevant project titles are "CALSTART Hydrogen Zero Emission Tugboat Design" and "GGZEM Harbor Craft Demonstration." Both projects received H2RAM funding from the CEC.
B60	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Is EPRI doing comparable research on fuel cell backup power applications? Is SoCalGas coordinating with their efforts? A: We are not aware of any active EPRI fuel cell projects at this time. However, they have conducted such projects in the past and are interested in the technology. We regularly coordinate and participate in projects directly with EPRI. We also participate in the Low Carbon Resources Initiative, which EPRI co-manages.
B61	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Fuel cells have been available for many years, but they seem to be like nuclear fusion projects, too many years in the future to be practical. Have fuel cell costs declined in recent years and is lowering their costs a focus of your research? A: There has been a steady decrease in fuel cell prices over the past decade in Japan, where the ENE-FARM program has deployed over 400,000 fuel cells to residential customers. This is a result of technology advancements and market scale. This type of price reduction is something that RD&D is interested in achieving in California. RD&D is interested in directly reducing costs through fundamental research as well as demonstrating the benefits of fuel cells in the field so they can achieve widespread adoption.
B62	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Do fuel cells require the use of expensive imported rare earth elements or other hard-to-obtain materials? A: This is dependent on the fuel cell technology, as well as the manufacturer. Each system is a little different; some technologies do not require precious metals. Developing technologies that reduce the use of these materials is of interest to SoCalGas RD&D.
B63	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Is the CAISO supportive of the increased use of fuel cells on the grid? Are fuel cells forecast to be an important source of generation over the next 20 years? A: The RD&D team can't speak to this, but SoCalGas does have policy teams dedicated to working with CAISO and other regulators to address this question.
B64	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com)

	Q: For industrial and commercial applications, will customers have to replace existing end-use devices—boilers, fryers, etc.—to use hydrogen as a fuel source instead of natural gas? A: The Customer End-Use Applications subprogram is actively working with researchers and original equipment manufacturers to develop solutions that enable the SoCalGas customer base to retrofit its existing end-use devices to use blends of hydrogen. It remains to be seen how this will play out in the long term, when pure hydrogen might be the main fuel source, but it is a topic that SoCalGas RD&D is exploring.
B65	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: What type of safety issues does the use of hydrogen present to end users and the existing pipeline systems? It is my understanding that pure hydrogen can degrade existing pipelines and I would anticipate end-use equipment as well. A: There are potential safety concerns regarding burner flashback that SoCalGas RD&D is currently exploring, but preliminary research suggests that at low blends of hydrogen (0-30%), flashback is typically not a concern and there are no major safety hurdles at the lower blends. As far as the higher blends are concerned, flashback could be a part of SoCalGas RD&D research. RD&D staff are currently exploring design improvements to reduce any possible safety issues. Gas Operations RD&D is currently funding research to identify any potential safety considerations or gaps that need to be addressed with the addition of hydrogen blends to the natural gas infrastructure. The status of existing projects can be found in the SoCalGas RD&D 2021 Annual Report, Appendix 2021 *Summary of Ongoing and Completed Projects*.
B66	Submitter: Jason Zeller, UCAN (Jazzell2@yahoo.com) Q: Is SoCalGas looking into using fuel cells as a source of battery-type storage for use when renewable generation declines in the late afternoon/evening? A: This is one of the use cases that SoCalGas RD&D is interested in researching and demonstrating around fuel cells. Hydrogen could be generated from renewable energy during the day via electrolysis, stored, and then used to fuel a fuel cell to produce power. This could be done at the microgrid level behind the meter or at grid scale. In addition to reducing emissions in the evening, hydrogen storage and fuel cells help improve energy resilience.

Appendix C: Post-Workshop Stakeholder Input

C1	Submitter: Ron Chong, **Road Runner** (ron.chong@roadrunner.com) **Q:** Thanks for the opportunity to participate in the Public Workshop last Wednesday. It was interesting to see the wide variety of projects past and present. Maybe you could share some of these projects to business and residential users, especially those which will be beneficial by lowing their carbon footprint and utility bills. A handout could be inserted into the utility bills, maybe quarterly and/or promoted online. A few comments on hydrogen blending. Hydrogen's energy content is lower than methane on a volume basis and this will lower the heating value supplied to consumers. What does that do to the amount of gas that is combusted? How much more gas has to be consumed for cooking and heating? Does it raise the price for the consumer? **A:** You are correct when you say hydrogen contains less energy, by volume, than natural gas. Since hydrogen is less dense than natural gas, however, a gas blend flows faster than pure natural gas. Thus, for many residential appliances, a greater volume is delivered and combusted to produce the same amount of heat. Notably, this isn't true for all applications. At low hydrogen blend ratios, the lower energy content is approximately canceled out by the higher flow rate, and the overall amount of heat delivered is similar. At higher blend ratios, though, the gas eventually reaches a maximum flow rate and the amount of heat delivered also reaches a maximum value. At some ratio, this maximum heat value becomes increasingly less by volume than that of pure natural gas. The higher flow rate does not necessarily cause the bill to increase, however, because SoCalGas charges by energy content, not by volume. Some combustion effects, like flame size, may affect heat efficiency and thus energy usage.
C2	Submitter: Ron Chong, **Road Runner** (ron.chong@roadrunner.com) **Q:** Hydrogen is known to cause embrittlement in some metal at certain pressures and temperatures. In the refinery, hydrogen attacks stainless steel and causes it to crack. Will it affect the burner material on our cooktops similarly? **A:** Cooktops operate at relatively low pressures, so embrittlement is not expected to be as problematic as it can be in high-pressure cylinders and pipes. Due to the proximity of the hydrogen flame, though, the cooktop burner may grow too hot, which could affect durability. The SoCalGas RD&D team is actively planning to look into this.
C3	Submitter: Ron Chong, **Road Runner** (ron.chong@roadrunner.com) **Q:** SoCalGas injects mercaptan (sulfur) to odorize methane gas for safety. Will the addition of hydrogen in natural gas result in a reaction of the hydrogen with the sulfur to form hydrogen sulfide (H2S)? If there is any moisture present in the natural gas, it may form an acid solution and cause

	corrosion because the pipes to deliver natural gas to homes are galvanized steel pipes. What are the safety issues in using high hydrogen content in the natural gas delivered to residences? A: The SoCalGas RD&D team does not expect sulfur compounds to react with hydrogen at room temperature in the distribution system, but it could be different in power plants. Sulfur compounds could form sulfur dioxide (SO_2) upon combustion and would then be converted to sulfite (SO_3) on a Selective Catalyst Reduction (SCR) catalyst. The RD&D team is actively evaluating the effect of hydrogen blends on SCR catalyst performance in the presence of SO_2. Downstream of the SCR unit at lower temperatures, SO_3 would react with water vapor to form sulfuric acid which would likely cause corrosion issues.
C4	Submitter: Rick Brown, Aspen (rick.brown.138@gmail.com) Q: Can you send a link to the location of the webinar PowerPoint presentation? A: A recording of the workshop is available on our website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd. Look for the section labeled “Public Workshop Notice” and follow the link marked “View Recording.”
C5	Submitter: Vicki Shattuck, Spire Energy (vicki.shattuck@spireenergy.com) Q: I was able to attend the webinar yesterday and had thought I downloaded the deck but am unable to find it now. Can you give me access to the presentation from yesterday? A: A recording of the workshop is available on our website: https://www.socalgas.com/sustainability/research-development-demonstration-rdd. Look for the section labeled “Public Workshop Notice” and follow the link marked “View Recording.”
C6	Submitter: Bianca Tippett, Sowing Seeds for Life (receptionist@sowingseedsforlife.org) Q: It was nice to listen in on the webinar. I will tell you right now I had no idea that SoCalGas Company has so many projects each year to help save energy. Your beginning spokesman Mathew Gregori was very well spoken and knew what he was talking about. I did have a couple questions. First, in what ways can we, at home, try to save on energy? Are there certain windows we should have or particular types of appliances? Second, what type of scholarship funding do you provide? A: Please visit our “Ways to Save” webpage:

	https://www.socalgas.com/save-money-and-energy/energy-saving-tips-tools/ways-to-save. You can complete your Energy Profile and get a household energy analysis and customized energy-efficiency recommendations. You can also build a personalized Savings Plan to help you keep track of your energy-efficiency progress and ultimately help lower your bills. Please, also, visit the Scholarship Program webpage: https://learnmore.scholarsapply.org/socalgas/ SoCalGas has established a scholarship program to assist current high school seniors in select Southern California counties who plan to continue their education in college pursuing a STEM, finance, or accounting field of study. The program is administered by Scholarship America®, the nation's largest designer and manager of scholarship, tuition assistance, and other education support programs for corporations, foundations, associations, and individuals.
C7	Submitter: Bianca Diaz-Hladek, Mar Vista Family Center (bdiaz@marvistafc.org) Q: It's really great that SoCalGas is working to provide a better environment using natural gas. I especially appreciate the effort in reaching out to all communities through partnerships with universities and non-profits that SoCalGas can support with ensuring that underrepresented communities are included. I would like to learn more about how we can support these efforts through providing education to families in our community. Are there or will there be workshops that our staff can attend to implement this in our programming? I believe that getting people in our community to make environmental issues a priority is a great challenge for different reasons, one being the fear of higher prices. What is the best way for non-profits, that work directly with the community, to support these efforts in partnership with SoCalGas? Thank you so much for the opportunity to participate in the webinar and become informed of the RD&D Program. A: All attendees of the public workshop are automatically added to the RD&D email list to receive notification of future workshops and webinars. Anyone interested in signing up for notification should contact us by email at RDDInfor@socalgas.com.
C8	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: I recently read an article in the Los Angeles Times about the effects that heavy truck traffic coming to and from the Ports of Long Beach and Los Angeles are having on a low-income area of Wilmington. I believe that hydrogen-fueled trucks and locomotives could substantially (if not largely) eliminate much of the particulate and nitrous oxide pollution associated

	with heavy freight hauling operations near the port. Because many of the vehicles and locomotives involved are part of larger corporate fleets, it makes sense to focus on converting these vehicles to hydrogen and/or batteries as a first step towards decarbonizing transportation. I urge SoCalGas to pursue research initiatives in this area. A: The emissions from heavy-duty trucks traveling to and from the ports are a significant contributor to local air pollution. As you noted, this pollution often affects many disadvantaged communities located near the ports and along inter- and intra-state trucking corridors. SoCalGas RD&D currently has several active projects focused on heavy-duty trucking. Examples can be seen on pages 172-178 of the 2021 RD&D Annual Report. In addition, RD&D plans to allocate 30% of the 2023 Clean Transportation budget to On-Road projects, which focus on developing and demonstrating zero-emission vehicles to help address this critical issue, while simultaneously meeting the technical needs of fleet operators.
C9	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: The increased use of renewable generation in California and adjacent states has created a mismatch between peak power generation periods and times of peak demand, which typically arise after renewable generation declines. I urge SoCalGas to develop an RD&D project that would use excess renewable generation (in California) to power electrolysis of water to produce hydrogen that could be used in adjacent fuel cells to serve as a backup power source similar to battery storage. Rather than sending excess generation out of state, this excess generation could be used to create "green" hydrogen that could in turn power fuel cells as surrogate batteries. I recognize that SoCalGas's research program and budgets have already been set for 2022/2023, but I urge you to explore this option in your future research endeavors. A: We agree that the current dynamic with renewable energy production and customer energy use provides a good opportunity for hydrogen and fuel cells. This is an area RD&D is exploring developing more projects around. SoCalGas RD&D currently has two active projects with UC Irvine that seek to address this issue: “UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research” and “UCI Hydrogen Energy Storage and Integration with Dispatchable Power Generator System Design.” The latter of these is co-funded by the DOE. RD&D is also in the process of finalizing the contract on another related DOE-co-funded project with the National Renewable Energy Laboratory and GKN Hydrogen.
C10	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: I'm curious about the relative efficiencies of natural gas heat pumps versus electric heat pumps. Has SoCalGas (or someone else) examined the overall carbon footprints of these two technologies? A: For residential applications, GTI Energy published a study last year that compared a gas heat pump (GHP)-based combi system (furnace/water heater replacement) to alternatives, including electric heat pump options, using experimentally calibrated building energy models. The primary

	takeaway was that for the climate zones modeled, the GHP option provides the least-cost and lowest-GHG-emission approach for the current grid mix. This publication can be found at: https://docs.lib.purdue.edu/ihpbc/354/.
C11	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: It is my understanding that carbon capture and storage is an expensive technology and that the prospect of future leaks of the stored gas is a continuing concern. Has SoCalGas explored the possible commercial use of stored carbon dioxide? A: SoCalGas RD&D has worked with commercialization partners to help develop technology that can utilize CO_2 by conversion to durable goods like building materials and plastics or to fuels. RD&D has also supported projects to upgrade biogas by conversion of CO_2, through biomethanation, to RNG.
C12	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: Has SoCalGas or GTI, or any other group looked into whether there are inexpensive or low-tech means of modifying existing gas transmission and distribution pipelines to carry hydrogen? A: Currently, the focus of research has been on identifying the impact of introducing natural gas hydrogen blends into the existing infrastructure and determining any gaps in research. Research is being conducted in a variety of areas by several research organizations to provide the necessary technical basis for implementing hydrogen blends. The status of existing projects can be found in the SoCalGas RD&D 2021 Annual Report, Appendix *2021 Summary of Ongoing and Completed Projects*.
C13	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: Given the on-going challenges associated with the Aliso Canyon Underground Storage Field, has SoCalGas considered conducting some research on alternatives to the continued use of this facility? A: This question falls outside the scope of the SoCalGas RD&D Program.
C14	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: I urge SoCalGas to reach out to its suppliers in the Permian Basin and the San Juan Basin to use infrared sensors (or other devices) to survey sources of methane leaks both in production areas and along El Paso, Transwestern, and Kern River's pipelines. Methane is a far more potent global warming catalyst than carbon dioxide alone and efforts to control methane leaks need to be a priority. A: This question falls outside the scope of the SoCalGas RD&D Program.
C15	Submitter: Jason Zeller, UCAN (jazzell2@yahoo.com) Q: Many low-income communities in Southern California are bisected by freeways and/or industrial/warehouse facilities that have substantial

	negative localized health effects on affected communities. I urge SoCalGas to reach out to its network of community-based organizations to develop local RD&D projects in these areas that will reduce GHG emissions and improve local air quality. For example, retrofitting a backup diesel generator at a local hospital with a fuel cell. A: Working with community-based organizations (CBOs) to develop projects that benefit our local communities is of great interest to SoCalGas RD&D. Thank you for the project suggestion.
C16	Submitter: Peggi Hazlett, Greater Ontario Business Council (phazlett@ontario.org) Q: Thank you so much for such an informative workshop recapping the past year's RD&D projects and programs for SoCalGas. I really appreciate the connection with local universities and the emerging workforce. Strategically placing these projects on campuses brings an exposure to the next generation of research employees. As I stated in my question, partnering with institutions of higher education in the Inland Empire could be a win-win for everyone! With so many challenges facing the logistics and distribution industries, the emergence of alternative fueled trucks is key. Decarbonization of GHG emissions by replacing older vehicles that are impacting our region with hydrogen cell vehicles along with electric-powered fleets needs to be in the forethought of policy makers. I found the handouts to be particularly helpful and easy to read. Thank you for that!! If there is anything that we can do at the Greater Ontario Business Council to assist SoCalGas, please let me know. A: Thank you for your comments and your participation in our Public Workshop.

Appendix D: Project Selection Process

When identifying promising projects and evaluating them for potential funding, RD&D Program staff take a comprehensive yet flexible approach that enables them to 1) identify potential projects most in alignment with RD&D Program goals, state and federal environmental policy, and industry demand; 2) accurately assess the likelihood of potential projects to succeed; 3) work with proven partners and technologies over time; and 4) respond nimbly to changing market, technology, and policy drivers. In addition—remembering that some technologies will not result in concrete benefits until implemented at scale—RD&D Program staff consider the overall development and implementation process and research life cycle of a given technology or product.

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

Table 6: RD&D Program area staff explore many avenues to identify and conceive potential projects.

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

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

Policy Drivers	SoCalGas strives to align the RD&D Program with California's policy goals, including building and transportation decarbonization. RD&D Program staff leverage a network of relationships with experts at local, state, and federal agencies to track current and potential future policies and regulations in order to identify and develop project concepts to achieve these goals.

Although staff from each of the five program areas have distinct research interests, goals, and industry relationships, all follow a similar high-level approach to project identification and selection. In summary, program staff 1) identify potential areas for research, development, and demonstration and collaborate with researchers to develop project proposals; 2) prepare or receive project proposals; 3) review project proposals with the RD&D Program team and SMEs, considering a wide range of evaluation criteria and the overall portfolio strategy; 4) refine scopes of work for approved projects, if necessary; 5) allocate funding following SoCalGas accounting policies; and 6) execute the project contract and initiate project research.

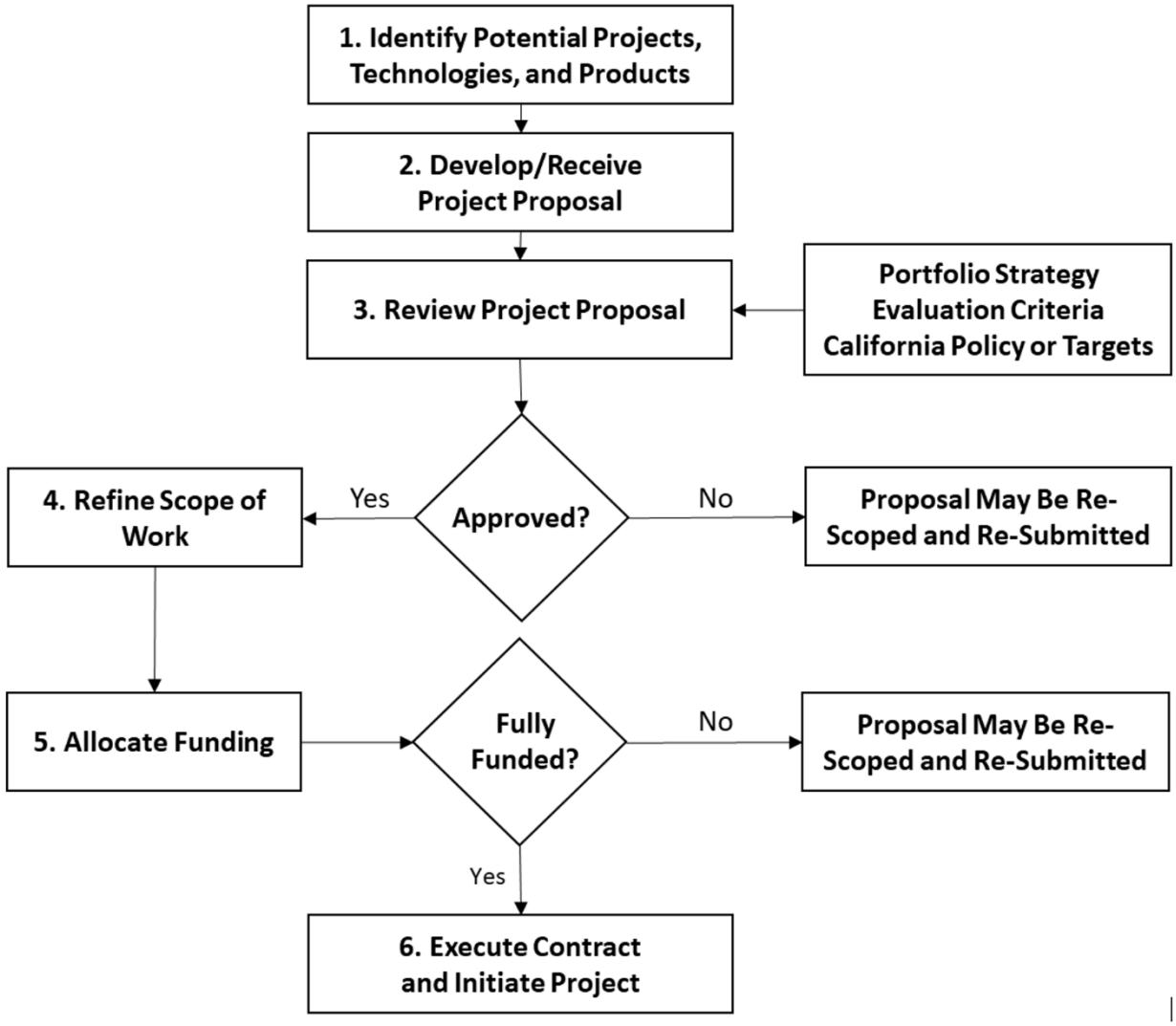


Figure 1: High-level internal RD&D project proposal review process.

During the internal project review process, RD&D Program staff evaluate potential projects using numerous selection criteria. Project selection criteria are based primarily on California Public Utility Code 740.1 which provides guidelines in evaluating the research, development, and demonstration programs proposed by electrical and gas corporations (Table 2). The criteria were also influenced by stakeholder input, industry best practices, and the RD&D staff's extensive experience

evaluating research proposals. , Program staff do not numerically score potential projects or, necessarily weight the selection criteria for several reasons, including the need to retain flexibility to respond to changing market, policy and technical conditions while supporting promising projects, the diversity of types and scope of individual projects, and the variety of business needs and policy drivers.

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

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

Equity	N/A	SoCalGas included equity in response to feedback from multiple stakeholders and regulators and was guided in part by the CPUC's ESJ Action Plan.

The 2023 project selection criteria are as follows:

Criteria	Description/Justification
Customer Benefit	RD&D Program staff also seek to advance a significant portion of the products, technologies, and solutions they help develop to the point where they can be implemented by SoCalGas and other utilities for the benefit of ratepayers. To assess this criterion, RD&D Program staff ask questions such as: Will advancing the proposed technology benefit gas utility ratepayers? If the technology becomes commercially available, how will it help SoCalGas customers, as well as internal (*i.e.*, RD&D Program operations teams) and external stakeholders in a meaningful way? Does the technology address a key policy driver relevant to the SoCalGas service territory? Is the research new and not duplicative of previous or ongoing work by other research and development (R&D) organizations?
Alignment with California Policy	The RD&D team also seeks to align its program with key company, state, and federal objectives. To assess this criterion, RD&D staff ask questions such as: Does the project address a key California state policy driver or corporate initiative? Does the project advance the state of the technology along a development roadmap? Does the research address an internal operational need?
Lead Investigator/Team	Successful R&D Program teams need industry knowledge and technical skills to succeed, but they must balance these characteristics with soft skills, such as curiosity, perseverance, people management, and critical and strategic thinking. To assess this criterion, RD&D Program staff ask questions such as: Are the researchers, labs, or technology developers skilled and experienced in the space? Do they have a track record of success in executing research projects of a similar scope and successfully leading research teams? Do they have unique capabilities or facilities for conducting the required research? Do they have the skills and resources necessary to commercialize the proposed new technology?
Technical Feasibility	Although the RD&D Program team funds early-stage RD&D Program projects, it has a responsibility to ratepayers to fund projects with a high likelihood of success. To assess this criterion, RD&D Program staff ask questions such as: Has the technology been vetted internally or externally for

	feasibility? Is the basic science sound? Does the technology display favorable thermodynamic modeling or technoeconomic fundamentals? Does documentation of proof-of-concept work exist?
Co-funding Collaborators	One of the key objectives of the RD&D Program is to leverage the funds it uses to support promising projects with significant additional funding from other organizations, such as public agencies, universities, and private businesses. In fact, in 2021, every dollar of RD&D Program funds expended was matched by an average of $5.20 in funding from other sources. To assess this criterion, RD&D Program staff ask questions such as: Are other R&D programs, government agencies, or industrial entities collaborating on the project, either via co-funding or time and expertise? Can co-funding collaborators help validate and substantiate the feasibility of the technical claims? Is co-funding available to leverage the RD&D Program funding? Are other stakeholders supportive of the research? Is there consortium involvement to minimize the risk of duplicating work?
Commercialization Potential	Ultimately, RD&D Program staff seek to advance a significant portion of the products, technologies, and solutions they help develop to the point where they can be advanced to market in support of energy decarbonization, safety, and reliability. To assess this criterion, RD&D Program staff ask questions such as: Does the proposed level of funding match the technology readiness level (TRL)? Does a clear path to commercialization exist for the technology that this research advances? Is there immediate and anticipated future demand for the proposed technology based on defined market trends and competitive advantages in comparison to the status quo or alternative technologies? Does the project team bring sufficient financial support to the project to fund multiple years of development runway? Is the project team working with established commercialization experts who have proven track records with similar products or technologies?
Equity Considerations	The RD&D Program seeks to advance and champion products and technologies that support widespread access to clean, affordable, and renewable energy for all Californians, including those living and working in Environmental and Social Justice (ESJ) communities. To assess this criterion, RD&D Program staff ask questions such as: Does the proposed technology directly address the specific needs of a Disadvantaged Community (DAC) or Low-Income Community (LIC)? Is the project sited near a DAC or LIC? Does the project include engagement by a

	Community Based Organization (CBO) or Diverse Business Enterprise (DBE)? Is the Principal Investigator (PI) a member of an underrepresented population?

Appendix E: Project Details

The project data provided is a current snapshot of the RD&D project portfolio including all current projects that are multi-year continuing into 2023 as of May 1, 2022.
For clarity, we have mapped our data response to 16 data fields described in the Discussion sub-section titled ***Detailed budgets broken down by research subprogram*** of the resolution.

a) **Project title**
b) **Unique number identifier for project**
c) **Program and sub-program**
d) **Project Start date**
e) **Project end date or anticipated end date**
f) **SoCalGas budget for project**
g) **Total cost contracted**
h) **Amount already spent**
i) **Amount still to be spent**
j) **Co-funding partners**
k) **Monetary contribution of each co-funding partner**
l) **Project benefits of research**
m) **Research area**
n) **Technology readiness level**
o) **Next steps at end of project**
p) **One-paragraph narrative description**

ATTACHMENT B

Advice No. 5991

Contracted Projects for 2023

No.	Project Title	Project Number	Program	Sub-program	Research Area	Start Date	Anticipated End Date	SCG Budget	Total Project Cost	Amount Already Spent	Amount Still to be Spent	Co-funders & Co-funding contribution	Project Benefits	Technology Readiness Level	Anticipated Next Steps at End of Project	Project Description
1	A Combined Water and CO2 Direct Air Capture System	20210219225633	Low Carbon Resources	Low GHG Chemical Processes	Low GHG Chemical Processes	10/1/2020	9/30/2023	$650,000	$3,135,447	$425,000	$225,000	DOE - $2,485,447	Environmental: GHG Emissions Reduction	Late Stage (TRL 7-9)	Field demonstration/testing	The objective of this project is to demonstrate the outstanding technical and economic performance of a transformational Hybrid Direct Air Capture ("HDAC") technology that simultaneously captures CO2 and water from the air. Air is passed over a CO2 selective sorbent to remove ≥85% of the CO2 from the air stream. The atmospheric water extraction ("AWE") section of the unit utilizes a novel isothermal pressure swing regeneration cycle with desiccant beds thermally coupled by heat pipes that provide a passive heat transfer mechanism to "cancel" the heat of water vapor adsorption. By proving system performance through a demonstration project, our initial technoeconomic analysis ("TEA") will be validated, showing that HDAC technology: 1) is deployable in many more locations with limited water resources, 2) improves the financial returns, and 3) reduces risks from volatility in the price of CO2. The end goal is field testing of the HDAC unit and preparation of a final report on the testing, results, conclusions, and recommendations; and a commercial analysis of the economic viability of the system and candidate locations for commercial deployment. .
2	Direct Air Capture Using Novel Structured Adsorbents	20210222231948	Low Carbon Resources	Low GHG Chemical Processes	Low GHG Chemical Processes	10/1/2020	9/30/2023	$300,000	$3,714,202	$200,000	$100,000	Svante - $354,356 Climeworks - $529,846 DOE - $2,500,000	Environmental: GHG Emissions Reduction	Mid Stage (TRL 4-6)	Final report and demonstration	The proposed technical approach is to construct and operate an integrated Direct Air Capture (DAC) system, fielding and testing a novel combination of Climeworks' DAC process and hardware with Svante's transformational structured adsorbent laminate filter, advancing the process and identifying optimization options for this DAC configuration. Field testing will be conducted on a renewable power generation site in California to capture operational data on the novel process and material combination under real conditions. Data will be used to advise techno-economics and life cycle analysis of the technology. The objective of this project is to conduct applied research and development to address identified technical barriers on an existing, DAC system to drive down DAC cost to US$140/tCO2 for a 1Mt/y plant. A TRL 5 integrated unit will be deployed into the field for testing, producing a concentrated CO2 stream of at least 95% purity.
3	PNNL Integrated CCU System (IC3M) for C1 and C2 Production Development	20210628235331	Low Carbon Resources	Low GHG Chemical Processes	Low GHG Chemical Processes	9/1/2021	8/30/2024	$660,000	$3,300,000	$0	$660,000	DOE - $2,640,000	Environmental: GHG Emissions Reduction	Early Stage (TRL 1-3)	Final report	PNNL has been developing the Integrated Capture and Conversion of CO2 to Materials (IC3M) platform to make products from CO2 captured. This is a unique and promising technological pathway that can be explored in the utilization context of Carbon Capture. This project will explore C1- and C2-based material production from CO2.
4	LLNL Modular Hybrid Electrobioreactor Demonstration	20220105098	Low Carbon Resources	Renewable Gas Production	Renewable Gas Production	3/1/2022	2/29/2024	$150,000	$1,000,000	$0	$150,000	DOE - $1,000,000	Environmental: GHG Emissions Reduction	Mid Stage (TRL 4-6)	Final report and demonstration	The objective of this project is to scale up and deploy LLNL's in-situ electro bioreactors to determine the feasibility and economics of a commercial demonstration. In particular, goals of the project are to increase scale and productivity of current-gen reactors by at least two orders-of-magnitude, optimize electrode and flow field topology to maximize process efficiency, demonstrate successful fabrication of optimized electrode geometries, evaluate stability of the technology under variable electrical loads and variable feedstock purities, and develop technoeconomic models that will aid in demonstration of the technology.
5	Centrifugal Dry Gas Reliability Enhancement IV (CPS-5-10A)	20220427201225	Gas Operations	Environmental & Safety	Environment	4/13/2022	4/13/2023	$3,734	$29,500	$0	$3,734	SCG $3,734 | PRCI Members $25,766	Reliability, Safety, Environmental: Reduced GHG Emissions, and Environmental: Improved Air Quality	Late Stage (TRL 7-9)	•Share/Publish Results	Dry seals are critical components in preventing release of GHG in centrifugal compressors. These seals, however, are known to fail resulting in releases in GHG to the environment and causing centrifugal compressor shutdowns that cause service interruptions. This project will investigate the causes of seal failures. In previous phases under GMRC which PRCI did not participate in, the project team used test rigs in the laboratory to collect data on seal performance and factors that caused seal failure. Those data were used in a model simulation to predict failure and causes. In phase IV, the team will continue its root cause analysis on seal failure modes based on operational parameters as well as seal materials. This additional phase will help improvements in the predictability model for seal performance that minimizes seal failures and prevents accidental release of GHG to the environment. At the end of the project, a final report will be delivered along with the seal failure predictive model to sponsors. The results of research will also be dissimilated to seal manufacturers to improve seal design and performance. SoCalGas could benefit in the future from better and more reliable seals as well as other utilities who operate centrifugal compressors. Ratepayers would also benefit with safer and less risk of disruptions in their energy supply.
6	Development and Evaluation of High Resolution Historical Climate Dataset Over California (GFO-19-501, Group 2)	2021010815138	Gas Operations	Environmental & Safety	Environment	6/30/2020	3/31/2024	$5,000	$1,368,550	$2,500	$2,500	SCG $5,000 | CEC (GFO-19-501) $1,363,550	Reliability and Safety	Late Stage (TRL 7-9)	•Deployment of Results •Share/Publish Results	Weather forecasting models are used to find utility infrastructure vulnerabilities in extreme weather events. Examples of such events include extremely dry conditions posing wildlife threats and extremely wet conditions causing floods and mudslides. The two climate models currently used for forecasting are: (1) West Weather Research and Forecasting Model for California "dry" simulations, and (2) Desert Research Institute's Weather Research and Forecasting model for California "wet" simulations. A California Energy Commission (CEC) project titled, "Development of High Temporal and Geographical Resolution Characterization of Historical Climatic Conditions in California (CEC GFO-19-501, Group 2)," was awarded to UC San Diego and Scripps Institution of Oceanography. It will assemble climate data from California between 1980 to 2019 to be used to improve both models for forecasting weather conditions. The goal is to provide models that will enable utilities to assess infrastructure risks associated with exposures to short-term and long-term extreme weather events. The datasets will be made available in the cloud to utilities and climate researchers. The model results will also be made publicly available. The project team has started compiling the datasets for higher resolution refinements. SoCalGas is participating on the Technical Advisory Panel for the project.
7	Fuel Reforming and Segregation as an Alternative for Compressor Fuel (GHG SRP CPS-14-07)	20210408133828	Gas Operations	Environmental & Safety	Environment	3/16/2021	3/16/2023	$12,905	$289,100	$5,682	$7,223	SCG $12,905 | PRCI Members $276,195	Environmental: Improved Air Quality and Environmental: Improved Air Quality	Early Stage (TRL 1-3)	•Further Technology Development/Prototype	This Pipeline Research Council International greenhouse gas strategic research priority (GHG-SRP) project studies the use of hydrogen as a fuel to run compressor engines, and focuses on large bore, slow speed lean burn engines. Compared to fossil-fueled methane, hydrogen fuel has the advantage of not producing GHG emissions. The first tasks are to conduct a literature review and to produce a whitepaper. These will investigate methane reforming technologies to produce hydrogen fuel, and will explore how hydrogen-blended fuel affects engine operations, performance, and emissions. Methane reforming uses methane as a feedstock in a chemical process to generate hydrogen. In petroleum refining, a steam reformer and water-shift reactor are used to produce hydrogen for desulfurizing fuels. The first phase of this project looks at new and existing steam reforming technologies and compares the advantages and disadvantages of each. From this comparison, a technology will be selected to be used to produce hydrogen for compressor engines for laboratory evaluation, prototype development, field evaluation, and durability assessment. This project will also look at how hydrogen blended fuel will affect engine efficiency, GHG emissions, and NOx emissions. Prior research on methods of controlling the engine to accommodate varying levels of hydrogen and combustion modeling will be investigated. This work dovetails with other projects investigating the reduction of methane in engines exhaust. The goal is to reduce GHG emissions from compressor engines. The results of the study could lead to using hydrogen or hydrogen-blended fuels as a fuel for compressor engines including from SoCalGas's compressor engines
8	Greenhouse Gases Emissions Reduction (SRP-GHG-01)	20210720172927	Gas Operations	Environmental & Safety	Environment	1/1/2021	12/31/2023	$32,339	$3,838,835	$11,368	$20,971	SCG $32,339 | PRCI Members $3,806,496	Environmental: Reduced GHG Emissions	Mulitple - Program supports various projects.	•Mulitple - Program supports various projects.	Greenhouse gas (GHG) emissions are a global issue and have impact on the natural gas industry. Pipeline Research Council International established a Strategic Research Priority (SRP) to coordinate the efforts across all technical committees. The SRP goal is to provide a roadmap of projects researching means to significantly reduce GHG emissions from the natural gas transmission system. This information will provide the natural gas industry with GHG reduction solutions to implement and reduce its carbon footprint. The SRP funded and started eight projects in 2021: Regulatory Support for GHG Emission Reductions (CPS-11-09), Continuous Monitoring and Diagnostics for Facility Efficiency (CPS-14-06), Methods to Reduce Pipeline Blowdowns to Effectuate Repairs/Inspections (MATR-3-15), Flow Sensors for Continuous Monitoring and Diagnostics for Equipment Efficiency Monitoring (MEAS-5-28), Methane Leak Detection and Quantification (PL-1-08), and CPS-14-05 CFD Study of Prechamber Ignition Mechanism for GHG Reduction. More details can be found in the individual project summaries for: Fuel Reforming and Segregation as an Alternative for Compressor Fuel (CPS-14-07), Improvements in Facility Efficiency (CPS-17-07), and Reciprocating Engine Exhaust Methane Slip Reduction (CPS-17-08). In addition to the projects that started in 2021, two ideas are being considered for projects under GHG SRP: Low-Cost Instruments to Detect/Quantify Leaking Seals, Packings, or Dump Valves, and High Flow Sampler Replacement.

9	ORFEUS Obstacle Detection Technology for Horizontal Directional Drilling (5.16.k.2)	2018071855	Gas Operations	Environmental & Safety	Safety - Damage Prevention	12/1/2017	3/31/2024	$62,346	$3,786,446	$62,346	$0	SCG $62346 | OTD members $787,654 | PHMSA $993,970 | Others $1,942,476	Reliability, Safety, Operational Efficiency, and Environmental: Reduced GHG Emissions	Late Stage (TRL 7-9)	• Commercialization • Share/Publish Results	Regulations require pipeline operators to mitigate geohazard and land use threats to pipeline integrity, particularly on slopes near river and stream crossings. In addition to applicable regulatory requirements, detecting and mitigating geohazard motion and ROW land use encroachment threats are primary elements of pipeline operators' damage prevention strategies and programs. This goal of this project is to develop improved methods for satellite-based tools and technologies to enhance detection of natural changes, seasonal flooding, erosional effects, channel dynamics, and ground movement affecting pipelines installed near river crossings. Successful completion of this project will identify three leading classes of satellites available in the market to support pipeline integrity programs, enhance operators' risk mitigation programs through more frequent high-resolution detection of risk factors, and right-of-way (ROW) surveillance. In 2021, the project continued with the synthetic aperture radar (SAR) data acquisition for four sites. Validation of change results against field data and high-resolution optical data is underway. A final report was drafted to summarize the results and methods for monitoring of ROWs at river crossings along with the capabilities and limitations of satellite technology. .
10	Reciprocating Engine Exhaust Methane Slip Reduction (GHG SRP CPS-17-08)	20210408135911	Gas Operations	Environmental & Safety	Environment	3/16/2021	3/16/2023	$22,046	$454,300	$12,708	$9,338	SCG $22,046 | PRCI Members $432,254	Environmental: Improved Air Quality and Environmental: Improved Air Quality	Early Stage (TRL 1-3)	• Further Technology Development/Prototype	This Pipeline Research Council International Strategic Research Priority project is a multi-year effort to reduce criteria pollutants and greenhouse gas (GHG) emissions from legacy compressor engines. The project will investigate the effects of quenching the main chamber, nitrogen formation mechanism and pre-combustion chamber size, and an early ignition and seeding radicals in the main chamber. The initial planned literature review has been completed. The team is currently tuning the computational fluid dynamic model that will be used for pre-combustion chamber design and prototyping. Next steps include laboratory and field evaluation of the prototype. The results from this project could be used to retrofit legacy engines and changes in controls, which could lead to reductions in criteria and GHG emissions. Retrofitting legacy engines to reduce GHG and criteria pollutants is less expensive than replacing them. This option benefits ratepayers with a much more cost-effective alternative in combating climate change and improving air quality.
11	Smart Shutoff Technology for Commercial and Residential Buildings (5.20.k)(CEC GFO-19-502, group 2)	20200109154639	Gas Operations	Environmental & Safety	Safety	8/4/2020	8/4/2023	$25,019	$1,200,000	$25,019	$0	SCG $25,019 | OTD Members $118,981 | CEC $1,056,000	Reliability and Safety	Late Stage (TRL 7-9)	• New Research Project to Advance TRL Level • Commercialization	This project is funded by the California Energy Commission (CEC) to improve the safety and integrity of natural gas infrastructure. The objective is to provide the natural gas industry with the necessary hardware and software components to create a full-solution, smart shut-off system capable of detecting and terminating gas flow in response to a hazardous incident such as fire, flood, or gas leak inside a residential or commercial structure. Deployment of smart shut-off systems can provide the localized detection and mitigation needed to prevent hazardous events from becoming excessively dangerous and costly. This project will demonstrate and validate the technologies needed to implement a smart shut-off system, as well as identify any gaps or barriers that need to be addressed prior to commercialization. In 2021 the project scope was modified to better understand the deployment of a Low Power Wide Area Network (LPWAN) at scale after identifying knowledge gaps in the communication methodology. In 2021, a Site Readiness Report was prepared along with a draft Hardware Validation Report. Field demonstrations for the Smart Safety Shutoff System are scheduled to begin in 2022. .
12	Stanford Natural Gas Initiative Program	160101318	Gas Operations	Environmental & Safety	Environment	1/1/2019	12/31/2023	$225,000	$1,795,000	$225,000	$0	SCG $225,000 | NGI Members $1,570,000	Safety, Environmental: Reduced GHG Emissions, and Environmental: Improved Air Quality	Mulitple - Program supports various projects.	• Mulitple - Program supports various projects.	The Stanford Natural Gas Initiative (NGI) is a collaboration of more than 40 research groups at Stanford University drawn from engineering, science, policy, geopolitical, and business disciplines that works with a consortium of industry partners and other external stakeholders to generate the knowledge needed to use natural gas to its greatest social, economic, and environmental benefit. It focuses on creating innovative technologies for natural gas production from unconventional sources, alternatives to hydraulic fracking, and offshore methane hydrates. NGI organizes its research portfolio into seven focus areas and operates a seed grant program to encourage new research on natural gas by Stanford researchers. It provides strategic funding to support important research in other areas related to natural gas and energy. In 2021, NGI published three natural gas briefs, two white papers, nine research papers and conducted multiple seminars, dialogues, meetings, webinars, and workshops. .
13	Tracking Software Development for Pipeline Safety Management System (8.21.h)	20210824142625	Gas Operations	Environmental & Safety	Safety	11/24/2021	5/24/2023	$21,464	$220,000	$21,464	$0	SCG $21,464 | OTD Members $198,536	Safety, Operational Efficiency, and Improved Affordability	Mid Stage (TRL 4-6)	• Field Demonstration/Validation Testing	The objective of this project is to develop tracking software for Pipeline Safety Management Systems (PSMS) based on the American Petroleum Institute's (API) 1173 standard This standard addresses the program development and program performance assessments. The tracking software will develop a Key Performance indicator (KPI) and a scoring system to assist managers in evaluating the performance of their PSMS program. The software will aid in benchmarking PSMS performance for the continuous improvement process required under API 1173. With the software, utilities will continue to improve their PSMS to benefit ratepayers with a safer and more reliable service. .
14	Work Zone Intrusion Detection and Warning System (8.22.g)	2022010601739	Gas Operations	Environmental & Safety	Safety	11/19/2021	4/28/2023	$9,333	$140,000	$8,000	$1,333	SCG $9,333 | OTD Members $130,667	Safety	Mid Stage (TRL 4-6)	• Deployment of Results • Share/Publish Results	The objective of this project is to perform market analysis and testing of Work Zone Intrusion Alarm (WZIA) technologies. Deliverables will include a Cost Benefit Analysis detailing features and pricing of the evaluated solutions and recommendations based on the various work zone scenarios that field crews may encounter. The goal is to improve the safety of employees and contractors working in situations where there is a possibility of work zone intrusion by unauthorized vehicles or pedestrians entering the work zone. Research suggests that implementing WZIA technology aids in the prevention of work zone injuries or fatalities. There is a broad range of functionality and cost between the various available technology solutions, but there is not a well-established marketplace, so further research is needed. The project is expected to kickoff at the early 2022. .
15	3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management (8.20.m)(CEC GFO-19-502, group 4)	202001091765	Gas Operations	Operations Technology	Mapping and Locating Technologies	6/30/2020	7/31/2023	$89,349	$2,088,785	$89,349	$0	SCG $89,349 | OTD Members $261,000 | CEC (GFO-19-502) $1,738,436	Reliability and Safety	Mid Stage (TRL 4-6)	• New Research Project to Advance TRL Level • Further Technology Development/Prototype • Commercialization	A significant amount of third-party damage to buried infrastructure is associated with inaccurate or insufficient locating practices. Knowing the location of the buried infrastructure can significantly aid in mitigating these risks and prevent damages. In this CEC co-funded project, GTI will develop 3D visualization software for mapping underground pipelines and improving pipeline asset management. To achieve this, several existing and proven technologies will be combined to create the Locate Technology Platform (LTP). This solution creates a set of business process models that an organization may implement to improve the three-dimensional geospatial accuracy of existing GIS data in both the horizontal and vertical dimensional directions. This platform assists the field users in visualizing infrastructure location data from a variety of viewpoints. Once the LTP is completed, it will be validated in a field demonstration. In 2021, software development began and data fields to be collected were identified. Efforts to create an in-office web application that would display GIS features in a 2D and 3D format from an accessible website are in process. .
16	Alternative Steel and Composite Material and Liquid Pipeline Systems (5.22.f)	20220112185929	Gas Operations	Operations Technology	Pipeline Construction, Operations and Repair Technologies	12/14/2021	12/31/2024	$12,706	$1,008,320	$8,000	$4,706	SCG $12,706 | OTD Members $135,000 | PHMSA $873,320	Safety and Operational Efficiency	Mid Stage (TRL 4-6)	• Field Demonstration/Validation Testing • Modification to Regulatory; Policy & Standards	The objective of this project is to establish a framework and corresponding requirements for the installation, inspection, and integrity management of alternative-steel and composite systems in natural gas pipelines. The study addresses: (1) material testing, (2) construction requirements, (3) damage and assessment of defects, (4) degradation of the pipe material, and (5) inspection and maintenance activities. The project is designed to map the requirements under 49 Code of Federal Regulations (CFR) Part 192. The goal is to identify and address the gaps in implementing a qualification process for non-steel and alternate-steel composites similar to the ones currently used for steel pipes. Pipeline Hazardous Materials Safety Administration held their kick-off meeting in November 2021 where they started forming the Technical Advisory Panel. The next steps are to hold an Operations Technology Development kick-off meeting and to begin evaluating material properties and testing procedures to determine how they might be modified to be applicable for the full range of modern materials. .
17	Enhanced Locating Technologies for Underground Pipelines with Better Accuracy (8.20.l)(CEC GFO-19-502, group 3)	20200109162122	Gas Operations	Operations Technology	Mapping and Locating Technologies	11/4/2020	11/30/2023	$26,768	$2,222,903	$26,768	$0	SCG $26,768 | OTD Members $207,146 | CEC $1,821,631 | Other Technology Providers $167,358	Reliability, Safety, and Improved Affordability	Mid Stage (TRL 4-6)	• Further Technology Development/Prototype • Commercialization • Share/Publish Results	The objective of this CEC-cofunded project is to improve the safety and integrity of underground natural gas pipelines by increasing the accuracy and availability of horizontal and vertical pipeline location information. The approach is based on enhancing and adapting aboveground, large standoff, 3D electromagnetic detection technology to locate buried pipelines. It will supplement the technology with an in-pipe mechanism to focus on congested areas and plastic materials. SoCalGas will focus on transmission infrastructure while PG&E will focus on infrastructure in congested urban areas. Improved tools are intended to provide access to three-dimensional data in near-real time, and the combined solution is anticipated to apply to most in-field conditions including varying pipeline material, depth, and surface cover. In 2021, gathering and analyzing data from the GTI test site with buried pipes continued. Planning of the 2022 field demonstration at SoCalGas started and a test plan was developed. .

18	Evaluation of Micro-Thermal Gas Metering Technology (5.22.d)	202201060215	Gas Operations	Operations Technology	O&M Technologies	11/19/2021	9/30/2023	$13,200	$132,000	$10,000	$3,200	SCG $13,200 | OTD Members $118,800	Reliability and Environmental: Reduced GHG Emissions	Late Stage (TRL 7-9)	• Field Demonstration/Validation Testing • Share/Publish Results	The objective of this project is to evaluate the accuracy and overall performance of micro-thermal gas metering modules while measuring hydrogen-blended natural gas and biomethane gas volumes. The microthermal gas meter module consists of a Micro-electromechanical Systems (MEMS) -based calorimetric microsensor. The MEMS measures the flow of natural gas using the thermal measurement principle. The sensor element is located on a membrane and consists of a micro-heater and upstream and downstream temperature sensors. The temperature distribution characteristics during gas flow are used to determine the gas velocity and the gas volume. It is integrated with signal conditioning electronics including memory for calibration data. Gas utilities are increasingly considering the proposition of transporting fuels of varying constituents. This includes low-carbon-based fuels such as hydrogen-blended natural gas and renewable natural gas. The source of these fuels varies and so does the gas compositions. A reliable metering technology that can be easily calibrated to varying gas compositions provides an additional layer of operational flexibility to gas utilities and enables the diversification of gas quality in the network. The project is expected to kickoff at the beginning of the second quarter of 2022. .
19	ARPA-E REPAIR Program (TTSP)	20201028143729	Gas Operations	System Design & Materials	Materials and Equipment	10/1/2020	10/1/2023	$0	$32,554,637	$0	$0	SCG $0.00 | DOE $32,554,637	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mulitple - Program supports various projects.	• Mulitple - Program supports various projects.	Old cast iron, wrought iron, and bare steel natural gas distribution pipes make up 3% of utility pipes in use, but account for a disproportionate number of gas leaks and pipe failures compared to newer steel pipe. The ARPA-E REPAIR program seeks to reduce natural gas leaks from these pipes by developing a suite of technologies to enable the automated construction of new pipe inside existing pipe. REPAIR will advance the state of gas distribution pipelines by incorporating smart functionality into structural coating materials and by developing new integrity/inspection tools. It will also create three-dimensional maps that integrate natural gas pipelines and adjacent underground infrastructure geospatial information with integrity, leak, and coating deposition data. SoCalGas involvement with the project is through the Testing and Technical Specification and Steering Panel Committee. In 2021, technical input was provided by operators. Draft test plans developed by the Testing and Analysis Team were sent out for comment in preparation for external loading, pressure and pressure testing on cast iron and bare steel pipe. .
20	Design and Placement of Compact Service Regulators - PHMSA Cofunding (5.22.j)	20211129162053	Gas Operations	System Design & Materials	Materials and Equipment	11/19/2021	5/31/2023	$5,733	$489,629	$5,000	$733	SCG $5,733 | OTD Members $105,904 | PHMSA $383,725	Reliability, Safety, and Operational Efficiency	Mid Stage (TRL 4-6)	• Modification to Regulatory; Policy & Standards • Share/Publish Results	This project will review existing practices and perform comparative service regulator testing that will result in recommendations and guidance to the natural gas industry on "vent-limiting" service regulators. It will also provide additional options to natural gas utilities for the safe, outdoor installation of regulators and meter sets. This project will determine if "vent-limiting" service regulators offer more options for outdoor installation by having a smaller footprint and, thus, reduced clearance distances in comparison to traditional IRV service regulators. The project team will determine safe distance allowances through testing the quantity of gas vented during various regulator operating flow conditions and failure modes, including diaphragm ruptures. Many gas utilities have set a minimum distance to a source of ignition for both indoor and outdoor meters and regulators based on the National Fuel Gas Code's requirement. Field crews must satisfy these clearance distance requirements when installing meter set assemblies, including the regulator, on the outside of a building. These clearance distances, however, were created with standard internal relief valve regulators in mind. New "vent limiting" service regulators, typically with "slam shut" features, are now available from a few manufacturers and are being used in a limited fashion by some natural gas utilities. This project, which is co-funded by the Pipeline and Hazardous Materials Safety Administration, kicked off in November 2021. In 2022, the project team will develop the test plan; establish a Technical Advisory Committee of industry subject matter experts; identify national and international service regulators with "venting limiting" capabilities; and determine service regulators to be included in the test plan. .
21	Efficacy of Offline and Online Methodologies to Measure Siloxanes in RNG (MEAS-15-04)	20210622155310	Gas Operations	System Design & Materials	Gas Composition And Quality	8/31/2021	3/31/2023	$14,603	$118,000	$14,603	$0	SCG $14,603 | PRCI Members $103,397	Reliability and Safety	Late Stage (TRL 7-9)	• Modification to Regulatory; Policy & Standards • Share/Publish Results	The objective of this project is to determine the precision, accuracy, and sensitivity of the GC-IMS (Ion Mobility Spectroscopy) through the analysis of data from a second field test in partnership with OTD. GTI previously completed laboratory and field testing at a landfill site of the GC-IMS. The project team will further test an online GC-IMS siloxane sensor at a site differing in digester feedstock (such as WWTP) and geographic location from the initial tests to provide a more robust dataset. Following ASTM D8230 Standard Method for the Offline Analysis of Siloxanes in Biogas, periodic grab samples will be taken during the testing period and analyzed at laboratories. to compare the online data to offline analytical techniques. Additional renewable natural gas (RNG) pipeline specifications similar to ones in California are expected to be established. Producers, regulators, and utilities would benefit from validated and standardized measurement methodologies which meet these new, lower specifications. The ability to develop a low cost, low maintenance online analyzer capable of meeting the sensitivity and precision needs of the industry will allow suppliers to ensure near same-time compliance to regulations compared to offline analysis. .
22	Field Test NeverWet & Other Nano-Tech Coatings to Reduce Aboveground Corrosion (5.17.p)	2017102393	Gas Operations	System Design & Materials	Materials and Equipment	9/6/2017	3/31/2023	$1,347	$187,000	$0		SCG $1,347 | OTD Members $185,653	Reliability and Safety	Mid Stage (TRL 4-6)	• Deployment of Results	This project investigates unique and promising coatings for challenging aboveground utility corrosion prevention applications. Corrosion is an ongoing threat to the integrity of metallic utility assets. For aboveground assets, one cannot rely on cathodic protection to back up coating protection. Therefore, specifying and applying the most appropriate and best-performing coating system is even more important. The unique and promising coatings that are available in the market have the potential to substantially reduce wet and dry aboveground corrosion in a wide variety of applications. Unfortunately, the NeverWet technology was discontinued, so it could not be included in the field trials. Field testing continues with three coatings being applied per the field test protocol. The project is in the planned "field exposure" phase, with the coatings logging time at their respective application sites. The plan was for the field test to include four seasons of exposure and then to assess performance. Due to COVID-19 restrictions, the field trial was extended. The extra time of exposure will benefit the meaningfulness of the assessments. To date, the applied systems continue to age in the field. .
23	Gas Machinery Research Council (GMRC)	20200102175422	Gas Operations	System Design & Materials	System Design	1/1/2019	12/31/2023	$20,160	$1,464,000	$20,160	$0	SCG $20,160 | GMRC Members $1,443,840	Reliability, Safety, Operational Efficiency, and Improved Affordability	Mulitple - Program supports various projects.	• Mulitple - Program supports various projects.	With more than 70 member organizations, Gas Machinery Research Council (GMRC) is a community of natural gas companies dedicated to investigating technical issues within the rapidly evolving gas machinery industry and uncovering innovative solutions that improve the reliability, efficiency, and cost-effectiveness of mechanical and fluid systems. GMRC provides members and industry an opportunity to exchange information and ideas and participate in applied research and technology programs. GMRC accepts proposals relevant to current issues facing the gas machinery industry and seeking to improve the quality and efficiency of pipeline facilities and gas compressor stations. In 2021, GMRC active projects included: Dry Gas Seal Reliability (Phase 4), Virtual Orifice Performance Evaluation, Improvements in Elemental Sulfur Test Methods for Natural Gas, Hydrogen Blending Impacts on Compressor Stations (in partnership with Pipeline Research Council International), Hydrogen Impacts on O-Rings, and Improvements to National Institute of Standards and Technology (NIST) - Reference Fluid Thermodynamic and Transport Properties Database (RefProp) and Water-Hydrocarbon Vapor Liquid Equilibrium (VLE) Prediction (Phase 2). Three projects were completed in 2021 and results shared with members. .
24	HyBlend Collaborative Research Partnership (5.21.k)	2021062301611	Gas Operations	System Design & Materials	System Design	9/1/2021	7/31/2023	$50,000	$15,050,000	$50,000	$0	SCG $50,000 | OTD Members: $4,100,000 | DOE: $10,900,000	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mulitple - Program supports various projects.	• Mulitple - Program supports various projects.	Begun in August 2021, the HyBlend Project is a joint effort of national labs, natural gas operators, and research consortia to evaluate technical and economic considerations associated with transporting hydrogen blends and other low-carbon fuels using existing gas infrastructure. The project team is addressing many topics related to hydrogen blending, including hydrogen compatibility with metals and polymers, life cycle analysis, techno-economic analysis, and building equipment. Five national labs will lead the research. Sandia National Laboratory will lead development of general pipeline integrity guidance for operating natural gas transmission and distribution systems with hydrogen blends by assessing the role of these blends in the degradation of metal pipelines. Pacific Northwest National Laboratory will lead the assessment of hydrogen blends on the degradation of polymer pipelines and material lifespan. Argonne National Laboratory will lead the life cycle analysis of technology pathways for hydrogen blends. The National Renewable Energy Laboratory will lead the quantification of costs and opportunities for hydrogen production and blending within the natural gas system. Oak Ridge National Laboratory will lead the evaluation of residential, commercial, and industrial end uses with hydrogen blends, assessing safety, emissions, reliability, and energy efficiency. In 2021, the team began establishing test conditions and materials and working on a literature review of global research and experience in operating natural gas pipeline systems with hydrogen blends. The team will publish a compilation of reports and white papers at project completion. SoCalGas will use these results to support the development of a hydrogen blending standard and to guide future research. .

25	Impact of Blended H2 on Threaded Connections (M2021-007)	20210810214230	Gas Operations	System Design & Materials	System Design	8/9/2021	3/31/2023	$19,011	$213,092	$19,011	$0	SCG $19,011 | NYSEARCH Members $194,081	Reliability, Safety, and Environmental: Reduced GHG Emissions	Early Stage (TRL1-3)	•New Research Project to Advance TRL Level •Modification to Regulatory; Policy & Standards •Share/Publish Results	The objective of this project is to determine if hydrogen blends in natural gas cause any change in 1) the presence or absence of leaks and 2) the leak flow rate for threaded connections. This project consists of four tasks involving threaded connections that conform to National Pipe Thread (NPT) standards. In Task 1, the team is developing test protocols and determining the test sample size. Tasks 2 and 3 includes tests to determine the change in a leak or leak flow rate with a 20% hydrogen blend. In Task 4, the project team will determine the impact of various pipe dope and sealants and if hydrogen blends influence this variable. The team will also perform tests on non-NPT threaded connections. The project kicked off in October 2021 establishing procedures for creating threaded connection leaks and methods to measure leak flow rates with hydrogen blends. SoCalGas will use this data to support the determination of a hydrogen blend limit for natural gas distribution systems that will contribute to a statewide hydrogen injection standard. .
26	Impact of Hydrogen/Natural Gas Blends on LDC Infrastructure Integrity (M2020-002 PhII)	20200052652138	Gas Operations	System Design & Materials	Gas Composition And Quality	4/22/2021	6/30/2023	$31,910	$425,024	$31,910	$0	SCG $31,910 | NYSEARCH Members $393,114	Reliability and Safety	Mid Stage (TRL 4-6)	•New Research Project to Advance TRL Level •Modification to Regulatory, Policy, Standards	The objective of this project is to determine if blending hydrogen into natural gas will change the physical properties of elastomers in a natural gas delivery system, the most common of which are styrene-butadiene rubber (SBR) and acrylonitrile butadiene rubber (NBR). Both are used as seals in compression applications and as gaskets for flanges in joining pipes and fittings. The lack of data on the effect of hydrogen concentrations in hydrogen/natural gas blends on elastomers in a natural gas infrastructure (e.g., piping, piping components, and appurtenances) may impact the safety and reliability of the gas delivery system. In Phase 1, the team performed exploratory tests using a limited set of test gas mixtures. Phase 2 will involve further tests on field-extracted and virgin materials using an expanded set of test gases. The team completed Phase 1 in April 2021 with a preliminary assessment of the impact of varying hydrogen concentrations in methane/hydrogen blends on the mechanical and physical properties of SBR and NBR elastomers in common use as coupling materials used to join metal pipes. Results from Phase 1 found that unrestrained SBR cubes exhibited a change during creep tests with a dimensional change and a reduction in elasticity. Phase 2 will leverage findings from Phase 1 and test new and vintage materials with a wide range of hydrogen blends (up to 20%), pressures, and temperatures. To date, the team has completed stress relaxation analysis for NBR and SBR materials at 5% hydrogen. The next step is to evaluate 20% hydrogen blends and constant load performance. This project will help SoCalGas determine if and how hydrogen blends will affect the physical properties of typical elastomers and the hydrogen blend level that the existing natural gas system can tolerate. .
27	Implementing API 5L RP 5MT, "Pipeline Inspection Documents for Material Traceability and Electronic Test Reports " (8.22.c)	20220114185642	Gas Operations	System Design & Materials	Materials and Equipment	3/1/2022	6/30/2023	$13,831	$255,000	$8,000	$5,831	SCG $13,831 | OTD Members $241,169	Reliability, Safety, Operational Efficiency, and Improved Affordability	Early Stage (TRL 1-3)	•Modification to Regulatory; Policy & Standards •Deployment of Results	American Petroleum Institute (API) Standard 5L is the standard for transmission pipes used in the natural gas and petroleum industries. This standard governs specifications for seamless and welded steel pipes of different grades. These specifications are validated with tests, and the results are published in a specification report for each type of steel and grade. Suppliers currently provide their reports in paper form. The goal of this project is to develop an electronic form of the report for manufacturers to use. The team will develop a digital template to make the report available to customers electronically. A common standard for electronic reports streamlines industry efforts. The project will also develop a method for verification that the report is from the manufacturer of the pipe. This will improve traceability by providing an electronic signature that ties the test report directly to the manufacturer. .
28	Integrity Impact of HAZ Softening on Type-B Sleeves and Hot Tap on Modern Steel (SBD-1-6A)	2021101422849	Gas Operations	System Design & Materials	System Design	10/13/2021	10/13/2023	$13,587	$177,000	$13,587	$0	SCG $13,587 | PRCI Members $163,413	Reliability and Safety	Early Stage (TRL 1-3)	•Field Demonstration/Validation Testing	Heat Affected Zone (HAZ) softening occurs in girth welds on pipelines. The HAZ area loses mechanical strength which creates a mismatch between mechanical properties of the pipe and the HAZ. Girth welds are not only used in pipeline construction but are also used in some pipeline repairs. Type-B sleeves are one such repair type. The sleeve is welded to the pipeline to repair leaks and damaged section of the pipeline. HAZ also occurs in another repair method -hot taps. This project investigates HAZ softening in Type-B sleeves and hot taps in pipeline repairs. Tests will be performed to test different welding and installation procedures to minimize the loss of mechanical strength in HAZ. A final report will be delivered with recommended welding and installation procedures for using Type-B sleeves and hot taps. This project will enhance pipeline integrity by minimizing pipeline failures. .
29	Living Lab for Hydrogen (M2021-008)	20210803205350	Gas Operations	System Design & Materials	System Design	12/13/2021	6/28/2024	$300,000	$1,222,402	$67,667	$232,333	SCG $300,000 | NYSEARCH Members $922,402	Reliability, Safety, Operational Efficiency, Environmental: Reduced GHG Emissions, and Environmental: Improved Air Quality	Late Stage (TRL 7-9)	•Deployment of Results •Share/Publish Results •Technology & Knowledge Transfer/Training	The goal of this project is to analyze and report data on the impacts of hydrogen blending at higher percentages (i.e., greater than 20 vol%) by evaluating safety, maintenance, and emergency response changes on gas distribution infrastructure and appliances. This is a SoCalGas project co-funded by NYSEARCH. The Living Lab demonstration aims to validate the feasibility of blending and injecting 20% or more hydrogen by volume into the existing natural gas infrastructure by simulating system operations with steel and plastic pipelines, a pressure regulator station, a compressor, and various end-use equipment. This project will yield valuable data on impacts to pipeline integrity, measurement, regulation, end-use equipment, and safety and maintenance procedures. .
30	Managing Stress From Uneven Support & Settlement (CNST-2-2A)	2022042722280	Gas Operations	System Design & Materials	System Design	3/25/2022	3/25/2024	$15,234	$188,000	$0	$15,234	SCG $15,234 | PRCI Members $172,766	Reliability and Safety	Mid Stage (TRL 4-6)	•Deployment of Results •Share/Publish Results	The objective of this project is to develop guidelines and procedures to manage strain and stress from uneven support and soil settlement in the design, construction, and maintenance of pipelines. High strain and stress could lead to fractures in pipelines causing failures and disruption to services for ratepayers. This project will investigate current practices of utilities to address external strain and stress. The project team plans to investigate excavation and backfill practices that cause high strain and stress by gathering utility data for analysis. The team also plans to delve deeper into the subject by covering terrain conditions that may contribute to higher strain and stress. Model simulations will be used to simulate and quantify the strain and stress to develop best practices to minimize strain and stress on pipelines. In addition to delivering the guideline and procedure for best practices, the project team will hold a workshop to train utilities on how to implement the best practices to minimize strain and stress on pipelines. The outcome of this project will lead to better integrity management of gas pipelines to prevent failures from uneven support and settlement of pipelines, making the pipeline system safer and more resilient. SoCalGas supported this project in anticipation that the guidelines and procedures for best practices could improve design, construction, and maintenance to minimize strain and stress on its pipelines. .
31	On-Line Biomethane Gas Quality Monitoring Ph III (7.16.e.3)	2021062301148	Gas Operations	System Design & Materials	Gas Composition And Quality	8/1/2021	3/31/2023	$56,439	$267,000	$56,439	$0	SCG $56,439 | OTD Members $210,561	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mid Stage (TRL 4-6)	•Field Demonstration/Validation Testing •Share/Publish Results	In past phases of this project, validation testing on several on-line biomethane analyzers were performed to identify which would have the potential to detect unconventional trace constituents. Two analyzers were proposed for consideration for further development under Phase 3. The goal of Phase 3 is to perform product development on the selected analyzer and to test the modified analyzer to validate the monitoring of the unconventional trace contaminants. These trace constituents are sometimes found in biomethane if cleanup technologies fail. These unconventional trace constituents are not routinely monitored by on-line instruments but are critical to gas quality. Utilities need technologies to provide real-time gas quality data for these trace constituents. In this phase, the analyzer manufacturer will work to modify their system to incorporate changes identified in Phase II with the goal of commercializing the analyzer. The newly developed on-line analyzer will be tested with continuous gas streams compared to laboratory measurements following standard methods to evaluate precision, accuracy, and operational experience. The deliverable will be a market-ready analyzer, available for field tests, which can monitor the predominant species of ethylbenzene, toluene, siloxanes, organic arsenics, halogenated hydrocarbons, and n-nitroso-di-n-propylamine. Once available, this analyzer could be installed at locations where there is a potential for trace constituents above the limits. The project kick-off meeting was held in November 2021, and sponsors discussed which analyzer should be developed further after reviewing data on cost and maintainability. The next step is to finalize the analyzer selection. .
32	Optimize the Detection and Mitigation of Mechanical Damage (SRP-MD-01)	20210720171815	Gas Operations	System Design & Materials	Materials and Equipment	1/1/2021	12/31/2023	$7,370	$2,042,507	$7,370	$0	SCG $7,370 | PRCI Members $2,035,137	Reliability and Safety	Mulitple - Program supports various projects.	•Mulitple - Program supports various projects.	Detecting and mitigating mechanical damage to pipeline infrastructure is a major concern to the natural gas industry. The Pipeline Research Council International established this Strategic Research Priority (SRP) to coordinate the efforts across all technical committees (Compressor Pump Station, Design Materials Construction, Surveillance Operations Monitoring, Measurement and Underground Storage). The SRP goal is to provide a roadmap of research projects to close the gaps on mechanical damage (MD) research and to produce a comprehensive set of guidelines and tools for managing the threat of MD. The SRP funded one project in 2021: Analysis of Pipeline Operator and Prior R&D Data (MD-2-5). An additional SRP project will be added in 2022: Improvements to Mechanical Damage Engineering Assessment Tool (MD-2-4). .
33	Pathway to Achieving Efficient and Effective Crack Management (SRP-CM-01)	2021072171434	Gas Operations	System Design & Materials	Materials and Equipment	1/1/2021	12/31/2023	$23,819	$5,193,400	$23,819	$0	SCG $23,819 | PRCI Members $5,169,581	Reliability and Safety	Mulitple - Program supports various projects.	•Mulitple - Program supports various projects.	This research intends to advance critical areas associated with the execution of crack management programs that eliminate crack-related failures. The Pipeline Research Council International established this strategic research priority (SRP) to coordinate efforts across all the technical committees (Compressor Pump Station, Design Materials Construction, Surveillance Operations Monitoring, Measurement, and Underground Storage). The goal of the SRP is to provide a roadmap of research projects to further understand and efficiently and effectively manage cracks in pipelines. Research will focus on four core areas: susceptibility, inspection, management, and assessment and remediation. The SRP funded two projects in 2021: Understanding Why Cracks Fail (MAT-8-3), and Improvement of ILI Capabilities Joint Industry Project (PHASE II) (NDE-4-12). .

34	Practical Girth Weld Evaluation Criteria Considering Weld Strength Mismatch and HAZ Softening (MATH-5-3D)	20211013141320	Gas Operations	System Design & Materials	System Design	10/5/2021	4/5/2023	$14,350	$212,400	$14,350	$0	SCG $14,350 | PRCI Members $198,050	Reliability and Safety	Mid Stage (TRL 4-6)	• Modification to Regulatory; Policy & Standards • Share/Publish Results	This project continues work from previous girth weld research projects for which new testing methods and welding guidance documents were developed (MATH-5-3B and MATH-5-3C.) This project uses these results to propose revisions to current welding standards - the American Petroleum Standard 1104 and Canadian Standard Association Z662- to address girth weld strength mismatch. These revisions will improve pipeline integrity, safety, and reliability of pipelines by updating the standards with new testing methods and new procedures for minimizing heat affected zone (HAZ) softening near girth welds to prevent strength mismatch. .
35	Review and Evaluation of the Utonomy Smart Regulator, Phase 2 (5.19.k.2)	20200113225859	Gas Operations	System Design & Materials	Materials and Equipment	1/31/2021	1/31/2023	$76,644	$291,800	$76,644	$0	SCG $76,644 | OTD Members $215,156	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mid Stage (TRL 4-6)	• Share/Publish Results • Technlogy & Knowledge Transfer/Training	The objective of this project is to demonstrate the operation and benefits of the Utonomy Smart Regulator (USR) through laboratory testing and field trials. The use of the USR could provide operators with the ability to remotely monitor and control district regulator stations. The project includes both laboratory and field testing with Utonomy as a partner. In 2021, the task of documenting the Products and System Needs Validation and Requirements began. The next steps are to complete the requirements documentation and perform tests at the Fisher Flow Laboratory. An interim report will be prepared after the laboratory testing is complete to determine whether the project should move forward with field trials. This project has potential technical links to company efforts to bring remote monitoring and control to our distribution system. Further, it aligns with the recently published Pipeline and Hazardous Materials Safety Administration Advisory Bulletin titled Pipeline Safety: Overpressure Protection on Low-Pressure Natural Gas Distribution Systems [Docket No. PHMSA–2020–0025]. .
36	Seismic Risk Assessment and Management of Natural Gas Storage and Pipeline Structure (GFO-18-502)(Group 1) - two projects Slate/Berkeley & UCLA	20200109213857	Gas Operations	System Design & Materials	System Design	6/1/2019	6/30/2023	$13,000	$5,207,752	$12,050	$950	SCG $13,000 | CEC $4,940,158 | LBNL $254,594	Reliability, Safety, and Improved Affordability	Late Stage (TRL 7-9)	• Field Demonstration/Validation Testing • Deployment of Results • Share/Publish Results	The CEC awarded two projects under GFO-18-502 Group 1. The projects each develop seismic risk assessment software tools using different risk models. SoCalGas is involved in both projects. The first project was awarded to Slate Geotech and UC Berkeley for the production of an open-source analysis tool that is easily usable by regulators and utilities. The tool will implement updated methodologies for assessment of seismic risk to underground and aboveground natural gas infrastructure. The tool will have the ability to identify areas of highest risk overlaid with population information to help regulators and utilities identify areas of highest risk to prioritize seismic retrofit projects. To date, a Beta version of the tool has been developed and is being tested. SoCalGas provided data and technical expertise for this project. The second project was awarded to UCLA. This project considers four hazards: Earthquake ground shaking, fault displacement, landslides and liquefaction and to develop a comprehensive set of fragility curves for pipelines and develop an open-source risk assessment tool based on probability-based methodology. To date the project is about 75% complete, and several fragility models have been developed. SoCalGas is participating on the TAP for this project. .
37	Study on changing Accuracy & Variability of Therm zones affecting metering of new gas supplies (M2022-002)	20220422202256	Gas Operations	System Design & Materials	Materials and Equipment	4/22/2022	6/30/2023	$32,640	$367,250	$32,640	$0	SCG $32,640 | NYSEARCH Members $334,610	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mid Stage (TRL 4-6)	• Deployment of Results	Blending hydrogen in natural gas and renewable natural gas (RNG) will change gas properties, such as density, viscosity, and energy content. These altered gas properties may affect the flow measurement performance of natural gas flow meters and interfere with meeting the California Public Utilities Commission (CPUC) requirement of ±2% accuracy in gas delivery to customers. The objective of this project is to characterize the impact of varying hydrogen blends with natural gas and RNG on different types of residential and commercial natural gas meters. First, the project will experimentally gather gas property data that is required to calculate a mass flow rate output from a gas flow meter, compare the results with existing equations of state (EOS), and provide recommendations for best practices and setting appropriate values of uncertainties with various EOS. Secondly, the project will evaluate the suitability and integrity of common metering devices by determining measurement errors and trends when hydrogen content varies with natural gas and RNG. The result of these two tasks will be communicated via a final report and will inform gas utilities on how to determine an accurate and repeatable way to measure and bill the energy delivered to their customers with varying gas supplies. .
38	T&T Component Counterfeit Detection, Two Way Product Communication Using GS1 Standards (8.17.b.4)	20210824144128	Gas Operations	System Design & Materials	Materials and Equipment	11/1/2021	12/31/2023	$13,263	$229,000	$13,263	$0	SCG $13,263 | OTD Members $215,737	Reliability, Safety, and Improved Affordability	Mid Stage (TRL 4-6)	• New Research Project to Advance TRL Level • Share/Publish Results	This project builds upon other research supporting PHMSA's Tracking and Traceability initiatives. The project objective is to develop a process to screen natural gas piping system components for counterfeits and to develop a mobile system software for communicating quality control concerns about piping system components directly to the component manufacturer in near real-time. Components used to construct natural gas delivery systems may pass initial hydro testing, but failures a few years into service have been linked with counterfeit components. The industry needs tools to scrutinize products used in natural gas piping systems to confirm that they are authentic and that the components are supplied with quality control test reports that are representative of the components received for use. Deliverables for this project include: (1) a Final Report documenting the system, (2) a prototype demonstration of the systems' ability to detect counterfeit components with map-based reporting program, and (3) a narrative of the requirements to deploy the system for commercial operation. The project kick-off is scheduled for early 2022. .
39	Universal Analytical Technique for Siloxane - Phase 2 (7.16.g.2)	20191007194636	Gas Operations	System Design & Materials	Gas Composition And Quality	5/1/2019	4/30/2023	$49,608	$253,000	$49,608	$0	SCG $49,608 | OTD Members $203,392	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mid Stage (TRL 4-6)	• Modification Regulatory; Standard & Policy • Share/Publish Results	The objective of this project is to develop a universal, industry-wide sampling and analysis procedure for measuring the presence of siloxanes in biomethane. The project team is developing this procedure in collaboration with the American Society for Testing and Materials (ASTM) Committee on Gaseous Fuels. In Phase 1, the team developed and published the ASTM Standard D8230 for the Measurement of Volatile Silicon-Containing Compounds in a Gaseous Fuel Sample Using Gas Chromatography with Spectroscopic Detection. ASTM requires that an Interlaboratory Study Program (ILS) be performed within five years of the procedure publication date. In Phase 2, the team will complete the ILS and field-test an online siloxane analyzer. In 2021, the scope of work was expanded to include a second field site for Pipeline Research Council International's research project, MEAS-15-04. The team will collect periodic grab samples during the testing period for analysis at laboratories following ASTM D8230 procedures to compare the on-line data to data produced using off-line analytical techniques. In 2021, the team continued the ASTM D8230 inter-laboratory study by: finalizing details on the laboratory participation list for the ILS and continuing to plan field evaluations. .
40	Advanced Through-Tubing Casing Inspection for UGS Wells (US-4-04)	20210916213947	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	9/30/2021	9/30/2024	$272,473	$1,760,777	$72,473	$200,000	SCG $272,473 | PRCI Members $630,535 | PHMSA $788,594 | Others $69,175	Reliability, Safety, and Improved Affordability	Mid Stage (TRL 4-6)	• Field Demonstration/Validation Testing • Share/Publish Results	The objective is to advance the sensor technology in through-tubing inspection tools' ability to detect, measure, and characterize metal loss features. This project is looking to work with PRCI to offer a Multi-String Well Integrity Platform that provides a circumferential measurement of corrosion and isolation of external casing strings. The proposed solution will be a fully combinable, advanced sensor technology. The combo will be capable of acquiring data in a single run without pulling out the production tubing. The development of this technological advancement will significantly save UGS operators time and cost by providing the means to evaluate well integrity and effectively plan well intervention activities. SoCalGas would utilize the results to manage well integrity as outlined in each fields Storage Risk Management Plan. The project kick-off meeting was held in November 2021 highlighting the general project objectives, work scope, schedule and responsibilities. The overall project execution plan and regular project meeting schedule were also discussed. SoCalGas would utilize the results to manage well integrity as outlined in each fields Storage Risk Management Plan. .
41	Alternate Crack Sensor (M2016-004 Ph IV)	164411262	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	8/9/2021	2/28/2023	$70,190	$491,324	$70,190	$0	SCG $70,190 | NYSEARCH Members $421,134	Reliability and Safety	Mid Stage (TRL 4-6)	• Field Demonstration/Validation Testing • Commercialization	The project team developed and commercialized a sensor probe system for crack detection in longitudinal seam welds (SWs) in 20"-26" diameter natural gas pipelines. In Phase 1, the team developed a concept to integrate the crack sensor probe with the Explorer robotic inspection platform. The concept used two probes: one for finding SWs and one for scanning for cracks. In Phase 2, a prototype was built and field-tested. The sensor successfully identified cracks in all SWs except for electric resistance welds (ERWs). In Phase 3, mechanical designs were refined to improve weld sensor ride and data quality, especially over protruding SWs. Further, the ERW SW detection was improved, such that the data proved consistent and accurate when detecting girth SWs, allowing a smooth operation of orientation transitions between pipeline segments. Data Analysis Tools were improved through testing and fine-tuning the integration of the weld sensor data to the analysis software. At the completion of Phase 3, sponsors elected to continue onto a Phase 4 where the focus is to improve the existing system (developed in Phase 1-3 of this program) with revisions to the mechanical design, weld detection capability and integrations with the Explorer 20/26 robot and operation. The deliverables are to be a revised circumferential MFL sensing system able to detect long SW anomalies as documented in the early phases, an alternative sensor probe for improving detection of low signature long SW, and established specifications of operation. Phase 4 kicked off in August 2021 and began testing to increase the sensitivity of the weld and material detection and modifications to the sensor housing to reduce the weight were made. .

42	Database of All Burst Tests for Corrosion, Cracking, Dent, and Interacting Defects (EC-2-11)	20211208175940	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	11/19/2021	5/31/2023	$8,780	$147,500	$8,780	$0	SCG $8,780 | PRCI Members $138,720	Safety	Mid Stage (TRL 4-6)	•Modification to Regulator; Policy & Standards •Share/Publish Results	The objective of this project is to develop and populate a database of burst tests for corrosion, cracking, dent, and interacting defects including fatigue tests. To validate improvement in defect assessment or modelling, burst tests and fatigue tests are usually done. These tests are time consuming and expensive, and finding the appropriate pipe samples for testing is also challenging. The project would develop a uniform format for burst test data collection and support future defect assessment and modeling efforts. The benefit of this project is to provide consistent and relevant data for future Pipeline Research Council International (PRCI) studies in defect assessment and growth modelling. The outcome is a database of burst tests and fatigue tests with open access to members. .
43	Develop guideline for API 1163 for Inspections Qualification for Level 1, 2, and 3 (IM-1-06)	20220427214251	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	3/25/2022	3/25/2023	$6,313	$154,000	$0	$6,313	SCG $6,313 | PRCI Members $147,687	Reliability, Safety, and Operational Efficiency	Late Stage (TRL 7-9)	•Deployment of Results •Share/Publish Results	API Standard 1163 provides requirements for qualification of in-line inspection (ILI) systems. The standard covers the selection, reporting, verification, and three levels of validation associated with in-line inspection systems. The standard also outlines the complexity and cost increase with each level of validation. This project will develop guidelines and procedures for utilities to implement the three levels of validation as prescribed in API 1163 in the qualification and validation of tools for inspection. The emphasis of the project is on developing guidelines and statistical methods to be used for level 1, 2 and 3 analyses. The project will also develop software for level 2 and 3 analyses. The results of this project will help utilities in determining and selecting the validation level that will optimize integrity management resources and reduce overall risk. Ratepayers will benefit from safer and more cost-effective pipeline operations. SoCalGas sponsors this project so that Integrity Management can improve its guidelines describing when level 1, 2 and 3 validation levels are applicable. Integrity Management is particularly interested in defining when a Level 1 validation can be used on pipelines, especially when insufficient anomalies are available for excavation to conduct a level 2 validation. In lieu of excavating anomalies to perform a level 2 validation, a Level 1 validation uses statistical analysis to validate the performance of the ILI tool. .
44	Electromagnetic Time Domain Reflectometry (EM-TDR) for Pipeline Integrity (M2021-004 Ph I)	2021052765423	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	5/1/2021	5/31/2023	$28,850	$339,000	$28,850	$0	SCG $28,850 | NYSEARCH Members $310,150	Reliability and Safety	Early Stage (TRL 1-3)	•New Research Project to Advance TRL Level •Further Technology Development/Prototype	Electromagnetic Time Domain Reflectometry (EM-TDR) is a mature technique developed to identify and locate faults in metallic cables. Lawrence Berkeley National Lab (LBNL) proposes to adopt the EM-TDR technique to the inspection of transmission natural gas pipelines. Variations in materials and pipeline geometry have a significant effect on this technique's performance and tuning. This project will evaluate method feasibility for the intended application, and if successful, it will lead to additional phases to develop and test an engineering prototype, a pre-commercial protype and ultimately result in commercialization. This technology would allow for SoCalGas to obtain more information on difficult- to -access portions of pipelines that are currently assessed by External Corrosion Direct Assessment (ECDA). If this tool is applicable to pipelines as outlined in the proposal, EM-TDR could be used to provide further assessment of carrier pipe within cased segments, as well as other crossings where ECDA techniques are not available. This tool would be used to supplement and enhance existing ECDA inspection techniques. .
45	Monitoring Solution for pipeline A/C Interference	20220207211737	Gas Operations	System Inspection & Monitoring	Corrosion Inspection and Monitoring	12/14/2021	12/31/2023	$96,759	$96,759	$0	$96,759	SCG $96,759	Reliability and Safety	Late Stage (TRL 7-9)	•Deployment of Results	Increasing energy demand has led many electric utilities to increase capacity. In some cases, this can cause AC interference and ground/earth faults, which occur when straying electrical current takes a pathway directly to the ground. This increases risk for buried gas pipelines within shared rights-of-way. These faults can also damage pipeline coatings. Thus, utilities need a wide variety of technologies and methodologies to identify and then mitigate or minimize any AC threats to pipeline integrity. SoCalGas's Integrity Management department is developing an AC interference procedure to identify, monitor, and mitigate this risk on segments along its pipeline. One of the key components in addressing AC interference is identifying powerline loading trends. Unfortunately, powerline load information is not readily available. This project will evaluate and demonstrate a technology that collects powerline load data independent of electrical utilities. The resulting data could support risk analyses to determine if AC interference events occurred and if there is a need for continual monitoring and/or mitigation. In addition, the data collected may be used with the AC PowerTool software developed in the OTD AC Earth Faults project completed earlier in 2021. .
46	Technology Development Center (TDC-1-1 & 1-A)	SCG1540077	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	1/1/2015	12/31/2023	$42,709	$3,440,727	$35,351	$7,358	SCG $42,709 | PRCI Members $3,398,018	Reliability and Improved Affordability	Late Stage (TRL 7-9)	•Field Demonstration/Validation Testing	This project provides support for the new Pipeline Research Council International Technology Development Center (TDC) in Houston, Texas which opened in the summer of 2015. The TDC is the result of a major commitment by the energy pipeline industry to address the key issues the industry is facing to ensure the safety and integrity of the vital national and international steel pipeline infrastructure. The TDC provides the industry with an independent third-party site to thoroughly describe the capabilities of current pipeline inspection tools and to guide the development of new technologies needed to push toward the pipeline safety and integrity goal. The TDC enables efficient and timely access to industry samples in support of technology projects and programs. In 2021, The TDC was utilized by PRCI projects, for example NDE-4-18 Validate ILI Capabilities to Detect/ Characterize Mechanical Damage. .
47	Xray and Terahertz Development for NDE of PE Pipe by Iowa State University (M2019-007 Phase II)	2021012620269	Gas Operations	System Inspection & Monitoring	Pipeline Systems Inspection Technologies	1/20/2021	1/31/2023	$45,400	$407,019	$45,400	$0	SCG $45,400 | NYSEARCH Members $361,619	Reliability, Safety, and Environmental: Reduced GHG Emissions	Mid Stage (TRL 4-6)	•New Research Project to Advance TRL Level •Further Technology Development/Prototype	The results of Phase I demonstrated the capability of X-ray radiography for polyethylene (PE) pipe inspection and paved the way to optimize a portable X-ray system in future phases of the project. X-ray radiography and computed tomography (CT) were shown to be complementary to terahertz (THz) methods in different aspects of PE pipe inspections. The objective of Phase II is to advance Iowa State University THz and X-ray NDE technologies with enhanced techniques that can interpret PE butt-fusion (BF) joint defects with 2D and 3D reconstruction imaging. THz and X-ray contour-following fixture construction will be performed, and defective BF samples will be developed and used for scanning, evaluating, and further developing the 2D and 3D scan data interpretation for each defect type. In 2021, the project team worked on redesigning the testing facilities to better handle the testing planned under the project. The project is awaiting The Welding Institute defected BF joint samples to begin testing. .
48	GGZEM Harbor Craft Demonstration	20201014173330	Clean Transportation	Off-Road	Off-Road	1/1/2021	12/31/2025	$200,000	$3,401,178	$100,000	$100,000	CEC - $2,000,000 Ocean5 Naval Architects - $15,158 ZEI - $1,186,020	Environmental Benefits: GHG Reduction, Environmental Benefits: Air Quality Improvement, Operational Efficiencies, Reliability, Affordability	Mid Stage (TRL 4-6)	Commercialization	In this California Energy Commission funded project, Golden Gate Zero Emission Marine (GGZEM) aims to develop and demonstrate a small, fast, hydrogen fuel cell powered, rigid inflatable boat for a variety of harbor craft use cases. GGZEM further proposes to develop and deploy supporting mobile and portable hydrogen fueling solutions. GGZM will demonstrate the vessel for six months in San Francisco Bay and Long Beach harbor. The project team will integrate a hydrogen fuel cell used by the automotive industry with a small, approximately 25-foot,commerically available rigid inflatable boat. Vessels under 40 feet in length have a wide variety of uses, including patrol, fire and rescue, fishing, pilot, excursion, ferry and taxi, and recreation. Developing a zero-emission hydrogen fuel cell vessel could help reduce emissions and improve air quality in and around harbors and ports. The vessel will be fueled through novel mobile, portable systems developed by GGZEM for marine vessel fueling and built through the project, using hydrogen sourced from California's retail hydrogen stations. GGZEM will apply their knowledge and experiences from the existing CARB funded 84-passenger hydrogen ferry project to this development. The project contracting was wrapped up in 2021, and work will commence in early 2022. .
49	GTI Hydrogen Fuel Cell Switcher Locomotive Demonstration	20201014172728	Clean Transportation	Off-Road	Off-Road	1/1/2021	12/31/2025	$537,500	$5,964,876	$179,167	$358,333	CEC - $3,999,971 LCRI - $324,000 Sierra Northern Railway - $573,405 SMAQD - $500,000 Ballard - $30,000	Environmental Benefits: GHG Reduction, Environmental Benefits: Air Quality Improvement, Operational Efficiencies, Reliability, Affordability	Late Stage (TRL 7-9)	Commercialization	GTI and Sierra Northern Railway will design, build, and demonstrate a hydrogen fuel cell, zero-emission, switcher locomotive in the seaport of West Sacramento. The project was awarded funding by the California Energy Commission's (CEC) Grant Funding Opportunity GFO-20-604: Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports (H2RAM), Group 1: Fuel Cell Demonstrations in Switcher Locomotives and Commercial Harbor Craft. Sierra Northern Railway will replace the diesel engine of a switcher locomotive with a hydrogen fuel cell, eliminating 10,000 gallons of diesel fuel use per year. This will improve local air quality and eliminate corresponding greenhouse gas (GHG) emissions. The locomotive will be demonstrated on Sierra Northern Railway's short-line operations which serve the railyard and seaport in West Sacramento.. It will remain in service after the demonstration period. The integration of advanced fuel cell and battery technologies represents a new platform that will enable commercialization within a few years. The project is in its earliest stages of activity, and ork is progressing to remove legacy diesel drivetrain, to design the fuel cell integration, and to acquire equipment for integration. .

50	CTE Fuel Cell Electric Delivery Van Demonstration	2021100115636	Clean Transportation	On-Road	On-Road	11/1/2021	12/31/2024	$750,000	$15,229,320	$250,000	$500,000	CARB - $4,302,896 CEC - $744,755 DOE - $2,982,081 SCAQMD - $980,000 UPS - $5,469,588	Environmental Benefits: GHG Reduction, Environmental Benefits: Air Quality Improvement, Operational Efficiencies, Reliability, Affordability	Mid Stage (TRL 4-6)	Commercialization	The Center for Transportation and the Environment (CTE) will develop and demonstrate 15 fuel cell electric delivery vans with UPS in Ontario, CA. Currently, there are no hydrogen fuel cell medium-duty vehicle for goods movement. UPS's existing battery electric fleet vehicles meet approximately 70% of UPS route range requirements. When configured with the fuel cell electric propulsion system being deployed by this project, the vehicle is expected to meet almost 95% of UPS service needs. The project will show that a van with UES's propulsion system can provide fleet operators with a zero-emission vehicle capable of meeting route range requirements while matching the performance characteristics of its existing fleet vehicles. According to Fleet DNA data compiled by the National Renewable Energy Laboratory (NREL), a vehicle with a 125-mile range will meet 97% of Class 3–6 daily delivery driving distances. Meeting CARB's desired 150-mile range threshold increases the attractiveness of zero-emission trucks to fleet operators and increases the commercial viability of fuel cell electric conversion kits. All fifteen fuel cell vans will be operated in routine UPS service for at least 5,000 hours of operation. During this period, maintenance and operational support will be provided by the Project Team. Throughout the period, all required operational data will be collected and reported. .
51	Cummins Integrated Fuel Cell Electric Powertrain Demonstration	20201201205442	Clean Transportation	On-Road	On-Road	3/31/2020	12/31/2025	$240,000	$7,451,859	$0	$240,000	Cummins - $2,825,666 DOE - $3,443,063 Gillig - $535,000 Navistar - $195,000 SCAQMD - $105,000 Stark Area RTA - $250,480 Werner Enterprises - $97,650	Environmental Benefits: GHG Reduction, Environmental Benefits: Air Quality Improvement, Operational Efficiencies, Reliability, Affordability	Late Stage (TRL 7-9)	Commercialization	Cummins will develop and demonstrate a modular scalable fully integrated heavy duty fuel cell prototype design and to collect operations and performance data on the units. Data will be collected and analyzed by CALSTART for two different applications - HD class 8 truck and transit bus. The HD class 8 truck demonstration will utilize a Cummins HD architecture with two fuel cell engines and the 40-foot transit bus demonstration will include one fuel cell engine. Each of the engines consists of two stacks that together produce 90kW of power. The overall goal of the project is to demonstrate the feasibility of this modular scalable platform that utilizes a plug and play design for ease of installation as shown in the adjacent picture. The project seeks to demonstrate that both the truck and bus applications can meet a 300+ mile range and exceed the current mileage limitations of pure battery electric HD vehicle solutions. The fully integrated powertrain that includes the fuel cell, battery, motor, inverter, and optimized controls will be installed as a vertically integrated solution on both demonstration platforms and allow for overall cost reductions. The project team proposes to demonstrate the truck in Southern California with a port drayage or regional delivery fleet and the bus with a transit property in Ohio. .
52	Bloom Energy Coupled Electrolyzer and Fuel Cell Demonstration	202102181213	Clean Generation	Distributed Generation	Distributed Generation	4/19/2021	6/30/2023	$500,000	$1,500,000	$300,000	$200,000	Bloom Energy - $1,000,000	Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Mid Stage (TRL 4-6)	Next phase of future product development	The goal of this project is to demonstrate the coupling of Bloom Energy's new solid oxide electrolyzer cell (SOEC) at an existing Bloom solid oxide fuel cell (SOFC) installation. A 300kW SOEC will utilize grid electricity to generate hydrogen, which will then be blended with natural gas to fuel Bloom SOFCs. Hydrogen blending will take place downstream of the SoCalGas meter, at a manifold that will feed multiple existing SOFC units on the Caltech campus. The tentative blending percentage is 12% hydrogen (Bloom SOFC's can currently accept up to 50% hydrogen blends). The project will include SOEC product development, hydrogen blending design, permitting, and 15 months of operating costs. The demonstration will showcase the potential to decarbonize the natural gas grid and serve as a steppingstone to developing a reversible SOEC/SOFC fuel cell product. .
53	Noble Thermodynamic Systems Ultra-Efficient CHP Using a Novel Argon Power Cycle Development	2020031822540	Clean Generation	Distributed Generation	Distributed Generation	8/14/2020	10/31/2023	$500,000	$5,279,034	$400,000	$100,000	DOE - $2,923,979, Project Partners - $736,868	Reliability, Operational Efficiency, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Mid Stage (TRL 4-6)	Potential field demonstration	The goal of this project is to demonstrate the ability of the novel Argon Power Cycle (APC) to provide an 18% increase in efficiency, while eliminating emissions, in an internal combustion engine. The APC was developed by researchers at the University of California (UC), Berkeley. It utilizes a closed-loop internal combustion engine with argon as the working fluid (instead of air), in conjunction with a membrane gas separation unit. The closed-loop nature of the system completely eliminates air pollutants and GHG emissions. The project will take place at UC Berkeley, with work to be completed in two phases: 1) high-fidelity modeling and sub-component development; and 2) full system integration and operation. The team has progressed according to plan, with only a few minor delays due to supply chain issues. In the meantime, the team has completed the development of high-fidelity code simulating the entirety of the technology, integrating carbon capture technology, reciprocating engine power train, and heat transfer mode. Additionally, the team has completed the design of the overall plant and the design and manufacturing of the retrofit kit for the stock diesel engine. Engine performance estimates show engine efficiencies reaching as high as 62% on an engine scale normally delivering no more than 40%. The entirety of the system is under construction and expected to be ready for firing and integration by Q4 2022. The system will be operated for 18 months after commissioning. .
54	NREL GKN Metal Hydride Storage Integration with Renewable Energy and Fuel Cells Demonstration	20211206183920	Clean Generation	Integration & Controls	Integration & Controls	1/1/2022	6/30/2025	$400,000	$2,614,114	$0	$400,000	DOE - $1,722,089, GKN -$492,025	Reliability, Improved Affordability, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality, Safety	Late Stage (TRL 7-9)	Commercialization	This project will validate and demonstrate the dynamic operation of GKN's HY2MEGA metal hydride hydrogen storage system integrated with NREL's ARIES platform. The H2MEGA will be the largest metal hydride storage system ever built (520 kg H2 / 17.2 megawatt-hour). The project will be constructed at NREL's Flatirons Campus and will leverage the following ARIES resources: 1.25 MW PEM electrolyzer, 1.0 MW PEM fuel cell, 600 kg compressed H2, 6.3 MW controllable grid interface, battery, and renewable power assets. Renewable electricity will be used to produce green hydrogen via electrolysis, which will then be stored in the HY2MEGA system and a compressed storage system. That hydrogen will then be used to generate electricity via the fuel cell. Simulated energy production and consumption via the controllable grid interface will enable the team to validate the HY2MEGA performance in various real-world scenarios. These simulated use cases will include data centers and remote communities. The project will aim to achieve the following goals 1) Validate the storage and delivery performance of the HY2MEGA technology under a variety of charging and discharging conditions; 2) Demonstrate commercial use cases for a megawatt scale power system; 3) Determine the large-scale hydrogen storage efficiency for a materials-based technology; 4) Demonstrate a safe operating system. .
55	NREL Grid Forming Inverters for Fuel Cells Research	20211215171616	Clean Generation	Integration & Controls	Integration & Controls	1/1/2022	3/31/2025	$500,000	$1,689,000	$150,000	$350,000	DOE -$1,189,000	Reliability, Operational Efficiency, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Early Stage (TRL 1-3)	Share/publish results	The purpose of project is to develop interconnection and interoperability standards for grid forming fuel cell inverters. Grid forming inverters are critical to maintain and regulate voltage and frequency for parts of the grid without traditional rotational assets (which typically perform this function). In the past few years, grid forming inverters have been successfully integrated with battery storage systems. Due to the operational differences between fuel cells and batteries, standards specific to fuel cell integration with grid forming inverters are needed. This project utilizes NREL's cutting edge ARIES research platform, which is capable of integrated systems modeling and testing at scales up to 20MW. The project will be performed in three phases: hardware-in-the-loop modeling, interconnection and interoperability requirement evaluation, and testing/validation of the developed standards in the ARIES platform. The project has three technical goals: demonstrating the ability of fuel cell inverters to transition between grid following and grid forming modes, interconnection standards (how fuel cells connect to the grid), and interoperability standards (how fuel cells communicate w/ other assets). .
56	UCI Fuel Cell Supported Nanogrid Controls Evaluation	2021082023224	Clean Generation	Integration & Controls	Integration & Controls	11/8/2021	4/30/2023	$436,653	$556,653	$275,000	$161,653	Heila Technologies and Instant On - $120,000	Reliability, Operational Efficiency, Improved Affordability, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Late Stage (TRL 7-9)	TBD	The purpose of this project is to evaluate two microgrid control platforms in the context of a fuel-cell-supported residential microgrid ("nanogrid"). This project leverages the results of an ongoing project to develop and test a nanogrid control strategy designed to achieve zero net energy in a residential setting with a solid oxide fuel cell (SOFC), PV solar, and battery storage. The university of California, Irvine (UCI) will work with two microgrid controls vendors to evaluate and further develop the capabilities of its control platform(s). The microgrid controllers will be installed in UCI's laboratory nanogrid, which includes a 1.5kW SOFC, 5kW of rooftop solar, and a 9.8kWh battery. The control platforms will be tested for their ability to meet the dynamic operating requirements developed in the previously mentioned supporting project. In addition to the technical testing, UCI will evaluate the greenhouse gas and criteria pollutant emissions implications of the control strategies and determine the cost and equity implications of the test scenarios as applied to the residential demands of various California climate zones. .
57	UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research	20211027203855	Clean Generation	Integration & Controls	Integration & Controls	11/22/2021	12/31/2023	$362,442	$562,442	$225,000	$137,442	Microsoft - $200,000	Reliability, Improved Affordability, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Mid Stage (TRL 4-6)	Potential field demonstration	The goal of this project is to demonstrate that hydrogen-based renewable fuels—in concert with a cheap and renewable power supply on the electric grid—provide the best techno-economic and long-term solution to meet both 100% renewable energy conversion goals and stringent reliability requirements for essential services like data centers and hospitals. This project leverages previous and ongoing Microsoft co-funded data center research. The University of California, Irvine will design and optimize a fully integrated energy system for a data center. System design will account for site loads, electrochemical energy conversion and storage devices (fuel cells, electrolyzers, batteries), renewable generation (on- and off-site), and dynamic integration with infrastructure grids (electric, gas, water). Optimizations and comparisons will be based on technical capabilities, achieved reliability, and cost. .

58	UTD High-Efficiency Combi System Integrating PV and Self-Power - Phase 2 (1.20.G.2)	20210820181519	Clean Generation	Integration & Controls	Integration & Controls	7/1/2021	7/31/2023	$95,769	$450,000	$48,000	$47,769	UTD Members -$354,231	Reliability, Operational Efficiency, Improved Affordability, Environmental Benefits: Reduced GHG Emissions	Mid Stage (TRL 4-6)	TBD	The goal of this project is to develop and demonstrate a hybrid residential combined HVAC and water heating (combi) system in the laboratory that uses off-the-shelf appliances and novel controls to integrate gas-electric systems with micro combined heat and power (mCHP), energy storage, and renewable energy in order to improve efficiencies, reduce greenhouse gas emissions, reduce operating costs, and increase resilience. GTI has successfully operated the nanogrid to achieve self-powered hybrid residential HVAC and water heating using the mCHP system and thermal/electric energy storage to power the combi system and air source heat pump (ASHP). The nanogrid controller manages the various power sources including mCHP, grid power, and solar PV. By using thermal heat recovery from the micro-CHP system together with the ASHP and supplemented with the tankless heater as necessary, GTI is targeting annual coefficients of performance greater than 1.0 serving heating loads down to 5,000 BTUs per hour. GTI is now implementing a test plan to determine the performance of various system configurations: grid parallel, islanded, and integrated with simulated solar PV generation. .
59	UTD Integrated mCHP System for Multi-family Building - Phase 2 (1.20.J.2)	202102250221	Clean Generation	Integration & Controls	Integration & Controls	7/1/2021	7/31/2023	$139,249	$480,000	$70,000	$69,249	UTD Members -$340,751	Reliability, Operational Efficiency, Improved Affordability, Environmental Benefits: Reduced GHG Emissions, Environmental Benefits: Improved Air Quality	Mid Stage (TRL 4-6)	TBD	The goal of this project is to leverage the results of Phase 1, which integrated a Lochinvar CHP, distributed air source heat pumps, and thermal storage in an integrated energy system (IES). This project will expand the capabilities of the system to further test and demonstrate the capabilities of the IES in a multifamily setting. The project team will integrate electric vehicle charging, PV integration, and hydrogen blending in a microgrid configuration to demonstrate resiliency and efficiency benefits. The system will be designed and evaluated in both grid-connected and islanded configurations. .
60	GTI Model-Based Control Hospital Deca	2020101532851	Customer End-Use Apı	Commercial Applications	Commercial Applications	12/1/2020	3/31/2024	$161,250	$1,585,954	$80,000	$81,250	CEC - $1,424,704	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Operational Efficiency	Late Stage (TRL 7-9)	CEC Final Report, Technology & Knowledge Transfer Activities	This project will demonstrate an integrated model-based control solution for reducing space heating and hot water loads in order to decarbonize large commercial buildings. The proposed technology will significantly reduce energy use and GHG emissions. GTI will monitor and report real energy savings and GHG reductions from the installation of advanced technologies at the Baldwin Park Medical Center. The goals of the project are to demonstrate an overall 30% reduction in natural gas usage and a simple payback of less than 3 years, advance the technologies integrated with model-based optimal control from TRL7 to TRL9, and showcase the retrofit measures and energy savings through outreach to encourage similar implementation of energy saving measures throughout the state. In 2021, the project team held their first technical advisory committee meeting on 7/2021 to share their project progress. During their meeting, they shared their analysis on the site characterization including technical information on the boiler and chiller systems used by the medical center. They also discussed their baseline monitoring plan which was submitted on 3/2021 and next steps in the project which include addressing outstanding metering issues, fine tuning energy models, and drafting the final hospital baseline energy usage and modeling report. .
61	UTD CleanO2 CARBiNX Carbon Capture (1.21.C)	20210822222945	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	1/31/2023	$30,000	$150,000	$30,000	$0	UTD - $120,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Improved Affordability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will evaluate the performance of a CleanO2 CARBiN-X v 4.0 carbon capture device in a laboratory setting in order to validate claims of a carbon dioxide capture rate of 4 metric tons per year and cost savings of at least 30% for hot water heating. It will furtherand identify areas for continued technical improvement. Besides the CARBiN-X v 4.0, CleanO2 is working on more advanced prototypes that look to further disrupt the distributed carbon capture market. Depending on the progress in the development of these prototypes, GTI may perform preliminary regulatory and technical analyses to support advancement of this technology. Implementing distributed carbon capture technology such as the CARBiN-X will help reduce greenhouse gas emissions in the residential and light commercial and industrial spaces while retaining natural gas in Zero Net Energy Buildings. .
62	UTD Commercial Heat Pump Water Heater Field Performance Comparison (1.21.F)	20210822223940	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	1/31/2024	$4,707	$916,000	$3,565	$1,142	UTD Members - $161,293 PERC - $30,000 DOE - $720,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Reliability, Improved Affordability, Operational Efficiency	Late Stage (TRL 7-9)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	In this project, a comparison between commercial gas and electric heat pump water heater technology will be conducted in one or two field locations as well as in GTI's laboratory using ASHRAE standards to establish the cost and energy saving capability of each technology. The goals are to assess the performance of of these technologies under various conditions, , and to provide equitable comparative information between commercial heat pump technologies. The project agreements were finalized in 2021, and work is expected to begin in early 2022. .
63	UTD Gas Engine Heat Pump Modeling, Testing, and Implementation (1.21.E)	2021082222354	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	1/31/2024	$7,631	$320,000	$6,200	$1,431	UTD Members - $312,369	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will validate natural gas engine-driven heat pump (GEHP) performance for variable refrigerant flow (VRF) systems across a range of conditions. It will expand the market through enhanced energy models using measured performance data, validation of a new method of testing (ANSI/CGA) for new GEHP performance metrics, a technoeconomic assessment to determine the best use of three new GEHP equipment options. These options includeAHU integration kits, Yanmar Hydrobox, and Aisin Hi-Power. The project agreements were finalized in 2021, and work is expected to begin in early 2022. .
64	UTD Gas-Fired Binary Fluid Ejector Heat Pump Water Heater (1.20.E)	2021022503444	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2020	7/31/2023	$19,125	$2,080,000	$19,125	$0	UTD Members - $160,875 DOE - $1,900,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Operational Efficiency	Late Stage (TRL 7-9)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project models, designs, and builds prototypes of a gas-fired ejector heat pump water heater (GFEHP). This first-of-a-kind heat pump uses a novel cycle that combines a binary-fluid ejector and sorption subsystem into one high efficiency cycle. The technology integrates several components that are thermally and hydraulically coupled. The overall objective is to develop and demonstrate GFEHP technology at 12,000 Btu/hr (3.5 kW) capacity in the laboratory and to achieve a COP of 2.0. This will make it twice as efficient as the current state-of-the-art technology on a primary energy basis. This will help retain a high-efficiency role for natural gas for more than 80 million residential users of gas fired water heaters in the U.S. alone. The research team is finalizing the burner design and will begin designing and developing the heat-exchanger system between the flue gas and the working fluid. .
65	UTD Hydrogen-Blended Gas in ResCom Combustion Equipment - Phase 2 (1.20.H.2)	20210822222121	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	7/31/2023	$4,350	$150,000	$4,350	$0	UTD Members - $145,650	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Improved Affordability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will support the potential deployment of up to 30% hydrogen blended gas in North America in commercial and residential buildings, by assessing operational performance, emissions, and safety impacts on at least five standard appliances in a laboratory setting. Specific goals of Phase 2 are to determine the impact of hydrogen blends on efficiency rating and seasonal performance on appliances, to project greenhouse gas (GHG) reduction potential of hydrogen blending at various levels for U.S and Canadian blocking stocks, and to identify safety, emissions, and efficiency benefits or concerns. .
66	UTD Ionic Liquid Absorption Heat Pump for Commercial Water Heating (1.21.I)	2021091522323	Customer End-Use Apı	Commercial Applications	Commercial Applications	12/31/2021	12/31/2023	$2,400	$225,000	$1,200	$1,200	UTD Members - $222,600	Operational Efficiency, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	The objective of this project is to design and demonstrate in a lab environment an "alpha" working prototype of a low-cost, ultra-high efficiency gas-fired commercial heat pump water heater with a novel semi-open absorption cycle (SOA-GHPWH) that uses a benign ionic liquid, and which provides integrated latent cooling to further maximize efficiency. The target efficiency is COPgas,HW ≥1.60 if only providing hot water, or COPtotal ≥1.80 if also providing indoor cooling and dehumidification. The prototype will be performance-tested at loads (steady and dynamic) typical of commercial buildings with 100 gallons storage and nominal heating output of 145 kBtu/hr. The system uses a simple plastic pump, and most materials of construction are polymers.
67	UTD Membrane Based Ionic Liquid Absorption Heat Pump for Commercial HVAC (1.20.I)	202102250400	Customer End-Use Apı	Commercial Applications	Commercial Applications	8/1/2020	8/31/2023	$24,033	$1,800,000	$24,033	$0	UTD Members - $150,967 PERC - $25,000 DOE - $1,600,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	The objective of this project is to develop an innovative thermally-driven cooling technology for commercial heating, ventilation, and air conditioning (HVAC) applications. The technology will be demonstrated in a prototype ultra-high-efficiency dedicated outdoor air system (DOAS). The core technology under development is a novel, scalable absorption system for dehumidification using a highly efficient open double-effect liquid desiccant cycle enabled by the use of non-crystallizing ionic liquids. This absorption system is centered on a compact membrane-based heat and mass exchanger with no desiccant entrainment. The compact size facilitates easy retrofitting into existing building infrastructure. Regeneration of the system is driven by efficient heating (natural gas, propane, waste heat, solar, etc.). Modine Manufacturing, a commercial HVAC market leader, will provide industry support. The project team is completing the fabrication and experimental investigation of the desorber/condenser combustion system evaluation in the laboratory.
68	UTD Sequestering Non-Condensable Gases for Enhanced GHP Reliability - Phase 2 (1.19.E.2)	20210822221232	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	7/31/2023	$2,364	$240,000	$2,364	$0	UTD Members - $197,636 SMTI, Robur - $40,000	Operational Efficiency, Safety, Reliability, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	To successfully advance the use of high-efficiency gas absorption heat pumps (GAHP), it is important to minimize the impact of non-condensable gases on long-duration performance and reliability. The goal of this project is to design and develop non-condensable gas isolation (NCGI) modules and provide research and development support to employ novel, low-cost aluminum heat exchangers to increase long-term system efficiency and reliability and safe operation and reduce the cost of any absorption-type heat pump. The project team plans on demonstrating the performance of the technology in a prototype GAHP. In 2020 through 2021, the project team initiated and completed rounds of corrosion testing with the alloy samples. In parallel, university researchers are initiating atmospheric pressure testing. .
69	UTD Thermoelectric Generator for Self-Powered Water Heater - Phase 4 (1.17.B.4)	20210822215444	Customer End-Use Apı	Commercial Applications	Commercial Applications	7/1/2021	7/31/2023	$6,000	$1,280,000	$6,000	$0	UTD Members - $234,000 DOE - $1,000,000 AO Smith, Sheetak, Marlow - $40,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Reliability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	The objective of this project is to develop a self-powered, gas-fired tankless water heater to save rate-payers money and energy while enhancing resiliency. In Phase 4, the team will design, build, and test a working alpha prototype. Phase 4 will build upon the hardware testing performed in prior phases to develop the critical components and integrate the design to power a condensing tankless water heater. GTI plans to utilize UTD's Phase 4 funding as cost share to leverage a next round of funding from DOE towards implementing this technology. Phase 4 will also leverage GTI's efforts and relationship with DOE BTO on a related current DOE BTO project, as well as past UTD projects. .

70	UCI Hydrogen Blend Commercial Stove	20210820204140	Customer End-Use Apr	Commercial Food Service	Commercial Food Service	11/1/2021	11/1/2023	$305,000	$305,000	$100,000	$205,000	N/A	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability	Mid Stage (TRL 4-6)	Final Report, PowerPoint, Peer-Reviewed Article, Press Release, Webinar	Currently, NOx emissions from cookstoves are not subject to regulation, but they are a strategic end-use device to be considered for future building emissions reduction. While studies suggest a modest decrease in NOx when low amount of hydrogen is added to natural gas in typical stove burners, the levels still approach 80-90 ppm. Reduction in NOx emissions can be achieved by i) reducing the combustion temperature, ii) decreasing the flue gas residence time in the high temperature zone and iii) reducing the excess O2 in the fuel/oxidizer mixture. Catalytic combustion provides the advantage of lowering the temperature of the oxidation reaction, thus resulting in significantly lower NOx emissions. Catalytic combustion of hydrogen and natural gas has been studied in literature separately for various applications. However, there is no study on the evaluation of fuel blends, resulting NOx emissions, and application for commercial cooking. Therefore, in the proposed work, an ultra-low NOx catalytic burner will be designed and built to burn natural gas/hydrogen blends (up to 50%) for commercial cooking applications. This work will be the phase I of a two-phase study. After burner development, phase II will include development of a commercial prototype and involve a commercialization partner to help with the commercialization process. Since the research agreement was executed in late Q4 of 2021, there are no project updates to report. .
71	UTD Gas Fired Warewasher Door Mach	20210822224724	Customer End-Use Apr	Commercial Food Service	Commercial Food Service	7/1/2021	7/31/2023	$19,938	$145,000	$11,000	$8,938	UTD Members - $125,062	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Reliability, Improved Affordability, Operational Efficiency	Late Stage (TRL 7-9)	UTD Final Report	The objective of this project was to develop gas-fired prototypes of two types of warewashers (dishwashers): the doortype (low-volume) and the conveyor-type (high-volume). These represent a combined 43% segment of the warewasher market. Presently, most commercial warewashers are electric driven, and many electric warewashers use chemicals rather than high temperatures to disinfect, which further increases their environmental impact. Initial estimates indicate a site will only use one-third of the source energy with a gas warewasher compared to alternative technologies. Even a low-usage restaurant, with onl 1,100 therms of annual usage, would reduce the carbon footprint of the restaurant from 49,610 pounds of CO2 per year with electric units to 16,088 pounds of CO2 per year with gas-fired units. In this project, researchers and a manufacturing partner modified current electric-driven warewashers. Different heat exchanger designs were modeled to determine the best-performing designs that fit into the needed footprint of an existing electric warewasher. Prototype heat exchanger(s) were fabricated and put into a prototype along with a burner and blower. A functional prototype was tested for combustion efficiency, safety, and emission standards. Researchers modeled 13 variations of different heat-exchanger designs and tested the combustion system in the laboratory with the prototype tank and heat exchanger. Custom controls were used to tune everything, and excellent results (under 10ppm NOx) were achieved. Technicians assembled the burner, blower, and gas valve assembly, along with a new control for the combustion system. Initial testing of the combustion system in the prototype heat exchanger was completed. .
72	UTD High Efficiency Smart Convection Oven - Phase 2 (1.19.A.2)	2021082222442	Customer End-Use Apr	Commercial Food Service	Commercial Food Service	7/1/2021	7/31/2023	$49,111	$215,000	$49,111	$0	UTD Members - $120,889 Blodgett - $45,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Improved Affordability, Operational Efficiency	Late Stage (TRL 7-9)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	In this project, researchers are incorporating a heat exchanger to recover heat from the flue and feed it back into the combustion air. The objective is to develop a prototype high efficiency smart convection oven that increases efficiency by at least 5%, and also integrates superior smart operating controls to maximize food preparation quality and consistency. Earlier, researchers investigated a high-efficiency oven design, showing that this design in bench-scale tests was able to achieve a 3% improvement to cooking efficiency and a 10% improvement to preheat energy use despite not being fully optimized. Based on these results and areas for improvement that were found in that initial design, the project team anticipates that a 5%-10% cooking efficiency should be achievable once the design has been optimized. In addition, a targeted 10%-20% reduction in NOx and CO emissions are expected. In 2021, the project team completed basic testing on the modified heat exchanger. Pre-mix testing will follow. The proposed design is targeted to be 10% more efficient than current ENERGY STAR designs. When compared to installed ovens, it could save more than 50% of the energy use (i.e., over 400 therms per year). A 50% savings translates to $300 in savings annually for the customer (assuming $0.75 per therm) compared to baseline existing ovens. It would be expected to pay back in one to two years, since the cost premium may only be around $300-$400. Discussions with a leading manufacturer continue regarding commercialization opportunities and other next steps to make this more efficient oven available to end users. .
73	GTI Booster Ejector Enhancement of Co	2020101525135	Customer End-Use Apr	Industrial Process Heat	Industrial Process Heat	12/1/2020	12/31/2023	$110,000	$1,731,556	$45,000	$65,000	CEC - $1,621,556	Operational Efficiency, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality	Late Stage (TRL 7-9)	GTI Final Report, CEC Final Report, Press Release, Webinars, Journal Publication (ASHRAE, ASME, and food processing journals)	In this CEC funded project (EPC-19-023), the project team is developing a Booster Ejector Enhancement of Compressor Refrigeration (BEECR) for field demonstration. The proposed solution recovers steam from a gas-fired cooker, extracts the waste heat and water, and sends the waste steam through the ejector which then drives the chiller displacing the consumption of electricity from the refrigeration cycle. Natural gas and water will be saved through utilization of the waste steam for facility needs and providing pre-heating/boiler infeed water heating. The project seeks to achieve at least a 20% reduction in energy consumption in addition to water savings and significant reductions in nitrogen oxides, particulate matter, and greenhouse gas emissions through energy savings. In October 2021, the project team submitted a draft report to the California Energy Commission pertaining to system design, baseline testing, and a field test plan. By the end of 2021, the project team had made progress towards completion of system installation and package monitoring. The project team of GTI, Wilson Engineering Technologies (WET), and Tetra Tech is currently finalizing the measurement and verification plan and the piping and instrumentation diagrams. GTI and WET are coordinating with the chiller and compressor manufacturers—Multistack and Danfoss—to finalize overall system design, including the booster ejector system and heat recovery unit to be installed on the boiler exhaust. Tetra Tech is planning to install a fuel flow meter on the boiler to measure the boiler load profile, which will inform the design of the heat recovery unit, and a buffer tank for thermal energy storage. .
74	GTI Waste Heat Effective Transfer in Bre	2020101535820	Customer End-Use Apr	Industrial Process Heat	Industrial Process Heat	12/1/2020	3/29/2024	$177,821	$1,948,387	$47,665	$130,157	CEC - $1,410,566 Tower and Campus Brewing - $100,000 UTD Members - $270,000	Environmental Benefits: GHG Reduction, Environmental Benefits: Air Quality Improvement, Operational Efficiencies, Improved Affordability	Late Stage (TRL 7-9)	CEC Final Report, Technology & Knowledge Transfer Activities, Commercialization Plan	In this CEC sponsored field demonstration (PIR-19-004), a Waste Heat Effective Transfer (WHET) technology will be installed in the flue of two micro-distilleries. The WHET recovers waste heat from the brew kettle to provide preheated plant water in the facility hot water tank which will result in significant reduction in natural gas consumption and emission. The WHET is unique because it utilizes a low-cost heat exchange module made of modified tubing that provides excellent heat transfer in minimum space and minimum pressure drop. The tubing surface features disrupt boundary layers which increases gas mixing, resulting in increased average gas temperature, and higher overall heat transfer rates as compared to its competitors. The objectives of this project are demonstrate a cost-effective, modular, and unintrusive waste heat recovery solution that can be installed in a variety of industrial applications and achieve a 15 to 25% recovery of heat from the brew kettle which would result in natural gas savings and the lowering of emissions (carbon dioxide and NOX). .
75	UCI Solid Oxide Electrolysis Cells for Gre	202012142447	Customer End-Use Apr	Industrial Process Heat	Industrial Process Heat	3/1/2021	3/1/2024	$550,000	$5,699,861	$275,000	$275,000	DOE - $4,043,993 UCI, Politecnico di Milano, FuelCell Energy, Inc., LEAP - $1,105,868	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Operational Efficiency	Mid Stage (TRL 4-6)	DOE Final Report, Technoloy Transfer Plan, Production Readiness Plan, Journal Publications, Conference Presentation, DOE Webinar/Press Release	The objective of this project is to study, demonstrate, and optimize an integrated, zero-emission prototype for the direct reduction of iron with H2 produced from a SOEC system. The project is a close collaboration of academia (University of California, Irvine and Politecnico di Milano), industry (FuelCell Energy, Inc.) and a technology transfer company (LEAP). In 2021, the team determined the specific primary energy consumption < 8 GJ/ton DRI for the best performing Hydrogen Direct Reduction configuration at nominal load. Three system configurations have been proposed representing incrementally integrated layouts between the SOEC unit and the shaft furnace. Additionally, the team completed a SOEC model validation on voltage-current curves with an average prediction error <5% on the steam electrolysis experimental measurements. The model predicted electric-to-hydrogen production efficiency of < 35 kWh/kg (or >95% with 120 MJ/kg of H2 Lower Heating Value) at nominal design steady-state conditions. The project team plans to complete validation of SOEC co-electrolysis model for Hybrid HDR scenario with literature data, begin pressurized stack testing at FCE's manufacturing site, optimize system layouts for steam electrolysis scenarios, and initialize system configurations for co-electrolysis (hybrid HDR) in 2022. .
76	UTD Energy Source Options for Industrial Users - Phase 2 (2.20.E.2)	2021082223233	Customer End-Use Apr	Industrial Process Heat	Industrial Process Heat	7/1/2021	1/31/2023	$2,581	$165,000	$2,581	$0	UTD Members - $147,419 ESC - $15,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Improved Affordability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project expands and simplifies the use of a detailed techno-economic analysis developed in a previous phase of the project. The analysis considered fuel-switching and electrification scenarios for industrial and large commercial end-users, by transitioning a spreadsheet-based analysis to a convenient online tool and including a spectrum of applications beyond boilers. The overall objective is to develop a roadmap basis for natural gas and other energy source options to support the reliable and cost-effective supply of energy to industrial and large commercial sectors to achieve the local environmental targets, by providing a robust user-friendly analytical tool that helps decision-making by end-users and others as they strive to decarbonize. .

77	UTD High Hydrogen Burner for Commercial and Industrial Applications (2.21.A)	2021082223515	Customer End-Use Apı	Industrial Process Heat	Industrial Process Heat	7/1/2021	7/31/2023	$84,000	$340,000	$84,000	$0	UTD Members - $216,000 ORNL, CalSteel, Gopher Resources, ANL - $40,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Safety, Reliability, Improved Affordability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will design, fabricate, and test an advanced fuel-flexible hydrogen/renewable natural gas (H2/RNG) 0.5 to 1 MMBH burner in a commercial scale furnace at GTI's laboratory. The team will partner with two leading large industrial end-users and two national laboratories to ensure that the final prototype burner meets the requirements of the representative end users. GTI has successfully developed and bench-scale tested a 3D-printed burner design at 0.05 MMBH scale capable of operating efficiently and robustly with hydrogen up to 40% H2. The funding will demonstrate a scaled-up burner with higher hydrogen (up to 60%) to evaluate and commercialize the technology with California Steel, Inc. (CSI), Gopher Resources, Inc., Oak Ridge National Laboratory (ORNL) and Argonne National Laboratory (ANL). Actual field testing of the prototype will be separately funded/authorized. The project agreements were finalized in 2021, and work is expected to begin in early 2022. .
78	UTD Zero Emissions Processes with Carbon Recovery (2.21.C)	202108222381	Customer End-Use Apı	Industrial Process Heat	Industrial Process Heat	7/1/2021	7/31/2023	$15,000	$150,000	$15,000	$0	UTD Members - $135,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Improved Affordability, Operational Efficiency	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will advance through laboratory testing the development of a new synthetic air combustion (SAC) process in order to simultaneously improve industrial boiler or furnace efficiency when using natural gas while also lowering CO2 emissions and providing a means to capture or convert CO2 to valuable products. Laboratory tests will be conducted at industrial conditions, and results will help compare calculated and experimental results when using SAC to typical air-fired combustion. The ultimate objective is for this process technology to help create a lower-carbon future while using natural gas in industrial boilers and furnaces. The project agreements were finalized in 2021, and work is expected to begin in early 2022. .
79	Lantec Development of Ultra Low NOx f	2019041616262	Customer End-Use Apı	Residential Appliances	Residential Appliances	5/1/2019	12/31/2023	$92,500	$432,500	$37,531	$54,970	SCAQMD - $340,000	Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Operational Efficiency	Mid Stage (TRL 4-6)	SCAQMD Final Report, Certified Low NOX Furnace	The goal of this project is to achieve the design, development, performance and operational testing, certification, and commercialization of residential condensing and non-condensing forced air furnaces utilizing MicroNOx ultra-low NOx combustion technology emitting no more than 7 ng/J NOx. This project will take a novel burner technology "MicroNOxTM", developed by Lantec Products from its current early product development stage along the product readiness levels to a point where the manufacturing partner has a viable product to begin introduction into a commercialized product line. The project team will test the prototype units in accordance with the certification test procedure contained in AQMD Rule 1111 including AQMD Method 100.1. The prototype furnaces will also be tested against ANSI Z21.47 including 10,000 combustion cycles as prescribed within the standard. In 2021, the project schedule was delayed by COVID-19. Despite this, Lantec focused on finalizing the condensing and non-condensing prototype design and completion of non-condensing retrofit furnace. The project team anticipates delivery of the furnaces to GTI for operational testing based on ANSI Z21.47 standards by March 2022. .
80	ORNL Residential Hydrogen Blended Sp	20210831175330	Customer End-Use Apı	Residential Appliances	Residential Appliances	11/1/2021	11/1/2023	$600,000	$600,000	$50,000	$550,000	N/A	Safety, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Improved Affordability	Mid Stage (TRL 4-6)	Final Report, Journal Article, Press Release, Webinar, Techno-Economic-Environmental report, Commercialization Plan, IP/Patent	In this project, a residential space heater will be retrofitted with a flameless heterogeneous burner technology to develop a clean and safe space heating appliance capable of operating on hydrogen and natural gas fuels; emissions, safety, turn-down, reliability, and efficiency will be addressed in designing the space heater. When hydrogen is introduced to the fuel mixture, special attention to flame velocity and temperature must be considered. Conventional burners lead to high NOx emissions due to the extreme flame temperature and high flame velocity makes it susceptible to flashback, thus creating safety hazards. Both factors can inhibit usage of hydrogen blended fuel in building heating equipment. Therefore, a low temperature, flameless, heterogeneous catalytic oxidation burner is ideal for safely converting the fuel energy into the desired heat quality. The primary focus of the proposed effort is to enable higher hydrogen blended fuels in a 40k Btu/h space heating system which would accommodate the typical 2000 sq ft home. The objectives of the project are to design, fabricate, evaluate, and optimize a burner capable of operating on natural gas containing up to 40% hydrogen, conduct a techno-economic-environmental analysis to support the business case, study the compatibility of the developed burner with different commercial systems with regards to form and fit with the goal of designing a universal retrofit kit, and identify and engage with an OEM towards a commercialization pathway. .
81	ORNL Residential Hydrogen Blended Space Heater Development	20210831175330	Customer End-Use Apı	Residential Appliances	Residential Appliances	11/1/2021	11/1/2023	$600,000	$600,000	$50,000	$550,000	N/A	Safety, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality, Improved Affordability	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, IP, Press Release, Commercialization Plan, SoCalGas Webinar	In this project, a residential space heater will be retrofitted with a flameless heterogeneous burner technology to develop a clean and safe space heating appliance capable of operating on hydrogen and natural gas fuels; emissions, safety, turn-down, reliability, and efficiency will be addressed in designing the space heater. When hydrogen is introduced to the fuel mixture, special attention to flame velocity and temperature must be considered. Conventional burners lead to high NOx emissions due to the extreme flame temperature and high flame velocity makes it susceptible to flashback, thus creating safety hazards. Both factors can inhibit usage of hydrogen blended fuel in building heating equipment. Therefore, a low temperature, flameless, heterogeneous catalytic oxidation burner is ideal for safely converting the fuel energy into the desired heat quality. The primary focus of the proposed effort is to enable higher hydrogen blended fuels in a 40k Btu/h space heating system which would accommodate the typical 2000 sq ft home. The objectives of the project are to design, fabricate, evaluate, and optimize a burner capable of operating on natural gas containing up to 40% hydrogen, conduct a techno-economic-environmental analysis to support the business case, study the compatibility of the developed burner with different commercial systems with regards to form and fit with the goal of designing a universal retrofit kit, and identify and engage with an OEM towards a commercialization pathway. .
82	UTD Mitigating Methane Emissions from ResCom End Use Equipment - Phase 3 (1.18.F.3)	2021082222623	Customer End-Use Apı	Residential Appliances	Residential Appliances	8/1/2021	8/31/2023	$19,000	$150,000	$19,000	$0	UTD Members - $131,000	Safety, Environmental: Reduced GHG Emissions, Environmental: Improved Air Quality	Mid Stage (TRL 4-6)	Final Report, Journal Article, Technoeconomic Analysis, UTD Webinar	This project will quantify methane emissions from at least six key residential appliances that have not been quantified in past phases of the project, in order to develop and publish representative methane emission factors and to determine the conditions under which these appliances release unburned methane and identify potential mitigation options. At least six residential appliances, including cooking ranges and tank water heaters, will be tested under specific operating conditions and representative use patterns, including both steady-state, standby, and cyclic operation. .