Recommendations for the Proposed

"Hydrogen Blending Demonstration Project @ UCI":

A multi-year Pilot Demonstration Project to Inject and Blend Hydrogen in a Portion of the Natural Gas Distribution System on UCI's Anteater Recreation Center (ARC) Building

Prepared by:

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February 14, 2024

CHARGE

Vice Chancellor for Research Pramod Khargonekar and Samueli School of Engineering (SSoE) Dean Magnus Egerstedt reached out to Associate Deans Foufoula-Georgiou (SSoE) and Penner (Physical Sciences), and Distinguished Professor Diran Apelian (MSE, SSoE) to evaluate the risks associated with the beta testing "Hydrogen Blending Demonstration Project" proposed at the UCI campus.

Briefly, the proposed project would involve the blending of 5-20% hydrogen by volume with natural gas into the nearby natural gas distribution system that will serve the UCI's Anteater Recreation Center (ARC). If this proposed demonstration project is approved by UCI, it will be one of the 5 projects to be included in an application by SoCalGas to the California Public Utility Commission (CPUC) with California's four natural gas investor-owned utilities to demonstrate hydrogen blending under various conditions.

The Hydrogen Blending Review Committee -- referred hereafter as the Review Committee (RC) -- was asked to review the initial MOU between UCI and SoCalGas; consider the concerns raised by a coalition of organizations and advocates dedicated to climate and social justice in Orange County; conduct our own analyses; and recommend actions to the administration moving forward.

PROCESS

The RC had three in person meetings during January 2024 to review the materials that were available (Exhibits A through G), establish the process to follow, and decide what additional information was needed for our analyses and before recommendations could be made.

The RC communicated questions (Exhibit I) to Prof. Jack Brouwer, Professor in Mechanical and Aerospace Engineering (MAE) and Director of the Clean Energy Institute. The RC had an in-person meeting with Prof. Brouwer on January 8, 2024, to discuss concerns and potential risks. Prof. Brouwer's responses were obtained in writing (Exhibit K). Following these discussions, a meeting was requested with the leadership of SoCalGas, and this meeting took place on January 16, 2024 at UCI. President Maryam Brown and her team met with the RC. The questions posed to the SoCalGas team (Exhibit J) were discussed during the meeting and SoCalGas was asked to follow-up with a written response addressing those questions (Exhibit H).

Below are some of the key questions that guided the RC's analyses and its recommendations.

1) What **precedents** exist globally for blending hydrogen with methane at 5% and higher ?

2) Will the existing steel pipes on the UCI campus be used for transporting the blended gas? and if so, does the inevitable **hydrogen embrittlement** of this pipe constitute a safety concern?

3) Is SoCal Gas, UCI's collaborator in the Hydrogen Blending Proposal, **prioritizing safety** in the design and build-out of this project?

ANALYSIS and DISCUSSION

Precedents: The decarbonization of our natural gas energy infrastructure in the U.S., including pipelines, will eventually involve the replacement of 100% methane with green hydrogen at some concentration. A necessary first step, and a major goal of the Hydrogen Blending Demonstration Project, is to evaluate the feasibility of mixing hydrogen gas (H_2) with natural gas (mainly methane, CH_4) at mixing ratios of between 5% to 20% by volume. At present, there are few, if any, examples of blending up to 20% H_2 in natural gas pipelines in the U.S.

However, several sites across Europe have conducted even more ambitious studies (Exhibit H): For example, in two separate studies carried out in England between 2019 and 2022, the company HyDeploy (https://hydeploy.co.uk/project-phases/) connected over 100 homes and university building on the Keele University campus to 20% blended gas supply. A second, larger study in the city of Winlaton involved over 600 homes, several businesses, and a church.

At least three other European countries – the Netherlands, Germany, and France have conducted similar studies, and details are available from the URLs provided in Exhibit H. Germany is presently conducting a study that investigates blends up to 30% hydrogen.

In the U.S., since 1974, Hawaii Gas has pioneered the blending up to 15% hydrogen into its "renewable natural gas" mix which is supplied to many gas customers on the Big Island.

These successful demonstration projects are important data points for UCI, providing clear evidence for the feasibility of safely blending at the 20% level (or 15% in Hawaii) for applications in residential and commercial heating and cooking. The proposed *Hydrogen Blending Demonstration Project* at UCI follows in the footsteps of successful European studies.

Hydrogen Embrittlement – Hydrogen is a small molecule, and it can diffuse and permeate into the metal conduit pipe, causing hydrogen embrittlement. The mechanical property of the ferrous pipe is degraded causing failure due to the embrittlement and loss of ductility leading to fatigue failure. Embrittlement and enhanced fatigue crack growth rate occurs mostly under scenarios when high pressures are utilized, and pressure fluctuations occur.

A key point is that hydrogen embrittlement is a very slow process, requiring more than ten years in typical cases. Even though the Anteater

Recreation Center (ARC) is less than 25 years old, and the metal gas supply lines to this facility have never been exposed to hydrogen blends, SoCal Gas is building all new, metal transfer lines connecting the ARC to the electrolyzer producing green hydrogen on the UCI campus. This effectively eliminates the possibility of hydrogen embrittlement from compromising these new metal pipes on the time scale of this project.

The pipes in the ARC are not metallic and are plastic pipes alleviating any concerns of embrittlement in the pipes.

Prioritizing Safety – The RC met with members of the SoGas Gas leadership and engineering team, responsible for the design and build-out of the *Hydrogen Blending Demonstration Project*. SoCal Gas was responsive to the many questions raised by the RC during this meeting (Exhibits H and J). Pipeline integrity is amongst the most important safety issues associated with this project. SoCal Gas has proposed an aggressive schedule of twelve inspections/year involving all the piping involved in the demonstration – a factor of 12 higher than the usual annual inspections conducted for 100% natural gas pipe. Testing of all plastic piping within ARC that will be carrying the blended gas will also be carried out prior to the start of the project.

Moreover, as indicated in Exhibit H: *"To promote independent and impartial review, SoCalGas will hire experienced third-party engineering firms to conduct a minimum of three safety studies."*

Based upon our interactions with SoCal Gas personnel connected with this project, at many levels, the RC is convinced of their absolute commitment to safety in this demonstration project.

RECOMMENDATIONS

1. The UCI H_2 Blending Proposal, as described in Exhibit G, **should be approved by the Campus to move forward** provided that the safety engineering protocols identified by SoCalGas given in Exhibit H are followed.

2. **An administrative team** including personnel from UCI Facilities Management and EH&S **should be constituted to oversee the build-out** of the facilities associated with this proposed project, and to confirm safety procedures and best practices are observed.

3. We recommend that **UCI central facilities be involved in the safety oversight** and be engaged in the selection of the third-party engineering firm to be hired by SoCalGas to perform the three proposed safety studies of the proposed blending project.

The following additional recommendations are intended to provide transparency for the UCI student body and to broadly convey information about the proposed UCI H_2 Blending project to our campus and the

community:

4. Create a **dedicated website/page** @uci.edu for the UCI H_2 Blending Project. Articulate goals and processes at this website, **in advance of build-out** of the work.

5. Track the progress of the work at this website. Include **samples of data generated** for, e.g., H_2 leak testing, performance metrics for ARC HVac operating at specified levels of added H_2, etc.

6. **Post the report submitted by this committee online**, at this website.

7. Constitute a **Student Advisory Committee** of interested undergraduates and/or graduate students to provide feedback to the Campus's Oversight Committee on any issue(s) relating to the UCI/SoCal H_2 Testing project.

EXHIBITS

(i) MOU dated August 26, 2022 (**Exhibit A**);
(ii) Press release from SoCalGas Newsroom dated September 9, 2002 (**Exhibit B**);
(iii) Article which appeared in the Orange County Register penned by Brooke Staggs, dated December 18, 2022 (**Exhibit C**);
(iv) Article penned by Brooke Staggs which appeared in Southern California News Group, March 9, 2023 (**Exhibit D**);
(v) Letter forwarded to CA legislators and US Senator and Congresswoman authored by the coalition of organizations and advocates dedicated to climate and social justice in Orange County, dated March 9, 2023 (**Exhibit E);**
(vi) Report by the Canadian Gas Association on Enabling Higher Hydrogen Blending in the Natural Gas Distribution System – October 2022 (**Exhibit F**);
(vii) Proposal titled: The UCI Hydrogen Blending Proposal (**Exhibit G**);
(viii) SoCalGas Responses - UCI Hydrogen Blending Demonstration Project Safety Engineering and Data (provided by SoCalGas - **Exhibit H**);
(ix) Questions we posed to Prof. Jack Brouwer (**Exhibit I**);
(x) Questions we posed to SoCalGas leadership – President Maryam Brown and her team (**Exhibit J**).
(xi) Prof. Brouwer responses to questions posed by RC (**Exhibit K**)

EXHIBIT A

MEMORANDUM OF UNDERSTANDING

By and Between

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, ON BEHALF OF THE ADVANCED POWER AND ENERGY PROGRAM AT ITS IRVINE CAMPUS ("UCI")
and
SOUTHERN CALIFORNIA GAS COMPANY ("SoCalGas")

RECITALS

WHEREAS UCI is an internationally recognized leading public research university;

WHEREAS UCI is a "living laboratory" incubating numerous clean energy initiatives and technologies that contribute to future decarbonized energy systems;

WHEREAS clean hydrogen is a promising carbon-free fuel that will be critical to supporting California's clean energy transition on the electric and natural gas systems;

WHEREAS the California Public Utilities Commission ("CPUC") has asked investor-owned gas utilities including SoCalGas to inform on a safe hydrogen injection and blending standard for California's natural gas pipeline system;

WHEREAS SoCalGas seeks to demonstrate safe hydrogen injection and blending in a steel distribution system before informing on a standard;

NOW, THEREFORE, UCI and SoCalGas enter into this non-binding memorandum of understanding ("MOU") effective as of the 26th day of August, 2022.

I. PURPOSE

UCI and SoCalGas enter into this non-binding memorandum of understanding ("MOU") to collaborate on a proposed multi-year pilot demonstration program to inject and blend hydrogen in a portion of the natural gas distribution system on UCI's campus as further described in Exhibit A attached hereto (the "Project"). This non-binding MOU summarizes principal terms of a proposed collaboration to be set forth in a future, definitive joint demonstration agreement (the "Joint Demonstration Agreement").

This proposed Project is part of a joint investor-owned gas utility ("IOU") CPUC application to study the impacts of hydrogen on California's natural gas infrastructure. Research is to

be developed between the IOUs and University of California (UC) system campuses, including UCI, UC San Diego, and potentially others. The Project requires and is dependent upon approval by the CPUC.

II. GENERAL CONSIDERATIONS:

1. This MOU does not supersede other existing agreements and/or memorandums of understanding between either of the parties.
2. Each party will retain its primary responsibility for meeting all legal and regulatory requirements pertaining to it and its property.
3. Participation in any phase of the MOU is voluntary. Nothing contained in this MOU shall obligate any party to continue participating in any phase of the MOU and any party may terminate its participation in any phase of the MOU at any time for any reason or no reason.
4. This MOU is not a contract but merely a memorandum of the understanding of the parties to coordinate their efforts with respect to establishing the basis for the proposed Project. Neither party shall be bound with respect to any of the matters set forth in this MOU. Nothing in this Agreement shall create, or be construed to be, a joint venture, association, partnership, franchise or other form of business relationship. At no time will the employees, agents or assigns of one party be considered the employees of the other party for any purpose, including but not limited to workers' compensation purposes. Neither party shall be authorized to act on behalf of the other party, or to make representations or commitments of any kind on behalf of the other party.
5. Amendments to this MOU may be made by notification of the proposed changes to the other party and will become effective upon written execution by both parties, which may occur in counterparts.
6. This MOU may be terminated by delivering written notice to the other party, effective thirty (30) calendar days following the date of delivery of such written notification.
7. This MOU shall be included as an Exhibit in SoCalGas' testimony to the CPUC.
8. Neither party will use the name, abbreviation of the name, logo, seal, or other mark of the other party (including in any advertisement, press release or publicity related to this MOU) without that other party's prior written approval. To seek approval, a party will submit a request to the other party's institutional contact, who will assist with obtaining any internal authorization required by their institution.

III. BOTH PARTIES SHALL WORK TOGETHER ON THE FOLLOWING TASKS:

1. Collaborate to establish Project plan and terms and conditions, including construction, siting, deployment, and removal of associated equipment and utilities and reasonable timelines. For clarity, execution of the Project will be subject to a separate written agreement between the parties ("Future Agreement").
2. Collaborate to determine communications, education, safety, and fire safety protocols with campus staff and residents who may be affected by the Project.
3. Seek to find research collaboration areas to support student and faculty research.

4. To the extent that the implementation of any agreed-upon activity related to the Project requires a commitment of personnel, facilities, funding, intellectual property, or other institutional resources, the parties will negotiate and enter into Future Agreement signed by each party's authorized representative. Future Agreement will specify each party's commitment of resources and terms related to funding, equal opportunity, intellectual property, confidentiality, export control, indemnity, liability and other matters relevant to the Project.

IV. SUBJECT TO TERMS AND CONDITIONS IN FUTURE AGREEMENT, SoCalGas SHALL INVESTIGATE:

1. Installing two temporary pressure regulator stations and associated pipelines and cut and cap two pipeline locations to isolate UCI's gas system and to continue providing gas to UCI and non-UCI customers in the area;
2. Managing the design, permitting, construction, procurement and temporary siting on campus of related hydrogen equipment, including fencing, an electrolyzer and blending skid;
3. Testing hydrogen injection and blending on the system in increments from 5% to 20% by volume over the course of the Project;
4. Performing inspections and maintenance of the hydrogen blending facility over the course of the Project;
5. Following the end of the Project, reconnecting the demonstration pipeline system to the main distribution system and removing the temporary pressure regulator stations and hydrogen blending equipment; and
6. Providing facilitation services to support the UCI community throughout the duration of the Project;
7. Seeking full rate recovery for the Project from the CPUC; and
8. Obtaining all required licenses and/or easements from UCI prior to performing any such work, which licenses and/or easements shall subject to Future Agreement.

V. SUBJECT TO TERMS AND CONDITIONS IN FUTURE AGREEMENT, UCI SHALL INVESTIGATE:

1. Providing easements (and/or temporary license) and site access sufficient to install, operate, maintain and remove the Project equipment;
2. Providing facility access to test end use equipment as necessary; and
3. Providing faculty and student engagement to further the achievement of Project goals, for example in the areas of environmental engineering, behavioral sciences, and environmental education, among others.

VI. MISCELLANEOUS:

This non-binding MOU is not a contract or an agreement for a contract, but an expression of the intention of the parties to negotiate toward a binding and definitive Future Agreement and such other transaction documents as necessary based on the understandings contained herein and such additional or different terms as may be

mutually acceptable to the parties. Neither party shall have any obligation to commence or continue negotiations for Future Agreement and may terminate negotiations for Future Agreement at any time for any reason or no reason whatsoever. Neither of the parties shall be bound with respect to any of the matters set forth in this MOU, except to the extent such matters are contained in binding and definitive transaction documents executed by both parties. Any such definitive transaction documents will contain usual and customary provisions for transactions of the types contemplated therein with due regard for applicable tax, financial, indemnity, liability and regulatory requirements.

IN WITNESS WHEREOF, the parties hereto have executed this Memorandum of Understanding as of the last date written below:

UNIVERSITY OF CALIFORNIA IRVINE	SOUTHERN CALIFORNIA GAS COMPANY
By: David Gibbons	By: Neil Navin
Full Name and Title	Full Name and Title
E-SIGNED by David Gibbons on 2022-08-24 09:21:21 PDT	E-SIGNED by Neil Navin on 2022-08-24 09:43:19 PDT
Signature	Signature
Date: August 24, 2022	Date: August 24, 2022

Reviewed by A.C.
Andrew Cheung
Sr. Counsel
August 24, 2022

EXHIBIT A

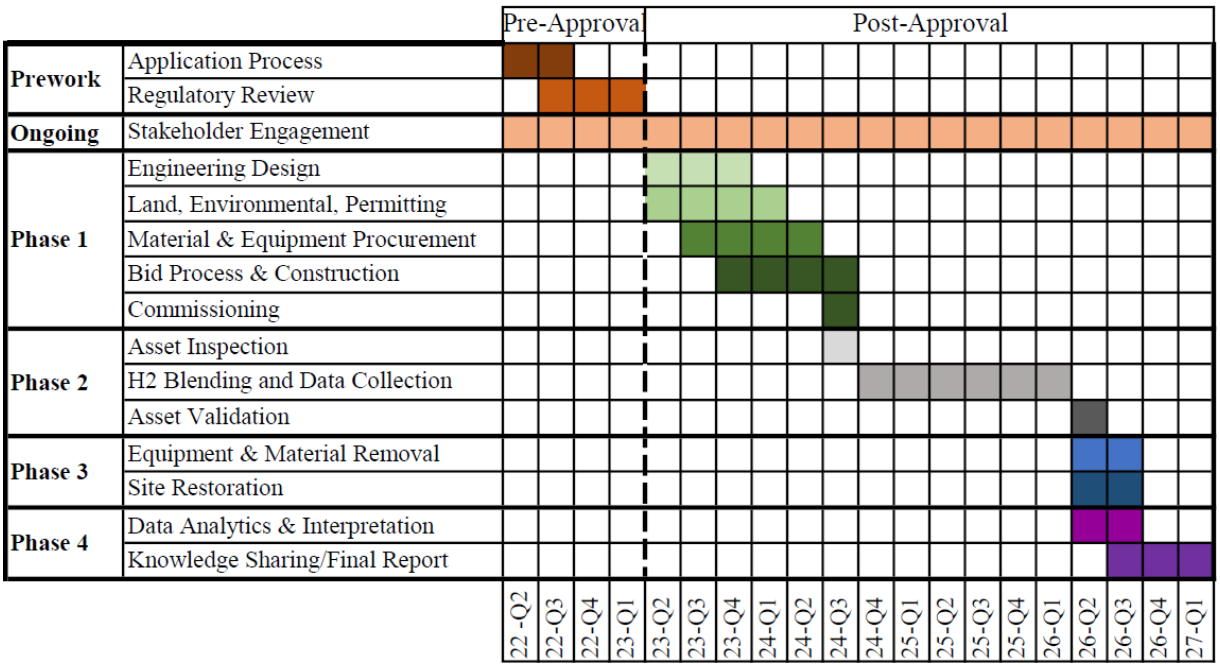
The purpose of the Project on the UCI campus is to specifically provide operational, live blending data for blending up to 20% hydrogen by volume in an isolated portion of a medium pressure steel and plastic distribution natural gas system. The Project will inform the feasibility of developing a state-wide hydrogen blending standard for steel and plastic pipe gas distribution systems that serve existing customers and equipment in the State of California.

The Project will be located on UCI's main campus along West Peltason Drive. The Project goal is to safely blend hydrogen into an isolated steel section of the medium pressure natural gas distribution pipeline system. The Project will begin by observing 100% natural gas in the pipeline system. Once that baseline is established, SoCalGas plans to blend and inject hydrogen into the system, starting at 5% hydrogen by volume and up to 20% hydrogen by volume over time. The blend volume will be gradually increased based on safety and technical feasibility validated with testing throughout the project duration, including evaluating key impacts on safety, odorant, pipes, valves, meters, and unmodified common appliances that will receive the blended gas.

The Project will be divided into four chronological phases ("Phases"). The Phases are briefly summarized in the table below; timing and duration of the Phases are estimated and subject to change. Phases have some overlap. See Estimated Project Schedule for details.

PHASE & ACTIVITY	DESCRIPTION	DURATION
1. Planning, Design, Construction, and Commissioning	Hydrogen equipment is procured; system is designed, constructed, and commissioned on campus; pre-demo equipment and pipeline system inspections and any necessary remediation are conducted; stakeholder engagement; temporary pressure regulating stations installed and campus isolated	18 months
2. Testing and Demonstration	Hydrogen is blended in system on a testing schedule; data is collected; periodic inspection of equipment and pipelines; test samples of pipelines and components pre- and post-hydrogen blend exposure	24 months (18 months live blending and 6 months asset inspection and validation)
3. Decommissioning, Equipment Removal, and	Hydrogen equipment is removed from campus; temporary regulating stations removed and campus restored	5 months

System Restoration		
4. Knowledge Sharing	Data from pilot is analyzed and a public report will be released	9 months



Figures 1 to 3 show the potential Project site layout, plot plan on the UCI campus, and the temporary pressure regulating stations and isolation points. Two other project sites along West Peltason Drive are also being reviewed for feasibility.

Figure 1: Potential SoCalGas Hydrogen Blending Demonstration Site Layout on UCI campus

Figure 2: Preliminary Project Plot Plan

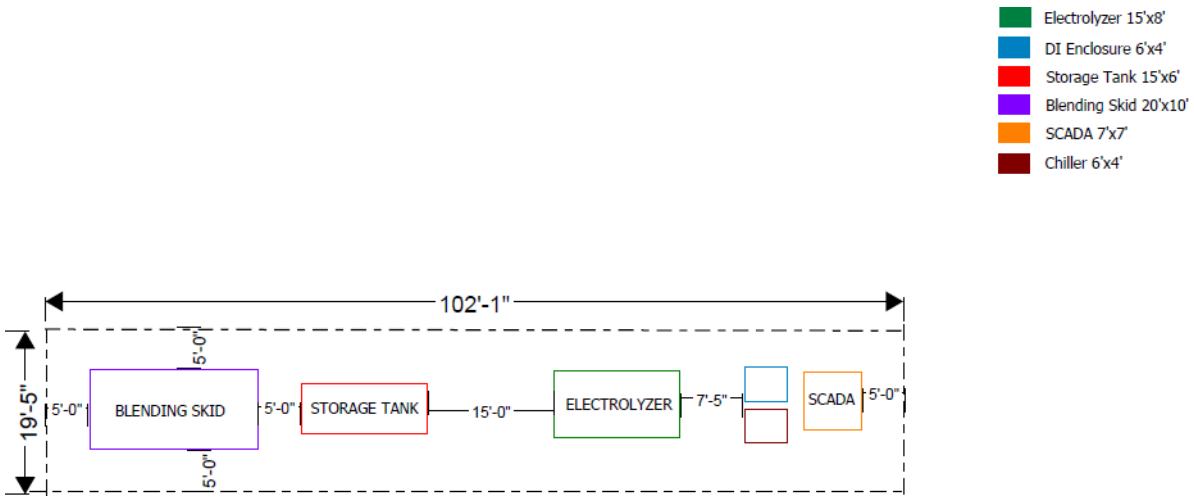
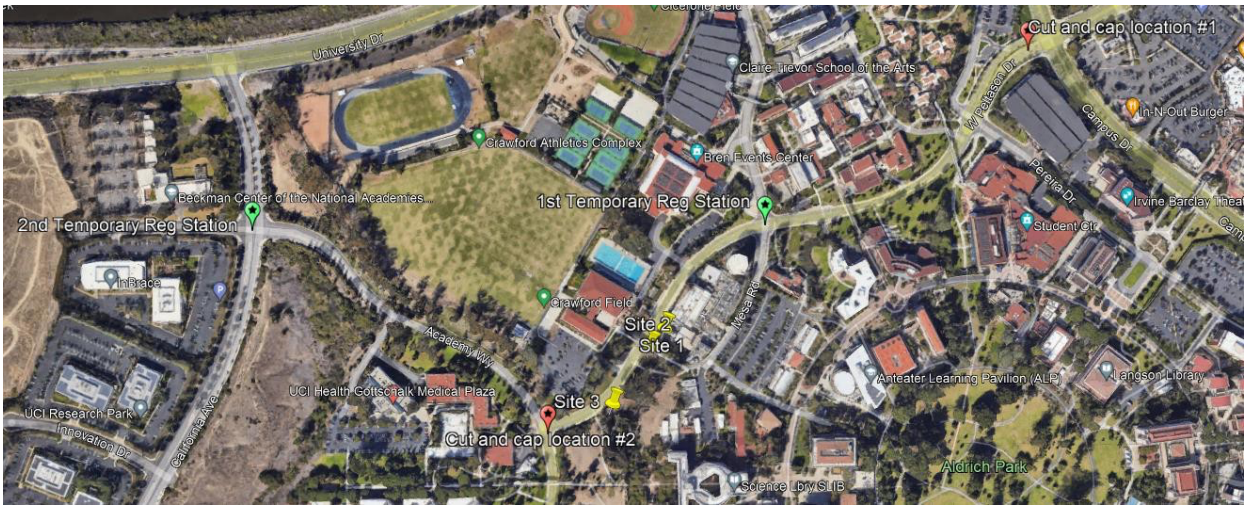


Figure 3: Locations of Temporary Pressure Regulator Stations and Isolation Locations Relative to Potential Project Site



The first cut and cap location is West Peltason Drive between Campus Drive and Pereira Drive. The second cut and cap location is Academy Way and West Peltason Drive. The location for the first temporary pressure regulator station is West Peltason Drive at Mesa Drive. The location for the second temporary pressure regulator station is California Ave and Academy Way.

EXHIBIT B

SoCalGas and the University of California, Irvine Announce Hydrogen Blending Project to Promote Clean Energy and Resiliency Goals

Sep 9, 2022

Project would build upon prior research to blend electrolytic hydrogen into existing pipelines

LOS ANGELES, Sept. 9, 2022 /PRNewswire/ -- Southern California Gas Co. (SoCalGas) and the University of California, Irvine (UCI) today announced a proposed collaboration to demonstrate how electrolytic hydrogen can be safely blended into existing natural gas infrastructure on the university's campus. The project aims to help better understand how clean fuels like renewable hydrogen could be delivered at scale through California's existing natural gas system, either to existing customers connected to the gas grid, or to generate clean electricity in zero-emissions fuel cells. The demonstration is an important next step in establishing a statewide injection standard for renewable hydrogen that would promote California's clean energy and resiliency goals. If approved, SoCalGas could begin testing hydrogen blending at UCI as soon as 2024.

"The use of existing natural gas networks to transport renewable hydrogen is actively being pursued around the world because clean fuels like hydrogen can do many of the critical jobs that natural gas does today," **said Neil Navin, vice president for clean energy innovations at SoCalGas.** "This demonstration project offers a real-world environment to better understand how clean fuel blends can be delivered to customers connected to the gas grid today. It can also help us assess how to more quickly deploy advanced technologies key to the state's climate and clean air goals such as neighborhood micro-grids that promote reliability and resiliency."

power use without the features of hydrogen," said **Jack Brouwer, UCI professor of mechanical and aerospace engineering and director of the UCI-based National Fuel Cell Research Center.** "The massive storage and resilient underground transmission and distribution of renewable energy that will be enabled by transformation of the gas system to renewable and clean hydrogen use will be investigated and advanced in this important effort."

"The current heat wave we are experiencing makes clear the urgency of decarbonizing our economy as quickly as possible," **said Senator Dave Min (D-Irvine)**. "I'm proud to represent UC Irvine, which has been a leading research hub for new green technologies, including in the important area of hydrogen fuel. UCI is an ideal location for this demonstration project, which should help us make significant progress in fighting climate change and restoring a bright future for our children and grandchildren."

SoCalGas' collaboration with UCI is part of a hydrogen blending demonstration application jointly filed with San Diego Gas & Electric Company (SDG&E) and Southwest Gas yesterday with the California Public Utilities Commission (CPUC).

The demonstration project builds upon the California Public Utilities Commission "Hydrogen Blending Impacts Study," performed by University of California, Riverside (UCR). The study recommended testing hydrogen blending in a real-world environment as an important step toward establishing a California hydrogen blending standard, which could accelerate the state's clean energy and resiliency goals.

As proposed, UCI would use an electrolyzer to convert water into hydrogen for blending into the existing gas grid on sections of the UCI campus. The demonstration would power existing residential and light commercial equipment, including water heaters, boilers, furnaces, and ovens in academic buildings, student amenities, and housing. The project would initially blend 5 percent hydrogen, with a goal of gradually increasing the hydrogen blend up to 20 percent, resulting in potentially significant CO_2 emissions reductions.

"Hydrogen will play an important role in reducing CO_2 emissions while also enabling access to clean energy in various sectors of our economy," **said Kristine Wiley, vice president of the Hydrogen Technology Center at GTI Energy.** "Advancing how we integrate hydrogen into our energy system is critical to the scale up and implementation of this technology. This project will be a proving ground for how we leverage our existing infrastructure to transport and supply clean hydrogen."

drive down costs for its widespread adoption across the state," **said Navin.** "A 20% clean hydrogen blend in a system as large as Southern California's could reduce CO_2 emissions in an amount equivalent to removing more than a million passenger vehicles from the road for a year."

"Hydrogen blending provides real and meaningful opportunities for participation in the clean energy economy for the tens of thousands of highly skilled southern California union members who build, operate, and maintain the natural gas utility infrastructure today," **said Jon Preciado, business manager for the Southern California District Council of Laborers.**

Growing Portfolio of Sustainability, Hydrogen Innovation

SoCalGas is at the forefront of sustainability having announced its aim to have net zero greenhouse gas emissions by 2045. It is the first large natural gas utility in the United States to do so.

SoCalGas' net zero strategy demonstrates the potential of innovative clean fuels like renewable hydrogen. More than a dozen hydrogen pilot projects are currently in progress within SoCalGas. These projects include testing a technology designed to separate out hydrogen blended into natural gas pipelines. The technology could allow quick access to pure hydrogen which could be transported as a blend in existing natural gas pipelines.

SoCalGas is also constructing a renewable hydrogen microgrid and home as part of its [H2] Innovation Experience. The renewable hydrogen microgrid for the [H2] Innovation Experience is a proof-of-concept project for resilient, clean energy using an electrolyzer to convert solar energy to hydrogen and a fuel cell to supply electricity to a home, neighborhood, or small business. The project was named a World-Changing Idea in North America by *Fast Company.*

Additionally, earlier this year SoCalGas proposed developing the Angeles Link, a dedicated green hydrogen energy infrastructure system for delivering clean reliable energy to the Los Angeles Basin to serve hard to electrify sectors of the economy like electric generation, heavy-duty transportation, and heavy industry and manufacturing.

SoCalGas is a recognized industry leader in hydrogen innovation. The company first partnered with UCI's National Fuel Cell Research Center in 2016 for the first successful green hydrogen blending project in the United States.

socalgas.com/Hydrogen.

About SoCalGas

Headquartered in Los Angeles, SoCalGas® is the largest gas distribution utility in the United States. SoCalGas delivers affordable, reliable, and increasingly renewable gas service to 21.8 million consumers across 24,000 square miles of Central and Southern California. Gas delivered through the company's pipelines will continue to play a key role in California's clean energy transition—providing electric grid reliability and supporting wind and solar energy deployment.

SoCalGas' mission is to build the cleanest, safest and most innovative energy company in America. In support of that mission, SoCalGas aspires to have net-zero greenhouse gas emissions by 2045 and to replacing 20 percent of its traditional natural gas supply to core customers with renewable natural gas (RNG) by 2030. Renewable natural gas is made from waste created by landfills, and wastewater treatment plants. SoCalGas is also committed to investing in its gas delivery infrastructure while keeping bills affordable for customers. SoCalGas is a subsidiary of Sempra (NYSE: SRE), an energy infrastructure company based in San Diego.

For more information visit socalgas.com/newsroom or connect with SoCalGas on Twitter (@SoCalGas), Instagram (@SoCalGas) and Facebook.

This press release contains statements that constitute forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995. Forward-looking statements are based on assumptions with respect to the future, involve risks and uncertainties, and are not guarantees. Future results may differ materially from those expressed or implied in any forward-looking statements. These forward-looking statements represent our estimates and assumptions only as of the date of this press release. We assume no obligation to update or revise any forward-looking statement as a result of new information, future events or other factors.

In this press release, forward-looking statements can be identified by words such as "believes," "expects," "intends," "anticipates," "contemplates," "plans," "estimates," "projects," "forecasts," "should," "could," "would," "will," "confident," "may," "can," "potential," "possible," "proposed," "in process," " construct," "develop," "opportunity," "target," "outlook," "maintain," "continue," "progress," "advance," "goal," "aim," "commit," or similar expressions, or when we discuss our guidance, priorities, strategy, goals, vision, mission, opportunities, projections, intentions or expectations.

differ materially from those expressed or implied in any forward-looking statement include risks and uncertainties relating to: decisions, investigations, regulations, issuances or revocations of permits and other authorizations, renewals of franchises, and other actions by (i) the California Public Utilities Commission (CPUC), U.S. Department of Energy, and other regulatory and governmental bodies and (ii) the U.S. and states, counties, cities and other jurisdictions therein in which we do business; the success of business development efforts and construction projects, including risks in (i) completing construction projects or other transactions on schedule and budget, (ii) realizing anticipated benefits from any of these efforts if completed, and (iii) obtaining the consent or approval of partners or other third parties, including governmental and regulatory bodies; civil and criminal litigation, regulatory inquiries, investigations, arbitrations and other proceedings, including those related to the natural gas leak at the Aliso Canyon natural gas storage facility; changes to laws and regulations; cybersecurity threats, including by state and state-sponsored actors, to the energy grid, storage and pipeline infrastructure, information and systems used to operate our businesses, and confidentiality of our proprietary information and personal information of our customers and employees, including ransomware attacks on our systems and the systems of third-parties with which we conduct business, all of which have become more pronounced due to recent geopolitical events and other uncertainties, such as the war in Ukraine; failure of our counterparties to honor their contracts and commitments; actions by credit rating agencies to downgrade our credit ratings or to place those ratings on negative outlook and our ability to borrow on favorable terms and meet our debt service obligations; the impact of energy and climate policies, laws, rules and disclosures, as well as related goals and actions of companies in our industry, including actions to reduce or eliminate reliance on natural gas generally and any deterioration of or increased uncertainty in the political or regulatory environment for California natural gas distribution companies and the risk of nonrecovery for stranded assets; the pace of the development and adoption of new technologies in the energy sector, including those designed to support governmental and private party energy and climate goals, and our ability to timely and economically incorporate them into our business; weather, natural disasters, pandemics, accidents, equipment failures, explosions, acts of terrorism, information system outages or other events that disrupt our operations, damage our facilities and systems, cause the release of harmful materials, cause fires or subject us to liability for damages, fines and penalties, some of which may be disputed or not covered by insurers, may not be recoverable through regulatory mechanisms or may impact our ability to obtain satisfactory levels of affordable insurance; inflationary and interest rate pressures, volatility in commodity prices, our ability to effectively hedge these risks, and their impact, as applicable, on our cost of capital and the affordability of customer rates; the availability of natural gas and natural gas storage capacity, including disruptions caused by limitations on the withdrawal of natural gas from storage facilities; the impact of the

regulations, including tariffs, revisions to international trade agreements and sanctions, such as those that have been imposed and that may be imposed in the future in connection with the war in Ukraine, which may increase our costs, reduce our competitiveness, impact our ability to do business with certain counterparties, or impair our ability to resolve trade disputes; and other uncertainties, some of which are difficult to predict and beyond our control.

These risks and uncertainties are further discussed in the reports that the company has filed with the U.S. Securities and Exchange Commission (SEC). These reports are available through the EDGAR system free-of-charge on the SEC's website, www.sec.gov, and on Sempra's website, www.sempra.com. Investors should not rely unduly on any forward-looking statements.

Sempra Infrastructure, Sempra Texas, Sempra Mexico, Sempra Texas Utilities, Oncor Electric Delivery Company LLC (Oncor) and Infraestructura Energética Nova, S.A.P.I. de C.V. (IEnova) are not the same companies as the California utilities, San Diego Gas & Electric Company or Southern California Gas Company, and Sempra Infrastructure, Sempra Texas, Sempra Mexico, Sempra Texas Utilities, Oncor and IEnova are not regulated by the CPUC.

SOURCE Southern California Gas Company

For further information:
Chris Gilbride, Office of Media and Public Information, (213) 244-2442,
cgilbride@socalgas.com

EXHIBIT C

Plan to test hydrogen energy at UC Irvine, other spots, stirs controversy

Gas companies may start blending hydrogen into pipelines to reduce emissions. Opponents say it's risky greenwashing.

The Orange County Register, December 18, 2022, By Brooke Staggs

Jack Brouwer is an engineering professor at UCI who heads up the National Fuel Cell Research Center. He's leading efforts with SoCalGas for an on-campus project to test whether hydrogen can safely be blended into natural gas pipelines to reduce emissions. (Photo by Paul Bersebach, Orange County Register/SCNG)

Supporters view a pilot project in the works at UC Irvine as a crucial step in helping California hit its clean energy goals.

Opponents, who protested the project on campus Friday, say it's a distraction from more viable climate solutions, and that it will "use college students as guinea pigs in a dangerous experiment."

And while many of those students remain oblivious to the brewing controversy, others are struggling to decide if they should feel pride or fear over being at ground zero as it all unfolds.

UC Irvine could be among the first places in the country, and one of a small number worldwide, where cleaner-burning hydrogen is blended with natural gas and injected into existing pipelines that directly fuel furnaces, water heaters and other gas-powered appliances.

The university signed a memorandum of understanding this summer with Sempra-owned Southern California Gas Co., which is the largest gas company in the country, to possibly work together on the pilot project. At the same time, San Diego Gas & Electric partnered with UC San Diego in hopes of blending hydrogen into pipelines there, while Southwest Gas wants to use hydrogen to help supply energy to commercial buildings in Truckee. If the California Public Utility Commission approves a joint application for the three hydrogen projects, and final deals are inked, blended fuel could start flowing to buildings as soon as 2024.

If the projects are approved, the commission could use the results to develop standards for safely blending hydrogen into more than 100,000 miles of natural gas pipelines that snake across the state.

Unlike natural gas, burning hydrogen does not produce planet-warming carbon. And, for now, the future use of hydrogen is part of state and federal plans to reduce the emission of greenhouse gases.

The California Air Resource Board's updated plan for the state to reach carbon neutrality by 2045, approved Thursday, Dec. 15, mentions hydrogen 88 times and calls for a massive boost in hydrogen production. And the federal infrastructure bill, approved last year, dedicates $9.5 billion to develop clean hydrogen, with $750 million of that funding made available Friday, Dec. 16, for projects aimed at lowering the cost of hydrogen power.

That's welcome news to people like Jack Brouwer, an engineering professor at UCI who's studied hydrogen for 25 years and heads up the National Fuel Cell Research Center, which is located on the Irvine campus.

"I am certain that if we don't invest in hydrogen as part of our zero-emission future, we will never achieve it," Brouwer said.

Jack Brouwer is an engineering professor at UCI who heads up the National Fuel Cell Research Center.
He's leading efforts with SoCalGas for an on-campus project to test whether hydrogen can safely be blended into natural gas pipelines to reduce emissions. (Photo by Paul Bersebach, Orange County Register/SCNG)

Some environmental activists aren't so certain.

They say there's a place for "green hydrogen," but that none of the three proposed pilot projects fit the bill. They also raise safety concerns, since hydrogen leaks and combusts easier than methane. And they cite emerging research that suggests hydrogen is a so-called secondary greenhouse gas that still contributes to global warming.

Arguments about hydrogen energy run similar to arguments over carbon capture systems. While even some ardent activists say such options must be part of the toolkit to reach carbon neutrality goals, some climate organizers, such as Adam Cooper, a PhD candidate in Atmospheric Chemistry at UC San Diego, oppose their widespread use. They cite safety risks and inefficiencies, and they worry that a focus on hydrogen might delay the necessary pivot away from dirty energy.

"We're trying to build a better future through climate policy in California," Cooper said. "A lot of these programs are just trying to extend the lifetime of the old fossil fuel reality."

Push to make clean hydrogen energy

Hydrogen is the smallest and most abundant element on Earth. When burned, it can deliver large quantities of power without emitting carbon. So the invisible, odorless gas has become a key focus in recent years for researchers, regulators and everyone else seeking cleaner substitutes for fossil fuels.

Pure hydrogen doesn't typically exist by itself in nature. Instead, it occurs in compounds such as water and methane. So to use hydrogen as a source of energy it first must be separated from other molecules. Currently that process almost always means burning some fossil fuels.

Roughly 98% of the hydrogen used commercially for things like refining oil or producing ammonia and fertilizer is made using natural gas or coal to separate out the molecule. That process, in turn, typically generates more carbon than it saves, making so-called "gray hydrogen" a no-go from the perspective of climate advocates.

But if the carbon emissions generated during traditional hydrogen production are captured, that's known as "blue hydrogen." Some environmentalists support that process, while others cite concerns with the effectiveness and efficiency of carbon capture systems.

Instead, many only support "green hydrogen." That's where an electrical current is shot through water, splitting hydrogen from

oxygen, a process known as electrolysis. Just 2% of hydrogen used today is made that way.

Even then there's debate over whether electrolysis should be considered "green" if the necessary electricity comes from the standard grid, which is still primarily powered by fossil fuels. Many activists argue that hydrogen is only truly clean if it's made entirely with renewables, such as wind or solar power.

That's one reason the planned pilot projects at UCI, UCSD and Truckee have drawn opposition from environmental groups. All three would use electricity from the state grid to power electrolyzers that would create hydrogen. The UCI project, for example, is estimated to use nearly 4,200 kilowatt hours of power each day â€" as much as used by 140 typical households.

Making hydrogen entirely from renewable energy, for now, is very expensive. The Department of Energy says renewable-generated hydrogen currently costs about $5 per kilogram, and that it needs to be about $1 per kilogram to be commercially viable. So it is funding projects aimed at driving down costs.

There also are questions to resolve around water use, since electrolysis now used to make hydrogen requires clean, potable water.

The UCI project would use about 170 gallons of water each day, or about half as much as one average household. That's not much for one pilot project, but if taken to scale, that use would add up. And with the West in the middle of a record-setting drought, it's not clear where that water would come from.

Testing hydrogen to power buildings

The other big debate in the push for hydrogen power is where the energy should be used.

There's solid support for hydrogen fuel cells, which are battery-like devices that can power vehicles, provide backup power and more. Since pure hydrogen is less dense than other gases, it's also being eyed for uses where weight is key, such as fuel for aviation.

And, since it burns hot, hydrogen is potentially attractive for industries, such as steel and cement, that require consistently extreme temperatures to make their products. Those industries aren't good candidates for electrification, so environmental groups generally support the idea of exploring green hydrogen alternatives there.

The controversy primarily kicks in when plans call for using hydrogen to power buildings. That's what the gas companies plan to test in the projects at UCI, UCSD and in Truckee â€" at a total cost of more than $35 million, to be recouped from ratepayers.

In a protest to the pilot projects that the Sierra Club filed with the commission in October, the group argues that the focus for building should remain on electrification rather than letting fossil fuel companies find ways to keep their infrastructure relevant.

"We already have decarbonization strategies for residential and commercial buildings that can fully decarbonize these buildings, that are cost effective, where the technology is already established," said Rebecca Barker, an attorney with Earthjustice, the group representing the Sierra Club in the case.

With cities like Los Angeles passing laws that prohibit gas-powered appliances in new buildings as soon as next year, and with standards for blending hydrogen into gas lines still at least a few years off, Cooper said the regional pilot programs seem like a dead end.

"I'm not sure where they plan to actually use this technology, at least not in California. And as the saying goes, 'As California goes, so does the nation.'"

But Michael Colvin, a director with the Environmental Defense Fund and former CPUC staffer, sees value in gathering research on potentially blending hydrogen into natural gas pipelines. Even though the push in California is to make future appliances and new construction all electric, Colvin noted that existing appliances and buildings will be using natural gas for some time. If there's a chance to reduce the carbon footprint of those systems soon, without big capital investments, he's open to that conversation.

The Public Utilities Commission, so far, agrees.

In 2019, the commission asked gas companies to help develop standards for safely injecting hydrogen into the statewide natural gas system, including older steel and plastic distribution systems that fuel gas-powered appliances found in homes and smaller commercial facilities. The goal was to see how much, if any, hydrogen could be used without causing problems for the pipeline system or appliances. That way, the state could reduce carbon emissions without having to develop a new, dedicated hydrogen gas infrastructure system.

SoCalGas, SDG&E and Southwest Gas said they'd need to do research before making any recommendations. They pitched the hydrogen blending projects in 2020, but the commission shot that proposal down a year later, calling it "incomplete."

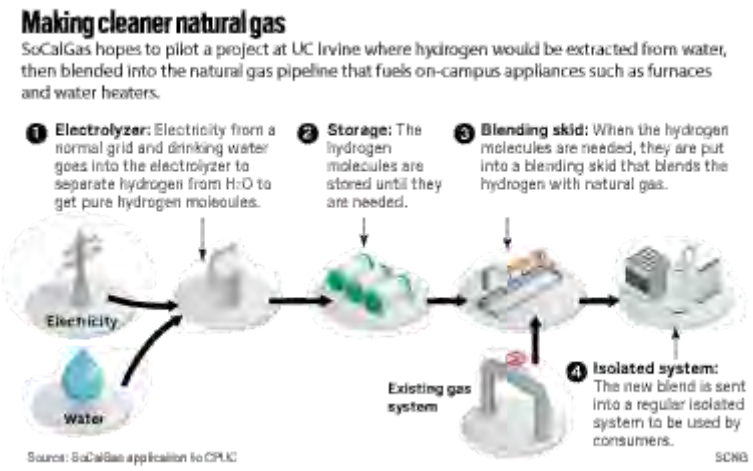
Meanwhile, the commission had asked a team at UC Riverside to do its own research and come up with recommendations for how to blend hydrogen into existing natural gas pipelines. That report, released in July, gave both proponents and opponents of using hydrogen in buildings more fuel for their arguments.

The gas companies cited the study when they came back to the commission in September with the three hydrogen blending project proposals now under consideration. Company officials noted in testimony and press releases that the UC Riverside study said there are key questions "that cannot be addressed through modeling or laboratory scale experimental work." They added that, in their view, it is "critical to conduct real world demonstration of hydrogen blending under safe and controlled conditions."

But the UCR report also raises concerns about safety, which organizers such as Cooper cite in speaking out against the gas companies' planned demonstration projects.

Safety risks spark concern

At UC Irvine, SoCalGas hopes to install an electrolyzer to make hydrogen on the northwest edge of campus, along West Peltason Drive, according to the proposal now before the CPUC. Hydrogen would be stored in tanks until being injected into a skid, where it would blend with natural gas. The mix then would be delivered to buildings further north -including the Mesa Arts Building, a freshman dorm, offices and a food court - to fuel equipment "such as ovens, furnaces, water heaters, dryers and boilers."



Initially, the mix would be just 5% hydrogen. Under that level, the UC Riverside study said there are few concerns about how the pipeline system and appliances fueled by it would perform. But after three months, the blend would be bumped up to 10% hydrogen. And at six months, it would hit 20% and stay there for one year.

Plans are similar at UC San Diego. But Cooper said university officials agreed to limit the project to nonresidential buildings after he led opposition to an original plan that called for sending the hydrogen blend to graduate student and family housing.

That plan, and the current plan at UC Irvine, has sparked a number of safety concerns.

First, hydrogen leaks more easily than natural gas alone, since it's a smaller, lighter molecule, noted Arun Raju, a research engineer who headed up the UC Riverside study. Those leaks also are harder to detect, since current systems aren't designed to catch hydrogen. Also, pure hydrogen is invisible and odorless, while Raju said the additive that gives natural gas its smell is not compatible with hydrogen.

Hydrogen also can make pipelines brittle. Brouwer said his research shows those risks are minimal, with pipelines perhaps needing to be replaced every 80 years instead of every 100 years. But Raju said more testing in real systems is needed before there can be certainty that adding hydrogen to the pipelines won't make them more likely to fail.

If they do, hydrogen also is roughly five times more likely than natural gas to ignite if exposed to air, Kevin Lang, a director with Southwest Gas, told the CPUC in testimony. The explosion risk is highest if hydrogen leaks into an enclosed space, making safety policies and monitoring even more important, Lang said.

In Oregon, such concerns recently sparked protests over a similar proposal, leading the gas company there to cancel that project.

Anusha Ghildyal, a sophomore at UC Irvine who serves as environmental justice coordinator for the student government, said that after hearing from both sides she's not completely opposed to the project on her campus. But she'd like to see some changes in the plan, such as taking student housing out of the mix and having the project start in summer, so there'd be time to monitor any changes before students, faculty and staff are on campus. She also wants to see much more public communication, so everyone can stay informed and weigh in on the project.

None of the students or faculty contacted by Climate Action Campaign knew about the project, according to Ayn Craciun, Orange

County policy manager for the group. They have launched a call to action, with Brouwer reporting that as of Dec. 12, he and university leaders had received nearly 100 emails critical of the project. (SoCalGas canceled an interview for this story.)

Both Brouwer and Raju said they're confident that, with safety protocols in place, the gas companies can safely manage these pilot projects and potential widespread use of hydrogen in their systems. They, along with SoCalGas, point to a more limited test project that already took place at UC Irvine, another in England and the existing use of hydrogen in a natural gas system on Oahu.

Asked if he'd be comfortable with his own kid living at UC Irvine, in housing where the blended hydrogen would be tested, Raju said, "Absolutely. I actually think it's exciting."

But Cooper and others pointed out that SoCalGas has been fined for fighting climate change, and that the company is responsible for the biggest methane leak in U.S. history, at Aliso Canyon.

"These companies can't even keep methane from leaking. And now they want to use something that's more prone to leakage, that's oftentimes harder to detect, and they just want us to trust them," Cooper said.

"After 50 years of fossil fuel misinformation campaigns, I don't think these fossil fuels companies make good partners."

A minor CPUC hearing on the project is scheduled for Thursday, Dec. 22.

EXHIBIT D

UCI leaders to SoCalGas: don't test hydrogen blend in dining areas and freshman dorms

An updated proposal is now expected this fall. UC Irvine students and climate advocates are asking local politicians to help block the project.

Anusha Ghildyal, a student at University of California, Irvine, along with students from University High School in Irvine, write messages and draw pictures with chalk on the sidewalk in front of Aldrich Hall on

the campus of UC Irvine on Friday, December 16, 2022, in opposition to a SoCalGas plan that would test blending hydrogen with natural gas in pipelines at UC Irvine and safety concerns that go with such tests. (Photo by Mark Rightmire, Orange County Register/SCNG)

By **BROOKE STAGGS** | bstaggs@scng.com | Southern California News Group

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After pushback from student and environment groups, UC Irvine leaders told Southern California Gas the utility is no longer welcome to use freshman dorms and on-campus dining areas to test the safety of blending hydrogen into the natural gas pipelines that fuel furnaces, water heaters and other gas-powered appliances.

That doesn't mean the proposed $13 million pilot project is dead. Other buildings at UCI remain available as test sites, with the gas company, researchers and state regulators still hoping the project will help them develop standards for safely blending cleaner-burning hydrogen into more than 100,000 miles of natural gas pipelines that snake across California.

But the UCI proposal already has been pushed back about a year, after the California Public Utilities Commission passed new rules requiring additional changes to the utility's plans. That includes requiring SoCalGas to hold a public meeting by June to let interested parties offer feedback before plans can advance to regulators for a vote.

Meanwhile, a coalition of students and environmental advocates sent a letter Thursday to Rep. Katie Porter and state and local leaders who represent Irvine asking them to help oppose the project.

“We are out of time for fantasy technologies that ‘may someday’ solve the problem,” the letter states. “This proposal is another fossil fuel industry scheme to make money by destroying our health and our future, wasting ratepayer dollars on a scam that will not decarbonize buildings while putting UC Irvine students and faculty at grave risk of injury and death.”

With a memorandum of understanding from UC Irvine in hand, Sempra-owned SoCalGas filed a request with the commission in September to replace up to 20% of natural gas in test-area pipelines with hydrogen. It was a joint application filed with San Diego Gas & Electric, which proposed a similar project at UC San Diego, and Southwest Gas, which proposed sending hydrogen to commercial buildings in Truckee.

But a commission decision in December called for Pacific Gas & Electric to also run a pilot hydrogen project at the same time, so all four of the state’s natural gas utilities could be involved. That updated application is expected back to the commission in November. (SoCalGas didn’t respond to requests for comment for this story.)

Several groups tracking the UC Irvine project say they aim to use the additional time to gather more information and push for additional safety measures or other changes — though there’s some disagreement about what those changes should look like.

Groups like Sierra Club and Climate Action Campaign’s Orange County chapter oppose any efforts to send hydrogen to buildings, saying environmental improvements should remain focused on electrification, and that hydrogen should be used only in hard-to-decarbonize sectors, such as powering jets and cement making. They argue that fossil fuel companies such as SoCalGas just see hydrogen as a way to extend demand for their products while still claiming some reduction in emissions.

Instead, Ayn Craciun, Orange County policy manager for Climate Action Campaign, said her team would like to see the UC Irvine project use hydrogen to power battery-like fuel cells, not buildings. That fact that hydrogen isn’t burned with those systems, she said, would ease concerns about safety and emissions.

That’s the direction UC San Diego went. A test planned on that campus originally called for blending hydrogen into the pipelines that powered gas appliances in family housing and other buildings. After students and faculty raised concerns, university officials directed the San Diego utility to shift to a fuel cell project.

But if the Irvine project also goes that direction, then Michael Colvin with the Environmental Defense Fund said we won't get the data his organization — along with state regulators, researchers and others — want. They're hoping to learn what happens when different levels of hydrogen are blended into natural gas pipelines.

"If we're going to study things, let's study a variety of options," Colvin said.

While the push in California is to electrify all future appliances and new construction, Colvin said existing appliances and buildings will be powered by natural gas for the foreseeable future. So if there's a chance to reduce the carbon footprint of those systems, soon, he said he's open to that conversation. He also said he believes the tests can be conducted safely.

Jack Brouwer is an engineering professor at UCI who heads up the National Fuel Cell Research Center. He's leading efforts with SoCalGas for an on-campus project to test whether hydrogen can safely be blended into natural gas pipelines to reduce emissions. (Photo by Paul Bersebach, Orange County Register/SCNG)

However, Craciun points to key questions about how much hydrogen can be safely transported in existing gas pipelines, which weren't designed to carry the slippery molecule.

Hydrogen leaks more easily than natural gas alone, since it's smaller and lighter. Such leaks also are harder to detect. And hydrogen can make pipelines get brittle and potentially fail faster than pipelines carrying natural gas alone.

If hydrogen does leak, emerging research suggests it's a so-called secondary greenhouse gas that still contributes to global warming. It's also roughly five times more likely than natural gas to ignite, raising the risk of catastrophic events.

Even if hydrogen blends can be delivered safely into buildings, it must be made with 100% renewable electricity before many environmental groups consider it "green" energy. The pilot at UC Irvine would use electricity from the grid, which is a mix of renewable and fossil fuel energy.

Student senators at UC Irvine raised many of those concerns during their Feb. 28 meeting, where they considered a measure to oppose the project.

"As of right now, at UCI, what we are trying to do is to get away from gas or anything even close to that as much as possible because we want that sustainable future," student Sen. Amin Mansouri said.

Jack Brouwer, an engineering professor at UCI who's been working with SoCalGas on the project, told students he doesn't believe we can reach a net-zero carbon climate without hydrogen. And of the pilot project, he said: "I can guarantee you that it will be safe."

When the Register asked Brouwer about that confidence, he noted his teams have been safely handling hydrogen in their laboratories for 25 years. And if the SoCalGas pilot advances, he said that they intend to install additional monitors to detect leaks, which he said should make the blended system safer than the campus' natural gas system as is stands today.

Student senators declined to weigh in on the project during their Feb. 28 meeting, instead referring the issue to their advocacy committee for further discussion.

University spokesman Tom Vasich said via email that the school responded to student concerns by verbally directing SoCalGas to move the project out of student housing and dining facilities.

As for where the pilot might now go, Vasich said it's still early in the process.

"We have not begun to look at other options, but we will keep in mind concerns shared by the UCI community."

2023 > March > 9

EXHIBIT E

March 9, 2023

U.S. Congressmember Katie Porter
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Senator Dave Min
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Assemblymember Cottie Petrie-Norris
19712 MacArthur Boulevard, Suite 150
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Donald Wagner, Chair of the Board of Supervisors
400 W Civic Center Dr
Santa Ana, CA 92701

Supervisor Katrina Foley
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Irvine Mayor Khan and City Council Members
1 Civic Center Plaza
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Via email

Re: SoCalGas hydrogen/gas blending experiment at UC Irvine

Dear Congresswoman Porter, Senator Min, Assemblymember Petrie-Norris, Chair Wagner, Supervisor Foley, Mayor Khan and Irvine City Council Members,

We are a coalition of organizations and advocates dedicated to climate and social justice in Orange County. **As an elected representative of Irvine, we ask you to join us in publicly opposing the SoCalGas proposal before the California Public Utilities Commission (CPUC) to spend nearly $13 million in ratepayer dollars to pipe, blend and burn a dangerous, experimental, and toxic mix of hydrogen and methane gas in ovens, furnaces, water heaters, dryers, and boilers in UC Irvine's "Mesa Arts Building, Mesa Court Housing (29 halls and 3 towers), Mesa Office Building, Alumni Center, art studios, and a food court."[1] Mesa Court is a 2,500-student freshman dormitory.**

There is no need to incur all the uncertainty, costs, health, and safety risks that come with these hydrogen blending experiments when electrification is an available, safe, pollution-free option for decarbonizing buildings today.

The proposed project will expose students and faculty to unacceptable safety and health risks, ignoring a mountain of research on the safety, health, climate, and environmental justice risks associated with burning hydrogen in buildings, as documented recently by the American

[1] Prepared Direct Testimony of Kevin Woo On Behalf Of Southern California Gas Company (SoCalGas' Hydrogen Blending Demonstration Project), p. 5, III. Project Description https://www.socalgas.com/sites/default/files/Chapter2-Technical_Presentation-SoCalGas_Project.pdf.

Medical Association,[2] Physicians for Social Responsibility,[3] Sierra Club,[4] NRDC[5] and Earthjustice.[6] SoCalGas ignored those well-documented concerns when it stated in its application that there are no relevant safety concerns[7] and no need for hearings[8] to review the evidence. SoCalGas says it will "collect data" on gas pipes, leakage and safety during the experiment, but nothing in the application or in reality guarantees that UC Irvine students and faculty will be safe from explosions or leaks of poisonous gasses from the project. Any equipment that burns hydrogen also creates lung-damaging NOx pollution, and the UC Irvine proposal relies on blending hydrogen and methane in combustion appliances.

The proposed project would, "begin with an initial hydrogen blend level of 5% and up to 20% over time,"[9] blending hydrogen into 80-95% methane, an extremely potent greenhouse gas. It is unclear from the application how the electricity to power the hydrogen electrolyzers will be produced, but if it is produced using dirty, fossil fuel-based grid electricity, then emissions from hydrogen generation will far outweigh any emissions reductions achieved by the hydrogen blend.

Similar projects have been rejected elsewhere due to environmental justice, health, safety, cost and feasibility concerns. In 2022, UC San Diego moved the hydrogen/methane project location proposed for UCSD graduate student housing to a non-residential location that will use a hydrogen fuel cell (which does not involve combustion or dangerous NOx emissions), and a similar proposal in Oregon was canceled.[10]

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[2] American Medical Association House of Delegates resolution, Informing Physicians, Health Care Providers, and the Public of the Health Dangers of Fossil-Fuel Derived Hydrogen, 2022, https://www.ama-assn.org/system/files/a22-438.pdf

[3] Physicans for Social Responsibility, "*Hydrogen use in homes would fuel climate change, increase health and safety risks from gas system*," June 2022 https://psr.org/hydrogen-use-in-homes-would-fuel-climate-change-increase-health-and-safety-risks-from-gas-system/

[4] Sierra Club, "Hydrogen: Future of Clean Energy or a False Solution?" Jan. 2022, https://www.sierraclub.org/articles/2022/01/hydrogen-future-clean-energy-or-false-solution

[5] Natural Resources Defense Council, "Hydrogen in Buildings: The Poster Child of Tech-Crastination," September 07, 2021, https://www.nrdc.org/experts/rachel-fakhry/hydrogen-buildings-poster-child-tech-crastination

[6] Earthjustice, "Reclaiming Hydrogen for a Renewable Future," at 27–30, Aug. 2021, https://earthjustice.org/features/green-hydrogen-renewable-zero-emission

[7] Joint Application Of Southern California Gas Company (U 904 G), San Diego Gas & Electric Company (U 902 G), And Southwest Gas Corporation (U 905 G) To Establish Hydrogen Blending Demonstration Projects, Page 14, iii. Issues to be Considered and Relevant Safety Considerations and p. 15, section d Safety https://www.socalgas.com/sites/default/files/A22-09-XXXJoint_IOU_Hydrogen_Blending_Demonstration_Application.pdf

[8] Ibid, Page 14, ii Need for Hearings

[9] Prepared Direct Testimony of Kevin Woo On Behalf Of Southern California Gas Company (SoCalGas' Hydrogen Blending Demonstration Project), p. 2, I. Purpose https://www.socalgas.com/sites/default/files/Chapter2-Technical_Presentation-SoCalGas_Project.pdf.

[10] *Register-Guard*, "NW Natural cancels west Eugene hydrogen blending project," Nov. 3, 2022 https://www.registerguard.com/story/news/2022/11/02/nw-natural-cancels-west-eugene-hydrogen-blending-project/69612987007/

Sierra Club and Earthjustice lawyers have filed a protest[11] against the proposal citing "numerous and wide-ranging safety-related concerns" identified in many studies of hydrogen/methane blending as well as other concerns.

None of the high school students who recently applied to UC Irvine, current students, faculty or neighboring families whose lives will be put at risk by this experiment gave their consent to be used as test subjects for the project. California law requires consent and a description of any risks prior to human experimentation.[12]

SoCalGas is the largest industrial funder of engineering research at UC Irvine, providing $7 million or 14% of their industrial funding in the last ten years. A study published recently in the journal *Nature* finds that favorability toward "natural" gas in academic research is tied to the funding sources of university energy centers.[13]

UC Irvine professor and hydrogen proponent Jack Brouwer and SoCalGas lobbyists continue to spread misinformation about the facts and dangers of the proposal within UC Irvine and in the wider Irvine community. Brouwer told Associated Students of UC Irvine (ASUCI) students at their Feb. 28 board meeting, "I can guarantee you it will be safe," and "The CPUC has to approve before UCI can engage with SoCalGas to negotiate what we will do."[14] In fact, the project involves numerous and well-documented safety and health risks, and if the CPUC approves the project, there will no longer be a meaningful opportunity for students to change or stop it, so the project must be stopped now.

Greenwashed Gas Industry Delay

This proposal is an attempted lifeline for the fossil fuel industry, and part of a larger gas industry campaign to maintain its profits while delaying necessary building electrification policy, which is the only feasible pathway to building decarbonization that meets the climate crisis.

Although gas industry representatives and hydrogen advocates claim their goal is to demonstrate hydrogen's use for energy storage, their proposal and technical presentation[15] clearly propose to burn methane blended with hydrogen in UC Irvine freshman dorms and other buildings. Gas industry representatives also proposed hydrogen/methane blending as an alternative to building electrification to the City of Irvine last year.

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[11] A. 22-09-006 *Sierra Club Protest To Application Of Southern California Gas Company (U 904 G), San Diego Gas & Electric Company (U 902 G), And Southwest Gas Corporation (U 905 G) To Establish Hydrogen Blending Demonstration Projects*, Sept. 8, 2022, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M497/K621/497621760.PDF

[12] California Health & Safety Code §24172, Experimental subject's bill of rights, https://oag.ca.gov/sites/all/files/agweb/pdfs/research/safety_24172.pdf

[13] *Nature*, "Favourability Towards Natural Gas Relates To Funding Source Of University Energy Centres," Nov. 10, 2022, https://www.nature.com/articles/s41558-022-01521-3

[14] ASUCI Senate Meeting, Feb. 28, 2023, discussion of hydrogen resolution, see 2:07:40 https://www.facebook.com/associatedstudentsuci/videos/927438974959773

[15] Prepared Direct Testimony of Kevin Woo on Behalf of Southern California Gas Company (SoCalGas' Hydrogen Blending Demonstration Project), Purpose, p. 1, Sept. 2022 https://www.socalgas.com/sites/default/files/Chapter2-Technical_Presentation-SoCalGas_Project.pdf

SoCalGas Record of Harm to the Community

SoCalGas has proven that it cannot be trusted to safeguard community health or safety. In 2015, SoCalGas was responsible for the largest methane gas leak in U.S. history,[16] which dumped 100,000 tons of toxic chemicals into the air north of Los Angeles for months, forcing more than 8,000 families to flee their homes. Last year, SoCalGas and Sempra paid $1.8 billion to settle with thousands of residents sickened by the blowout.[17]

The SoCalGas proposal for UC Irvine would add risks to already-leaky and dangerous SoCalGas pipes and products. **A recent CPUC-funded study by UC Riverside found that metals and alloys used in methane gas transmission systems experienced "hydrogen induced embrittlement" when exposed to hydrogen gas, and that plastic pipes also become brittle and susceptible to explosions when used for hydrogen blending levels equal to what is proposed in the UC Irvine experiment.**[18] The UC Riverside study states, "As the percentage of hydrogen increases, end-use appliances may require modifications, vintage materials may experience increased susceptibility, and legacy components and procedures may be at increased risk of hydrogen effects." The SoCalGas proposal states it will inject hydrogen into steel and gas pipes at UC Irvine and that UC Irvine's gas pipeline system was built in the 1970s.

Here are some of the risks that SoCalGas and UC Irvine left out of their proposal:

Explosions/safety: Hydrogen is highly explosive and prone to leakage

- Hydrogen is one of the lightest molecules in the universe, so it leaks more easily than already-leaky methane gas. When it leaks, hydrogen ignites more quickly and easily than gas.[19]
- Hydrogen is four times as explosive as methane.[20] Existing pipelines and appliances can't handle large quantities of hydrogen, and injecting hydrogen into steel pipes causes them to become brittle and more likely to explode.
- U.S. government scientists at the National Renewable Energy Laboratory (NREL) last year found that blending hydrogen into the gas network could affect

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[16] *Los Angeles Times*, "Porter Ranch leak declared largest methane leak in U.S. history," Feb. 25, 2016 https://www.latimes.com/science/sciencenow/la-sci-sn-porter-ranch-methane-20160225-story.html

[17] *Los Angeles Times*, "SoCalGas agrees to pay up to $1.8 billion in settlement for 2015 Aliso Canyon gas leak," Sept. 27, 2021, https://www.latimes.com/california/story/2021-09-27/so-cal-gas-settles-over-huge-aliso-canyon-gas-leak

[18] University of California, Riverside final report prepared for the CPUC, "Hydrogen Blending Impacts Study," filed July 18, 2022, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M493/K760/493760600.PDF.

[19] U.S. Dept of Energy, Safe Use of Hydrogen, webpage accessed Feb. 2023, https://www.energy.gov/eere/fuelcells/safe-use-hydrogen#:~:text=Specifically%2C%20hydrogen%20has%20a%20wide,design%20of%20safe%20hydrogen%20system.

[20] Physicians for Social Responsibility, "Hydrogen Pipe Dreams: Why Burning Hydrogen in Buildings is Bad for Climate and Health," at 13, June 2022, https://psr.org/resources/hydrogen-pipe-dreams-why-burning-hydrogen-in-buildings-is-bad-for-climate-and-health/ ("In the United Kingdom, a comprehensive risk assessment conducted by Hy4Heat evaluating a theoretical methane-hydrogen blend predicted that **the number of explosions per year and the risk of injuries from in-home explosions would be four times higher with a 20 percent blend of hydrogen compared to methane alone**.")

the molecular structure of plastic gas pipes and has the potential to nearly double the volume of leakage. NREL researchers also found large gaps in data around the effects of hydrogen blends in gas infrastructure such as pipelines — even when using plastic pipes, which have long been touted by the gas industry as a safe way to transport hydrogen blends.[21]

Health: Air pollution from burning hydrogen in home appliances brings major health risks

- A 2022 meta-analysis of lung-damaging nitrous oxides (NOx) emissions from combustion of hydrogen/methane gas blends found hydrogen blends over 5%–20% led to NOx emission increases of 7%–30%.[22] The UC Riverside Study also cautioned that combustion of a hydrogen blend can increase NOx emissions.
- Burning 100% hydrogen creates six times more lung-damaging NOx than burning methane gas alone.[23]
- These risks recently prompted the American Medical Association to adopt a resolution warning of health risks from hydrogen blending in home appliances.[24]
- Long-term safety risks of household hydrogen appliances are unknown and haven't been studied adequately.[25]
- Despite the well-established NOx risks of hydrogen combustion, the SoCalGas/UCI application to the CPUC barely discusses this issue or mentions NOx. UCI and SoCalGas fail to offer a plan for monitoring, reporting, and mitigating NOx emissions.[26]

Hydrogen increases environmental injustice

- Research has demonstrated that pollution from hydrogen fuel could widen inequality gaps.[27]

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[21] National Renewable Energy Laboratory, "Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology," Oct. 2022, https://www.nrel.gov/docs/fy23osti/81704.pdf
[22] *Elementa: Science of the Anthropocene*, "Emissions of NOx from blending of hydrogen and natural gas in space heating boilers," at 7, 11, May 31, 2022, https://doi.org/10.1525/elementa.2021.00114.
[23] *International Journal of Hydrogen Energy*, "Investigations on performance and emission characteristics of an industrial low swirl burner while burning natural gas, methane, hydrogen-enriched natural gas and hydrogen as fuels," Jan. 11, 2018, https://www.sciencedirect.com/science/article/abs/pii/S0360319917319791.
[24] American Medical Association House of Delegates resolution, Informing Physicians, Health Care Providers, and the Public of the Health Dangers of Fossil-Fuel Derived Hydrogen, 2022, https://www.ama-assn.org/system/files/a22-438.pdf
[25] Physicans for Social Responsibility, "*Hydrogen use in homes would fuel climate change, increase health and safety risks from gas system*," June 2022 https://psr.org/hydrogen-use-in-homes-would-fuel-climate-change-increase-health-and-safety-risks-from-gas-system/
[26] See generally Test. Ch. 1. See also Testimony Chapter 4, *Prepared Direct Testimony of Kevin M. Lang on Behalf of SW Gas (SW Gas' Hydrogen Blending Demonstration Project)*, Sept. 8, 2022, "Test. Ch. 4", https://www.socalgas.com/sites/default/files/Chapter4-SWG_Technical_Presentation.pdf.
[27] *Nature,* correspondence from Dr. Alastair Lewis, "Pollution from hydrogen fuel could widen inequality," July 31, 2021, https://www.nature.com/articles/d41586-021-01926-8

- Even green hydrogen used for electricity generation creates NOx when combusted, and those impacts would deepen inequalities for low-income communities of color.[28]
- Research from Stanford University finds that gas stoves constantly leak pollution into our most-used living spaces, exposing people to disease-triggering pollutants. Research has shown that more than ¾ of methane emissions occur while stoves are off because gas fittings, stove connections, and in-house gas lines leak.[29] Cooking with methane gas is closely linked with childhood asthma—a disease suffered by people of color and lower-income groups at much higher rates than the rest of the population.[30]
- Hydrogen projects also carry very high costs which would be forced on customers already struggling to afford rising energy rates.

Fossil fuels: most hydrogen is made from fossil fuels.

- 99% of commercially available hydrogen is made from fossil fuels like gas.
- The SoCalGas proposal also ignores the reality that the project requires blending and burning 5-20% hydrogen into 80-95% methane, an extremely potent greenhouse gas that the IPCC says must be eliminated in order to prevent catastrophic climate impacts.

Climate delay: studies show hydrogen for buildings is a false solution.

- Only green hydrogen produced from 100% renewable energy can play a role in our clean energy future — but it doesn't belong in buildings. The very tiny amount of green hydrogen that is available must be preserved for hard-to-decarbonize industrial sectors.[31]
- A peer-reviewed study of 32 studies of hydrogen concluded hydrogen is unlikely to play a major role in home heating because there are too many technical difficulties to overcome to make hydrogen a viable and economic low-carbon heating fuel. The study concluded that all-electric alternatives such as heat pumps are much more efficient and less expensive.[32]

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[28] *Los Angeles Times*, "L.A. needs clean energy. Hydrogen could be the answer — or gas industry greenwashing," March 21, 2022, https://www.latimes.com/business/story/2022-03-21/los-angeles-needs-clean-energy-hydrogen-could-be-the-answer

[29] Stanford University, published in *Environmental Science & Technology*, "Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes," Jan. 27, 2022, https://pubs.acs.org/doi/10.1021/acs.est.1c04707n

[30] Asthma and Allergy Foundation of America, "Asthma Disparities in America, A Roadmap to Reducing Burden on Racial and Ethnic Minorities," 2020, https://aafa.org/asthma-allergy-research/our-research/asthma-disparities-burden-on-minorities/

[31] *ReCharge News,* "Liebreich: 'Oil sector is lobbying for inefficient hydrogen cars because it wants to delay electrification,'" June 30, 2021, https://www.rechargenews.com/energy-transition/liebreich-oil-sector-is-lobbying-for-inefficient-hydrogen-cars-because-it-wants-to-delay-electrification-/2-1-1033226

[32] *Joule*, "Is heating homes with hydrogen all but a pipe dream? An evidence review," Oct. 19, 2022, http://www.janrosenow.com/uploads/4/7/1/2/4712328/is_heating_homes_with_hydrogen_all_but_a_pipe_dream_final.pdf.

- In the most recent Integrated Energy Policy Report, the California Energy Commission ("CEC") recommended electrification of end use equipment as the "perfect pathway to decarbonize buildings" because appliances like heat pumps are "substantially more energy-efficient than the combustion alternative," and their adoption "reduces local emissions of the criteria pollutants associated with combustion."
- To heat homes using significant volumes of hydrogen, every gas stove, furnace, and water heater in the country would have to be replaced — an astronomical cost that the gas industry leaves out of studies.[33]

We have reached a place and time in the climate crisis when we must focus on solutions that actually work and are ready to scale now, and clean electrification is the only approach that meets both criteria. We are out of time for fantasy technologies that "may someday" solve the problem. This proposal is another fossil fuel industry scheme to make money by destroying our health and our future, wasting ratepayer dollars on a scam that will not decarbonize buildings while putting UC Irvine students and faculty at grave risk of injury and death.

UC Irvine's Dean of Students recently told the ASUCI executive board that hydrogen blending is "off the table" for campus housing and dining facilities, but the proposal is still before the CPUC and neither UC Irvine nor SoCalGas has issued a public statement to clarify exactly which parts of the project are canceled or ongoing.

To protect Irvine students and families and advance climate justice, we ask you to stand with us by issuing a public statement opposing the SoCalGas/UC Irvine proposal and submitting a letter to the CPUC through the CPUC's comment form (search for proceeding A2209006 and click Add Public Comment).

Sincerely,

Hasti Soutehkashan, Executive Board, College Democrats at UC Irvine 2022-2023 and Organizing Director and At-Large Senator,
Associated Students of UC Irvine (ASUCI)

Anusha Ghildyal, Environmental Justice (Students Enacting Environmental Defense **SEED**) Coordinator
Associated Students, UC Irvine (ASUCI)

Hannah Woo
Campaign Organizer
California Public Interest Research Group Students (CALPIRG Students)

[33] *Energy Innovation*, "Assessing The Viability Of Hydrogen Proposals: Considerations For State Utility Regulators And Policymakers," March 28, 2022, https://energyinnovation.org/publication/assessing-the-viability-of-hydrogen-proposals-considerations-for-state-utility-regulators-and-policymakers/

Veronika Michels
Organizing Director
California Public Interest Research Group Students (CALPIRG Students)

Ayn Craciun, OC Policy Manager
Climate Action Campaign

Luba Al-khalili, CEO and Founder
Act for Change, AFC Irvine Chapter

Nathan Taft, Senior Digital Campaigner
SAFE Cities with Stand.earth

Tomas Castro, Co-Leader
Citizens' Climate Lobby OC Central Chapter

Maryam Dallawar, Hub Coordinator
Sunrise Movement Orange County

David A, Smith, PhD, Co-Chair
Irvine UCC Advocates for Peace and Justice

Richard Busch, Co-Chair
SURFRIDER FOUNDATION North Orange County

Michael Y. Shin, Co-founder
Young Greens of Orange County

Deeti Shah, Co-founder
Fridays For Future Orange County

Linda Kraemer, Chapter Chair
Climate Reality Project: Orange County, CA

Azeem Syed, Vice Chair
Islamic Shura Council of Southern California

Ali Monge, Executive Director and President
WAVE (Women for American Values and Ethics)

Alex Jasset, Nuclear Threats and Energy Justice Manager
Physicians for Social Responsibility - LA

Carol Tuch, President
Women For: Orange County

Patricia Jovel Flores, Executive Director
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Monica Embrey, California Energy Director
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Sandra Smallshaw, School District Spanish Interpreter/Translator
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Linda Heath, Irvine resident

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Amy Parekh, Irvine Resident

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Anthony Falcone, Office of Congressmember Katie Porter
James Black, Office of Senator Dave Min
Lillian Hollar, Office of Assemblymember Cottie Petrie-Norris
Nick Anas, Office of Supervisor Foley
Oliver Chi, City of Irvine

EXHIBIT F

CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

Enabling Higher-Hydrogen Blending in the Natural Gas Distribution System

Global Technology and Market Scan Summary Report for Distributing Hydrogen at >5% into Natural Gas Energy Distribution Systems

Canadian Gas Association **October 2022**

CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

Enabling Higher-Hydrogen Blending in Natural Gas Distribution Systems

Distributing Hydrogen at >5% into Natural Gas Energy Distribution Systems

CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

October 2022

CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

A SUSTAINABLE FUTURE

As society transitions towards a cleaner and more sustainable future, it is vital to consider all available energy solutions and pathways, particularly those integrating low-carbon and renewable sources. Renewable sources, such as wind and solar, promise the delivery of energy with little or no operational carbon emissions. However, the intermittent nature of these sources requires a resilient and dependable backbone network of distribution and storage to ensure the ongoing health and safety of Canadians.

The ultimate objective of the natural gas industry's hydrogen evaluation work is to increase the industry's understanding and to facilitate the safe, effective blending of hydrogen into natural gas streams. This objective must continue to uphold the industry's overarching commitment to the safety and security of its consumers, the public and its workers.

HYDROGEN AT THE FORE

One of the most significant low-carbon and renewable energy distribution and storage options is the utilization of hydrogen as an energy carrier and storage medium. Globally, hydrogen is emerging as one of the most significant opportunities to decarbonize energy systems. Canada has a competitive advantage in leveraging its abundant renewable and low-carbon resources to economically produce hydrogen at scale. The modern natural gas system offers benefits for hydrogen adoption in terms of bulk energy transportation capacity, long-term energy storage and supply resiliency.

FROM LESS THAN 5% TO GREATER THAN 5%

The natural gas industry is committed to increasing the availability of low-carbon and renewable and alternate energies in North America. In 2017/2018, the American Gas Association's (AGA) Operations Section Managing Committee and the CGA's Standing Committee on Operations and Safety jointly produced an **Information Summary Report** on the **Blending of Hydrogen into Natural Gas Delivery Systems** at less than or equal to 5% (≤5%). This 2022 CGA hydrogen study begins where the previous AGA/CGA study concluded, i.e., the blending of hydrogen into natural gas streams at greater than 5% (>5%).

Within this study, the different considerations and the potential impacts of hydrogen use in the natural gas system at between 5% and 20% are assessed in detail. This study is intended as an information source for organizations considering how to build a future where natural networks are a viable low-carbon and renewable energy supply option. This study also contains a scan of the growing development and use of hydrogen in global markets.

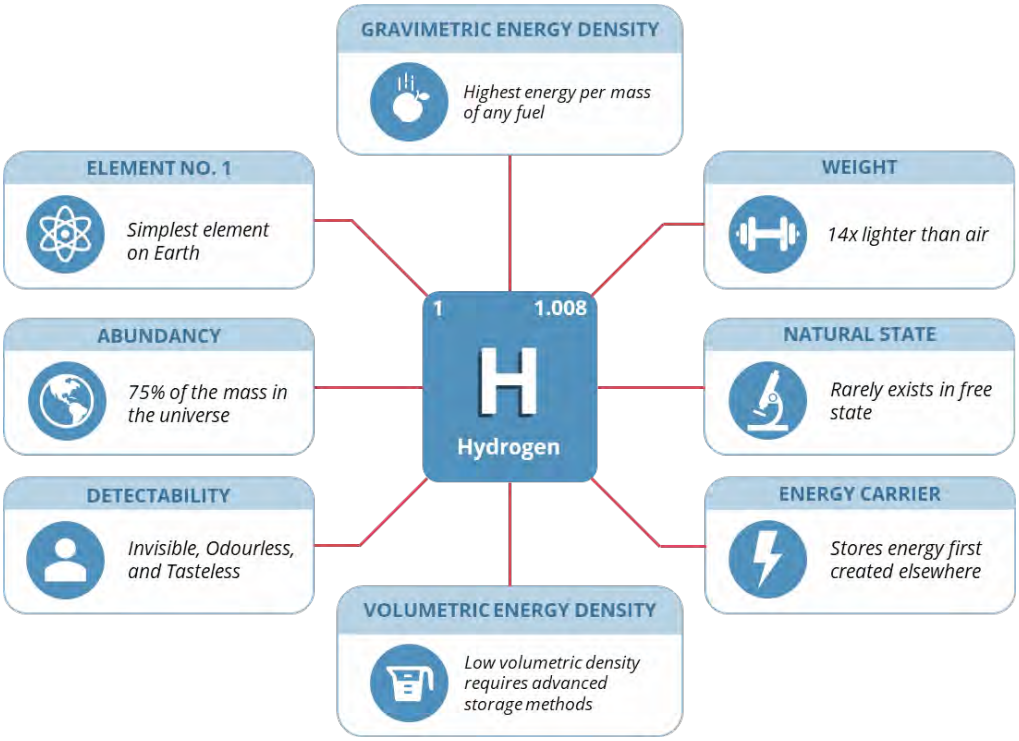
LEVERAGING EXISTING NATURAL GAS INFRASTRUCTURE

The integration of low-carbon and renewable hydrogen, along with renewable natural gas (RNG), offers the natural gas pipeline sector the ability to maintain and extend its technical and economic benefits across the economy. The natural gas infrastructure of today can be used to transport, store, and distribute a more complex and variable mix of gases in the near- to medium-term future. The composition of gases in the network will increasingly include RNG (co-produced with hydrogen), and blends of traditional methane natural gas and high volumes of hydrogen. In the future, there is the

potential for 100% conversion of pipeline systems to hydrogen.

hydrogen fuel or as part of a fuel blend with natural gas and other renewable gases.

PRODUCTION OF HYDROGEN



Low-carbon intensity hydrogen is produced through three main pathways: electrolysis of water with low-carbon intensity electricity, autothermal reforming (ATR) and steam methane reforming (SMR) of natural gas with integrated carbon capture, utilization, and storage (CCUS). Additionally, new production methods are emerging like advanced thermal cracking of methane where the carbon is separated from hydrogen as a solid. When produced using low-carbon upstream feedstocks or by managing the by-product carbon dioxide downstream, hydrogen can be used as a scalable, low-carbon, or carbon-free, energy carrier. Just as important, the potential exists for it to be delivered to Canadian consumers via natural gas infrastructure that is already in place for over 7.25 million homes, businesses, hospitals, institutions & industries. It can be delivered to these end users as a dedicated

The use of electrolysis for the production of hydrogen can also be a mechanism that helps balance electric power systems. This occurs where electrolysis provides an interface between the electricity system, which must be balanced in real time, and the pipeline networks, which could offer a variety of ancillary services including long-duration, seasonal energy storage. Using off-peak, or surplus, electricity to produce hydrogen can offset conventional carbon-based fuels directly in appliances. Alternatively, the hydrogen can be stored and then be used to displace conventional fuels that would otherwise have been required such as on-peak dispatch of natural gas power plants. In effect, natural gas infrastructure can facilitate increased growth of solar and wind energy supplies when converted to hydrogen for blending with natural gas. The result is improved feasibility for

intermittent energy supplies so they become a more predictable energy supply for consumers where hydrogen can be stored in natural gas infrastructure for seasonal balancing.

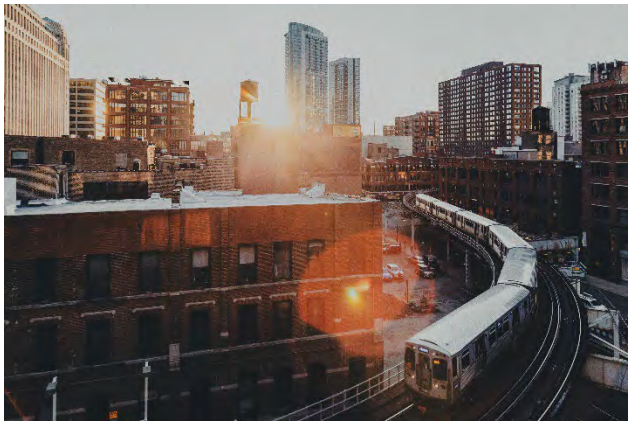
HIGHLIGHTS AND KEY CONCLUSIONS

This report indicates there is a justifiable and feasible technical pathway for the blending of hydrogen in the natural gas distribution infrastructure. Hydrogen can serve as means of reducing the carbon intensity of natural gas and reducing the carbon dioxide (CO_2) emissions from end-use appliances. As more information on global best practices is gathered, it is becoming clear that a step-wise approach to gradually increasing the hydrogen composition in natural gas should be considered. Significant work is underway to safely integrate hydrogen, and the next-generation RNG supplies that co-produce hydrogen, into the natural gas transmission and distribution systems and in end-use appliances.

- The consensus from this report's aggregation of the various studies and projects, finds that the industry's metering technologies can support up to 10% hydrogen blends, and confidence is building for measuring 20% blends with existing metering technology.
- Overall, a natural gas distribution system that is 'leak tight' will remain 'leak tight' with hydrogen.
- Additionally, 'selective leaking' of only hydrogen from hydrogen blended systems is not a phenomenon found within natural gas distribution systems.
- Technically, there are no known chemical incompatibility issues of note between hydrogen and the odourising compounds commonly used in natural gas. Hydrogen should therefore have no deleterious interaction with odourants.
- Major gas turbine manufacturers such as GE, Siemens, Solar, etc. are committed to not only having new electricity powerplant turbines 100% hydrogen compatible, but their objective is to provide a technical pathway for the existing legacy turbine fleets to also be upgraded to this capability.
- End-use equipment and appliance manufacturers can also aspire to seamless operation on fuels ranging from 0% to 20% hydrogen by volume with little or no incremental cost to manufacturing. Certification costs for Hydrogen-Ready appliances have some cost-impact today, but these certification costs are insignificant in a market where manufacturers understand that the lack of certification may preclude them from future unit sales.
- The permeability of hydrogen, through plastic (PE) pipe, is still being assessed for improved understanding, but this global scan could not identify any operating, safety or a any operating, safety or any conclusive and meaningful economic/life-cycle concerns with high-hydrogen blends in plastic distribution pipelines.
- Significantly, emerging from this global scan is the identification of a need for national, North American and global cooperation and sharing of best practices for hydrogen blending. The report summarizes the results of several diligence reviews that highlight the global work that has been completed, barriers encountered & dealt with, regulatory experiences, lessons learned, materials & component information, as well as the opportunity for improved or harmonized standards development.
- Several utilities have also suggested that opportunities exist for knowledge transfer, the development of best practices, and in-depth assessment of markets like Hawaii and Hong Kong where hydrogen concentrations of approximately 10%, and higher, are the norm. While these markets may not have extensive

gas transmission networks, their real-life operating and safety standards likely have a high degree of relevance to the distribution system materials, operations, and the performance of modern end-use appliances.

If trends continue, the historical, relatively homogeneous composition of natural gas will have increasing variability with increased RNG and hydrogen injections. The industry therefore is readying itself and signaling to stakeholders that greater flexibility in the typical composition of gas flowing through our pipelines is required.



RECOMMENDATIONS

This report includes specific recommendations across a series of technical topics. A table with key recommendations is also included in the report's conclusions. Some of the recommendations are related to the various research findings on a specific technical topic; however, several overarching recommendations are offered for the industry's consideration.

These overarching recommendations are also summarized, in a single-page, visual snapshot at the end of this document.

Overarching Recommendations Resulting from Global Scan

The preliminary scan of global hydrogen blending offers encouraging examples of projects and research that could be leveraged by utilities to close specific knowledge gaps with respect to hydrogen blending at >5% in the natural gas system. However, the earlier CGA Task Force work on *Blending of Hydrogen into Natural Gas Delivery Systems at 0%-5% by volume* identified some hurdles which become even more pronounced as hydrogen percentages increase. As a result, the following are recommended considerations for utilities to remove technical uncertainty as a means of accommodating higher hydrogen admissibility.

- The United Kingdom (UK) and Australia appear to have projects, and hydrogen strategies, that most closely align with the anticipated technical needs of Canadian utilities. It is recommended that gas utilities explore, through the CGA and other industry networks, how to participate in the technical work scope that is underway in both the UK and Australia.
- Utilities should continue to monitor specific hydrogen projects/market development activities in other nations to assess if their developments have applicability to the Canadian context. Examples include Austria's Sun Storage Project involving hydrogen storage in underground caverns as well as Germany's progress in establishing a 10% hydrogen blending accommodation with no restrictions.
- The industry should consider a specific research initiative to identify how markets like Hawaii and Hong Kong, which already operate with high-hydrogen composition in natural gas, address end-use appliance, material combability, operability and pipeline safety needs for gas containing hydrogen. These markets are too small to justify market-specific end-use appliances, etc., so their technical practices are worthy of review to understand how to support increasing hydrogen concentrations with low operational impact.
- It is recommended that Canada's gas utilities consider establishing expert panels that would

be tasked with tactical evaluations of hydrogen blending expertise occurring in different global markets. This tactical review would be with an eye to co-investing – i.e., a cost share – in the technical learnings that have occurred, or that are underway, in different markets.

- It is recommended that the natural gas industry consider how best to signal that future natural gas supplies will have more variability in the gas constituents including the inclusion of hydrogen as well as highlighting the potential benefits for developing a hydrogen-ready appliance certification to support the potential for full conversion of natural gas networks to dedicated hydrogen in the future.

Technical Recommendations Following Review of CSA Z662

CGA is aware that the CSA is undertaking significant efforts across a range of technical areas in exploring the implications of increased use of hydrogen. For example, the CSA Z662 Technical Committee has struck a task force focused on identifying changes to the CSA Z662 Standard for Oil and Gas Pipeline Systems to addressed increased hydrogen blends. Early updates to the standard will be reflected in the 2023 edition with further developments in the 2027 edition. The CGA is monitoring developments in these areas.

The initial scan of the CSA Z662 Standard for Oil and Gas Pipeline Systems has identified a single overarching detail that results in less-than-optimal clarity for engineers assessing the Standard's applicability, and any related interpretation, as it relates to hydrogen blended fuels. ***As a result, a recommendation going forward is:***

- Consider if CSA Z662 requires guidance on the applicable range for hydrogen concentrations in a gaseous service fluid that is denoted as Substitute Natural Gas and Synthetic Natural Gas (SNG). By including such clarity on the relevant range of hydrogen concentrations in SNG, technical designers and chief engineers can confirm they are interpreting the Standard's applicable guidance as it relates to pipelines conveying such service fluids. This guidance could be included in an amendment to the actual Standard.

The above recommendation is the primary finding. The Standard already applies to SNG; however, neither the Standard nor the subsequent Commentary on the Standard provides any guidance on the range of hydrogen that can be in the gas composition and still be classified as SNG. As a result, any future updates that establish this type of guidance are believed to be the most significant contributor to improving clarity for engineers and system operators when interpreting the Standard as well as regulators that apply the Standard to the activities over which they regulate.

In addition to the primary finding, several additional recommendations have been identified to improve the clarity for interpreting the Standard's guidance as it relates to the fuels having hydrogen as one of the constituents in the gas service fluid that is being conveyed by the applicable pipeline. The following are additional items for consideration that may improve the clarity for design engineers, pipeline operators, maintenance experts and regulators when assessing the Standard's requirements as it relates to gas service fluids that include hydrogen.

- Initial technical research suggests that existing odourant management practices are likely applicable for natural gas distribution that includes modest levels (up to 15%-20% H_2 by volume) of hydrogen. It is recommended that the relevant technical subcommittees assess what, if any, changes are required for odourant practices involving both natural gas – hydrogen blends as well as SNG if this is further defined under any updates to the Standard's guidance on SNG.

- Assuming the Standard or Commentary can be updated to include guidance on the applicable range of hydrogen for SNG, it will offer clarity for engineers when assessing when a "change in Service Fluid" requires an engineering assessment. If a specific range for the relevant hydrogen volume in SNG is not available some additional guidance would be appropriate to help assess what incremental hydrogen composition constitutes a change in service fluid compared to natural gas or an existing blend of natural gas and hydrogen.
- Assess and survey the growing body of research and best-practices related to hydrogen blended fuels in natural gas transmission and distribution systems. This could include pipeline applications involving SNG. This body of technical research can be assessed for its relevance to future updates of the Standard and Commentary.
- Consider if the Standard requires the establishment of a separate Subcommittee on Transmission or if other technical groups such as the Petroleum and Natural Gas Industry Systems group could expand the Standard's technical guidance with respect to SNG and higher-hydrogen service fluids in transmission systems.
- Engage the Standard's Subcommittee on Distribution to assess Section 12 of the Standard (Gas Distribution System) so as to confirm the Standard does not impart any downstream impacts or requirements on, i) the B149.1 Installation Code, or ii) impart any requirements for gas quality or consistency (e.g., Wobbe Index, Methane Number, etc.)
- Assess what, if any, requirements related to service fluids that include hydrogen sulphide may have relevance to pipelines conveying SNG (e.g., bake-out procedures)

- The Standard and Commentary include specific references to Carbon Dioxide and LPG pipelines. Consideration should be given to referencing what applicability this standard may have for pure (100%) hydrogen pipelines. At a minimum the Standard, or Appendix, could identify any interdependencies that may exist between this Standard and the Hydrogen Pipeline Code ASME B31.12-2019.
- Survey the Standard's Subcommittees involved in, i) Distribution, ii) Operations & System Integrity, and iii) Materials to identify what, if any, additional undertakings should commence to assess applicable updates to future versions of the Standard, and the Commentary, as it relates to hydrogen-natural gas blends.

Recommendations Following the Review of B149.1 Natural Gas Installation Code

It is recommended that the development of specific codes for renewable gas supplies be avoided wherever possible to ensure technician training, and code conversancy are not strained or compromised. A better approach is to identify where the development and adoption of renewable gas supplies creates a gap, or requirement for clarity, in the existing codes and standards. Then, seek to update the existing code/standard to address these issues.

- Consider how the B149.1 Natural Gas Installation Code could offer improved clarity

as to its applicability for both natural gas and synthetic natural gas (SNG). Definitions for SNG could be harmonized with the same SNG definition as CSA Z662 Standard if the Standard is updated to provide a range of applicable hydrogen concentrations under the definition of SNG.

- As part of the regular code review cycle, technical subcommittees for B149.1 could include a review of global best-practices as well as engineering and technical assumptions for end-use equipment operating on hydrogen blended natural gas.
- The code should also establish clear delineation between CAN/BNQ 1784-0000 (Canadian Hydrogen Installation Code) and CSA B149.1. The CSA B149.1 code may benefit from the creation of specific hydrogen section in a similar manner to the structure of International Fuel Gas Code (IFGC).

Technical Recommendations – Odourization

The prior report on 0% to 5% Hydrogen Blending stated the existing odourant practices were suitable for hydrogen natural gas blends, so long as the fuel was used in a normal combustion process. This report's findings suggest it is unlikely that a circumstance could occur where a leak was creating an unsafe condition due to a hydrogen release without odourant being detected at 1/5th the lower explosive limit (LEL).

- Utility odourization experts should conduct a peer review of the United Kingdom's H21 and H100 hydrogen project developments involving odourization practices. A review of the Australian report "Hydrogen in the Gas Distribution Networks" by these same utility experts is thought to be informative on the subject of odourization practices for hydrogen – natural gas blends.
- Consider further investigation in Germany's real-life operations involving sulphur-free odourants to advance North American utility knowledge in this area. The investigation could better prepare utilities for high-hydrogen blends of fuel distribution and also lessen the environmental impact from current odourant practices. The use of sulphur-free odourants is also expected to support future adoption of non-combustion end-use processes such as fuel cells that operate on pipeline fuels.

Technical Recommendations – Metering

The prior CGA/AGA report on blending (0% to 5% by Vol.) found metering accuracy and suitability for hydrogen blended fuels of up to 50% with an acceptable accuracy (<2%) for the most common bellows or diaphragm meters. Other high pressure metering applications such as CNG fueling can also use mass flow meters (Coriolis type meters). The accuracy of these meters has not been found to be affected by the addition of hydrogen since mass flow is the unit measurement. Key recommendations related to metering in this study include:

- Establish a billing and compliance strategy for managing the anticipated increases in energy content variations within different segments of the natural gas transmission and distribution networks. As the strategy evolves engage Measurement Canada in updating the *Electricity and Gas Inspection Act*. The Canadian Gas Association has initiated exploratory discussions with Measurement Canada to understand what level of knowledge and engagement the government department has on the topic of hydrogen blending and to establish a joint pathway forward.
- Consider the creation of a CGA task force to establish priorities for the next-generation of smart metering and gas analysis systems. Such a task force could evaluate the ongoing technology developments in the gas

chromatography space and the opportunities for adopting smart gas sensors and analyzers to manage the future energy content variations that result from increasing RNG and hydrogen supplies.

- Accuracy requirements (e.g. +/- tolerances established by regulatory mandates like the Electricity and Gas Inspection Regulations) should be evaluated to determine if a wider variation needs to be permitted in mass-market meter applications (e.g., Residential) versus high-volume meters where economies for added metering complexity can be justified. Based on current global studies, hydrogen blends of up to 20% are expected to meet Measurement Canada's accuracy requirements for mass-market meters; however, establishing clear acceptance by Measurement Canada should be a priority.
- Monitor Canadian metering developments related to hydrogen blends. As an example, Fortis has proposed an "Advanced Meter Initiative", that if approved, would establish testing and certification procedures for the gas meters to be hydrogen-ready.
- Through the CGA's Measurement and Regulation committee work, assess the industry's modeling equations, for gas heating value, density, compressibility, speed of sound etc. to verify these equations remain relevant for increasing concentrations of hydrogen.

Technical Recommendations – Materials

Material compatibility is a key area of research for hydrogen blending above 5%. The differences between materials and systems mean this question will require a case-by-case approach; however, several key recommendations include:

- Through the CGA, establish participation within the CSA Z662 Technical Committee Hydrogen Task Force to ensure the Standard's future updates reflect the current body of knowledge on global best practices when assessing material suitability for hydrogen-natural gas blends, as well as RNG. Subcommittee participation would also seek to have the Standard provide more clarity on establishing when an engineering assessment is required because the service fluid is deemed to have changed as a result of specific concentrations of hydrogen in the service fluid.
- Consider establishing industry support for dedicated evaluation of natural gas transmission systems which is separate from any materials and operational system reviews conducted for natural gas distribution systems. The ability to engage transmission system operators in meaningful consideration of transporting blended fuels with hydrogen is believed to better assist in the removal of any technical barriers in a timely manner.
- It is recommended that Canadian utilities explore how they might access the global technical findings from past, and on-going, technical reviews through cost-share and/or research sharing agreements.
- Global research efforts typically employ pure methane as the subject gas, whereas actual gas (line gas) flowing through pipeline systems are not pure methane. They include trace elements such as butane, ethane, O2. The presence of these may inhibit hydrogen embrittlement. Therefore, it is recommended that any future investment in hydrogen embrittlement research should be done on actual line gas, as this may yield markedly different results, which may prove a significant factor for transmission systems.

Technical Recommendations – Underground Cavern Storage

Projects in Europe have demonstrated that existing gas storage reservoirs can tolerate hydrogen blends of up to 10%. Understanding the implications of

long-term underground hydrogen storage will help demonstrate the viability of using power-to-gas as an energy storage method.

- Successful projects from Europe and elsewhere should be assessed by engineers familiar with Canada's different storage geology to determine if lessons learned could have applicability to Canada's unique geology.
- Consider if Canadian utilities have any operational storage fields that are sub-optimized and may offer the potential for domestic field trials for underground storage of hydrogen-natural gas blends.
- Consider the potential benefits of a Canadian consortium joining RAG Austria AG's current project which is the Underground Sun Conversion project to advance renewable gas innovation with underground (in-situ) methanation processes.

Recommendations – Improving Flexibility for Gas Turbine Operation on Hydrogen

Manufacturers producing large stationary engines and high-horsepower gas turbines are demonstrating the ability to accommodate higher-hydrogen blending. For mainline transmission compressor plants, the largest issue appears to be the increase in power demand needed to compress pipeline gas containing higher levels of hydrogen.

- Utilities may want to consider signalling that future natural gas compositions could include higher hydrogen compositions so that engineering firms and turbine suppliers can consider this at the early project planning stages.
- Survey the gas turbine industry to arrive at consistent feedback on existing and future technical capabilities for the North American gas turbine fleet operating on natural gas with hydrogen blends. This could be modeled after the "EU Turbine Stakeholder Group".
- Continue to expand manufacturer-specific surveys of hydrogen co-firing capabilities beyond GE and Siemens, particularly for the existing North American pipeline compressor fleets. Additional gas turbine suppliers active in North America include Solar Turbines (Caterpillar), OPRA Turbines, etc.
- Fast rates of change for the hydrogen composition in a gas turbine have not been found to be a concern to turbine suppliers during this initial survey. Future industry surveys should continue to gather confirmation from other turbine suppliers to confirm that rate of change on fuel composition is not a concern for any anticipated future ranges in hydrogen blending. Based on this research scan, it is suggested that rate of change in hydrogen composition should not be a high area of concern for gas utilities contemplating higher-hydrogen blends (as it relates to gas turbines).

Technical Recommendations – CNG Vehicle and Refueling Systems

CNG vehicles require several important considerations with regards to hydrogen blending. Both existing storage cylinder designs and engine designs may be affected by different hydrogen blending levels, but there are ways to mitigate these risks.

- Consider leveraging any program funding, that may be part of a National Hydrogen Strategy, to support a phased-in, Type-1 tank retirement program for CNG systems as part of natural gas grid and equipment end-use modernization. Such a retirement program may be able to be incorporated into allowable utility rate base. Regardless, the removal of these legacy assets from the gas infrastructure removes one of the most restrictive pinch points on a natural gas utility having the future flexibility to respond to market, government

or regulatory requirements that seek increased renewable content in the natural gas networks.

- Monitor the SoCal / University of California (UCR) emission research using the CWI engine in applications with high-hydrogen blends. The CGA or CNGVA may want to co-fund the study if the results also provide insights into the engine maintenance impacts, if any, for operations on high-hydrogen blends. Regardless, the CWI restriction on hydrogen is an example of an OEM having limited fuel-flexibility for hydrogen blends. The limitations on fuel flexibility to accommodate hydrogen blends appears to be related to a perceived lack of market need and limited testing on hydrogen blends. If utilities provided market signals that their future natural gas composition is expected to include more gas constituent variability, including hydrogen, then end-use OEMs would consider this when establishing operational, service and warranty programs for their customers. As it stands, these OEMs are shifting responsibility to utilities for any gas composition changes that may be required to comply with future clean fuel standards, etc.

Technical Recommendations – Appliance Operations on Higher-Hydrogen Blends

Home appliances appear to be largely compatible with lower blending amounts. Significant technical due-diligence and appliance testing has been completed in various markets and by Canadian utilities. This has also included physical appliance testing on high-hydrogen blends up to 30%. Additional considerations include:

- Consider proposals to have the industry and policy makers establish a hydrogen-ready appliance certification that could be structured in a manner similar to the Energy Star certification for electrical appliances. Establishment of such a program would provide a carrot to the pro-active, natural gas appliance OEMs to differentiate their appliances. Furthermore, it would start the shift of costs and the responsibility for establishing operational performance for high-hydrogen blending. The outcome would be that utilities are not the only stakeholder tasked with the implementation burden related to establishing fit-for-purpose operations of end-use appliances on hydrogen blends that are required to support the reduced carbon intensity for pipeline fuels.
- Look for market catalysts, like the introduction of next-generation natural gas heat pumps, to also advance consumer awareness of the benefits of purchasing next-generation natural gas equipment that could also incorporate hydrogen-ready operations. A survey of the natural gas heat pump OEMs suggests these appliance manufacturers are already considering how hydrogen-ready branding could differentiate their products, and their embracing of this certification would put pressure on legacy natural gas appliance OEMs to follow.
- It is recommended that future technical diligence reviews for hydrogen blending be streamed into two categories. The first, and most realistic early adopter opportunity, is for higher-hydrogen blending (5% to 20%) in the natural gas distribution grid including end-use appliances. The second category would validate the medium-term opportunity to accommodate higher-hydrogen blends in Canada's natural gas transmission network and the unique end-use operations linked to the country's transmission networks. This focused review of different asset classes (transmission and distribution) is also being practiced in Australia based on the country's National Hydrogen Strategy.

CONCLUSIONS - CGA STRATEGIC OVERVIEW FOR HYDROGEN BLENDING ACTIONS & RECOMMENDATIONS

To enable higher hydrogen blends in our natural gas networks, eleven different priority areas have been identified for the natural gas industry's consideration with various proposed timeframes from immediate to longer term.

The **primary recommendation** is to build-out a hydrogen admissibility plan, and for progress to be made in nine specific areas during the 2022 through 2025 timeframe.

The **second recommendation** is to seek government and regulatory policy support for Grid Modernization Programs. In the electricity industry, past smart grid programs have evolved into Grid Modernization Programs to enable the higher penetration of renewable energy within the nation's electricity grids. The programs addressed a variety of infrastructure developments to support new capabilities. These included the accommodation of more distributed resources, improve metering capabilities, new technology deployments and support for the utilities and standards organizations to embrace new processes that support the growth of renewable energy while maintaining or improving system reliability. The same Grid Modernization Program thinking can be leveraged to support the natural gas industry's growth, which also includes integrating similarly distributed resources, to accommodate higher hydrogen levels in the natural gas networks and by extension grow the renewable energy mix in the nation's pipeline networks.

Nine additional priority areas are identified including - standards and code updates, gas metering improvements and strategies for utilities to engage the industry's material suppliers, equipment manufactures, regulators and customers in preparing for a future where hydrogen is increasingly included as a component of natural gas supplies.

These priority areas are depicted in Table 1 – Key Recommendations and Actions and are elaborated upon throughout this report.

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Table 1 - Key Recommendations and Actions

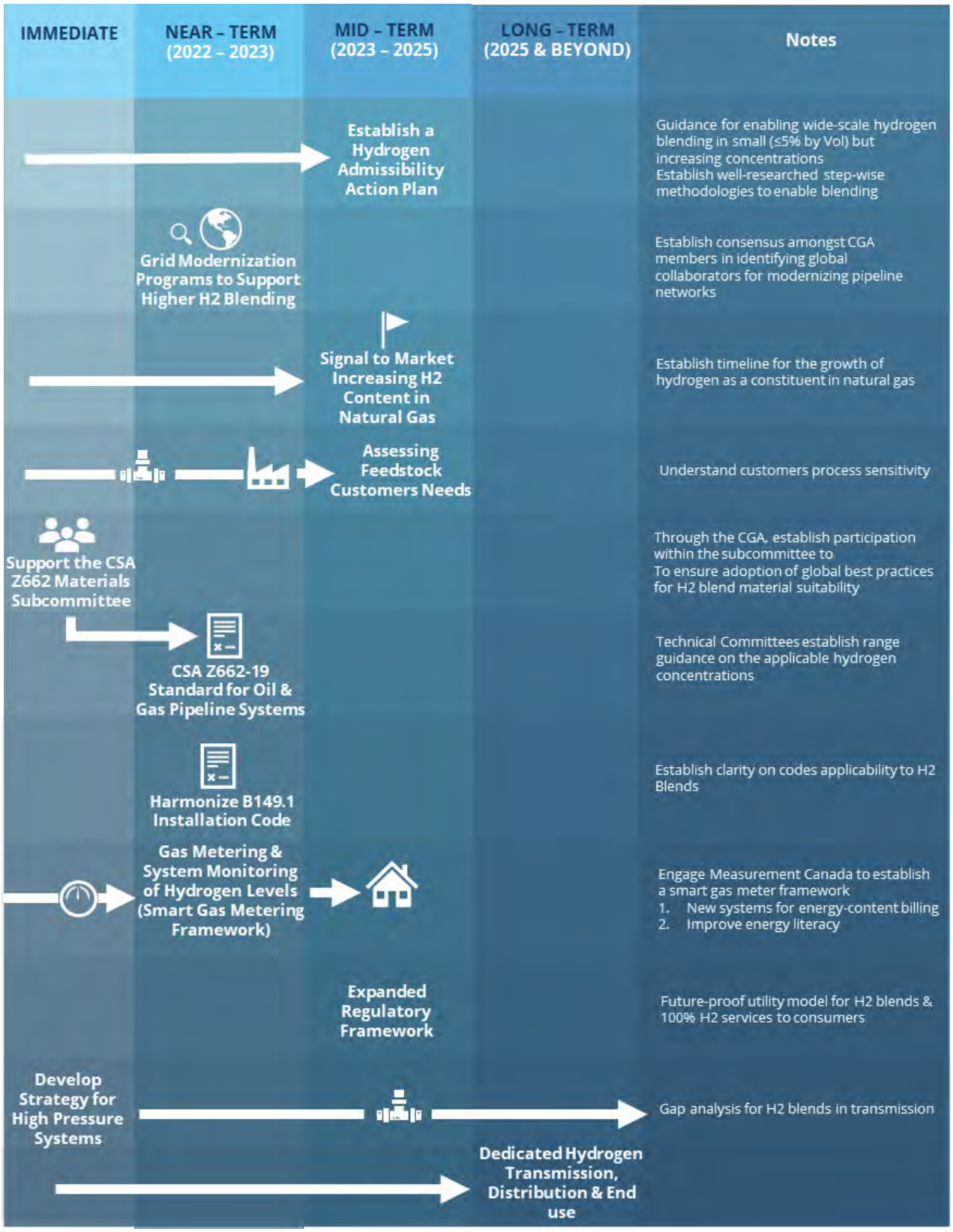
#	Area	Recommendation	Timeframe and Notes
1.	**Build out CGA's Hydrogen Admissibility Plan**	Establish guidance for enabling wide-scale hydrogen blending in small (≤5% by Vol) but increasing concentrations (>5% by Vol). The objective is to establish well-researched, engineered and step-wise methodologies to enable hydrogen blending while minimizing the requirement for network-specific engineering assessments at each injection node. Such an action plan could then be used to highlight the benefits for governments and regulatory bodies in supporting pipeline system modernization for improved flexibility in transmitting, distributing and storing renewable pipeline fuels.	**Medium-Term** **(2022-2025)** Note that some utilities suggested that such admissibility plans may benefit by focusing on large gas users (e.g., power plants) where high hydrogen concentrations could be engineered as "fit-for-purpose end-use" while still supporting a wider market transformation strategy
2.	**Grid Modernization[1] to Support Higher-Hydrogen Blending**	Establish consensus amongst CGA members in identifying global collaborators for modernizing the pipeline networks. This would include a review of peer-utilities to establish best practices in the area of high-hydrogen blending. The objective is to lessen the individual utility member costs involved in increasing the operational capabilities to deliver natural gas with higher-hydrogen concentrations. By establishing cost-share agreements and sharing of best practices with peer utilities and government funders, the capabilities of CGA members can be accelerated with less budget impact. Energy regulators should be educated on the benefits of supporting utility investments in this area.	**Short -Term** **(2022-2023)** Note that utility feedback also identified an interest in expanding the Grid Modernization activities to include modernization of end-use appliances and applications (e.g., NGV infrastructure) so as to achieve more flexibility on accommodating renewable gas compositions.
3.	**CSA Z662-19 Standard for Oil and Gas Pipeline Systems**	Assess how the Standard's Technical Committees could establish range guidance on the applicable hydrogen concentrations in a gaseous service fluid that is denoted as Substitute Natural Gas and / or Synthetic Natural Gas (SNG). By including such clarity on the relevant range of hydrogen concentrations in SNG, technical designers and senior engineering staff can confirm they are interpreting the Standard's applicable guidance as it relates to	**Short-Term** **(2022-2023)** Range Guidance as a % by Vol. is likely suitable for Distribution Systems with lower material stresses. For Transmission systems, it was suggested

[1] Over the last two decades governments have extended significant "Grid Modernization Funding" to the electricity sector to accommodate increased supplies of renewable energy and increasing the pipeline network capabilities for higher-hydrogen blends is a similar infrastructure modernization program to accommodate fuels with lower carbon intensities. Early findings within this global scan suggest both the United Kingdom and Australia are likely market collaborators with Canadian utilities.

		pipelines conveying such service fluids. Input into this process could be via the current CSA Taskforce activities that seek to identify the necessary updates to the CSA Z662 Standard for 2023. Recommended guidance could exist in the form of a clause note, or use of non-mandatory language, directly in the standard.	that guidance around the allowable "Partial Pressure of Hydrogen" may improve design criteria
4.	**Provide Market Signals for Increasing Hydrogen Content in Natural Gas**	Using range guidance on blend levels, establish a timeline for the growth of hydrogen as a constituent in natural gas (e.g., hydrogen content if defined in CSA Z662 definitions for SNG). This could have progressive milestone dates such as 2025, 2030 and 2040 where the natural gas industry would seek to support operational capabilities "up to" specific concentrations of hydrogen with no restrictions.	**Medium-Term (2022-2025)**
5.	**Harmonize the B149.1, 2020 Installation Code with Clarity on Hydrogen-Natural Gas Blends**	Prior to the next code update cycle, work with the technical subcommittee members to ensure that the upcoming code revisions establish clarity on the B149.1 Installation Code's applicability to SNG (as defined in CSA Z662, etc.). Establishing such clarity will assist subcommittee members, installers and appliance manufacturers in accounting for hydrogen as a constituent in natural gas when assessing code applicability and future evaluations of global best practices. This subcommittee work could run in parallel with the taskforce review of the CSA Z662 Standard, or a separate technical working group could be established for the B149.1 Installation Code.	**Short-Term (2022-2023)**
6.	**CGA participation on the Materials Technical Subcommittee for CSA Z662**	Through the CGA, establish participation within the CSA Z662 Materials Subcommittee to ensure future updates to the Standard reflect the current body of knowledge on global best practices when assessing material suitability for hydrogen-natural gas blends. Consider if the Standard may provide additional clarity on establishing when a service fluid in a pipeline is deemed to have been changed through the addition of hydrogen or an increase in concentration. A change in service fluid would necessitate an engineering assessment.	**Immediate** Additionally, the industry may benefit by establishing a process to support "Management of Change" with respect to evolving hydrogen competencies
7.	**Develop a Strategy for High-Pressure Pipeline Systems;** **Identify Unique Technical Considerations that are**	Consider establishing a separate stream of work, or Technical Working Group for natural gas transmission systems is required due to the unique material use, operating pressures, system cycling, etc. This work scope would be differentiated, where required, from the engineering and safety assessment work that is	**Immediate** Note that CSA Z662 has formed a single hydrogen and renewable gas taskforce to assess what changes are needed in the Standard. As an alternative to creating

	Specific to Transmission & High-Pressure Distribution System Suitability for Hydrogen-Natural Gas Blends	focused on natural gas distribution systems. As an example, British Columbia is establishing the BC Hydrogen Feasibility Study, where the Transmission, Distribution and behind-the-meter assets classes will be assessed separately but with a common end-state vision. Opportunities to share best practices learned from this type of activity should be explored to lessen the industry's cost of attaining proficiency across the operational and safety-related objectives.	separate Technical Work Groups for transmission and distribution systems, consider creating an industry backed project to compare the existing requirements of CSA Z662 against other references such as ASME B31.12 Hydrogen Pipeline Code.
8.	**Gas Metering, System Monitoring of Hydrogen Levels and Gas Detection Devices**	Through the CGA, engage Measurement Canada in establishing a smart gas measurement framework (or other suitable regulatory/rate constructs) to account for increasing variability in the energy content of natural gas due to the increasing levels of RNG and hydrogen that are expected in the future natural gas networks. This may require updates to the Electricity and Gas Inspection Act. It will also require the CGA to engage with its members to prioritize the development of specific technologies and/or system procedures to understand real-time changes in the energy content for gas distribution nodes and large customer / custody transfer locations. Verification of the performance for gas detection technologies used with hydrogen-natural gas blends will also be needed to ensure operational procedures remain safe when purging networks, etc. for gas that contains higher levels of non-carbon constituents.	**Short-Term** **(2022-2023)**
9.	**Expanded Regulatory Framework**	As part of the sustainability objectives, emission compliance measures and regulatory obligations that are being imposed on natural gas utilities, seek an expanded regulatory framework for hydrogen asset ownership and operation by natural gas utilities. Current legal and regulatory frameworks may limit the ability for natural gas utilities to own / operate assets involving hydrogen. Ensure CGA members have the optionality to expand their service models to include a wider range of gas supplies and leverage the process/operational safety benefits the utilities have to secure support for an expand the regulatory framework.	**Medium-Term** **(2022-2025)**
10.	**Assessing Feedstock Customers**	A technical and market assessment should be completed to understand the locations, supply infrastructure (transmission / distribution pipeline connections), and volumes of natural gas, that align with feedstock customers. The majority of feedstock customers are assumed to be transmission-connected, but this needs to be confirmed and the distinctions need to be understood. Transmission networks will invariably have a longer timeline for the	**Medium Term** **(2022 to 2025)** CGA member feedback suggested the nearest-term opportunity to assess feedstock customer solutions may be LNG facilities in BC, and it is noted that

		adoption of higher-hydrogen blends; however, work should start soon so as to understand if utilities might economically integrate hydrogen removal systems as part of the large-volume, customer metering station as a rate-base investment.	the CGA has also fielded extensive interest in this topic from the chemical and fertilizer associations in Canada.
11.	**Dedicated Hydrogen Transmission, Distribution and End-Use**	Consider establishing a CGA member task force to identify priority areas (technical, operational, legal, regulatory, etc.) that improve the utility's operational capabilities and eligibility to provide dedicated hydrogen services with respect to the production, transmission, storage, distribution and end-use adoption. Examples would be hydrogen metering capabilities, dedicated hydrogen micro-grids for community energy systems and next-generation pipeline design for transporting hydrogen (e.g., repurposing existing pipelines for hydrogen service, evaluating role of composite materials, etc.). Task force priorities would also include establishing a pathway for adaptive end-use technologies where hydrogen-ready certification of natural gas appliances could be established.	**Medium to Long Term (Beyond 2025)** CGA Member Feedback suggest that Legal and Regulatory relief, to pursue hydrogen related activities, should be the first priority starting as early as 2022


IMMEDIATE
NEAR – TERM (2022 – 2023)
MID – TERM (2023 – 2025)
LONG – TERM (2025 & BEYOND)
Notes
Establish a Hydrogen Admissibility Action Plan
Guidance for enabling wide-scale hydrogen blending in small (≤5% by Vol) but increasing concentrations
Establish well-researched step-wise methodologies to enable blending
Grid Modernization Programs to Support Higher H2 Blending
Establish consensus amongst CGA members in identifying global collaborators for modernizing pipeline networks
Signal to Market Increasing H2 Content in Natural Gas
Establish timeline for the growth of hydrogen as a constituent in natural gas
Assessing Feedstock Customers Needs
Understand customers process sensitivity
Support the CSA Z662 Materials Subcommittee
Through the CGA, establish participation within the subcommittee to
To ensure adoption of global best practices for H2 blend material suitability
CSA Z662-19 Standard for Oil & Gas Pipeline Systems
Technical Committees establish range guidance on the applicable hydrogen concentrations
Harmonize B149.1 Installation Code
Establish clarity on codes applicability to H2 Blends
Gas Metering & System Monitoring of Hydrogen Levels (Smart Gas Metering Framework)
Engage Measurement Canada to establish a smart gas meter framework
1. New systems for energy-content billing
2. Improve energy literacy
Expanded Regulatory Framework
Future-proof utility model for H2 blends & 100% H2 services to consumers
Develop Strategy for High Pressure Systems
Gap analysis for H2 blends in transmission
Dedicated Hydrogen Transmission, Distribution & End use

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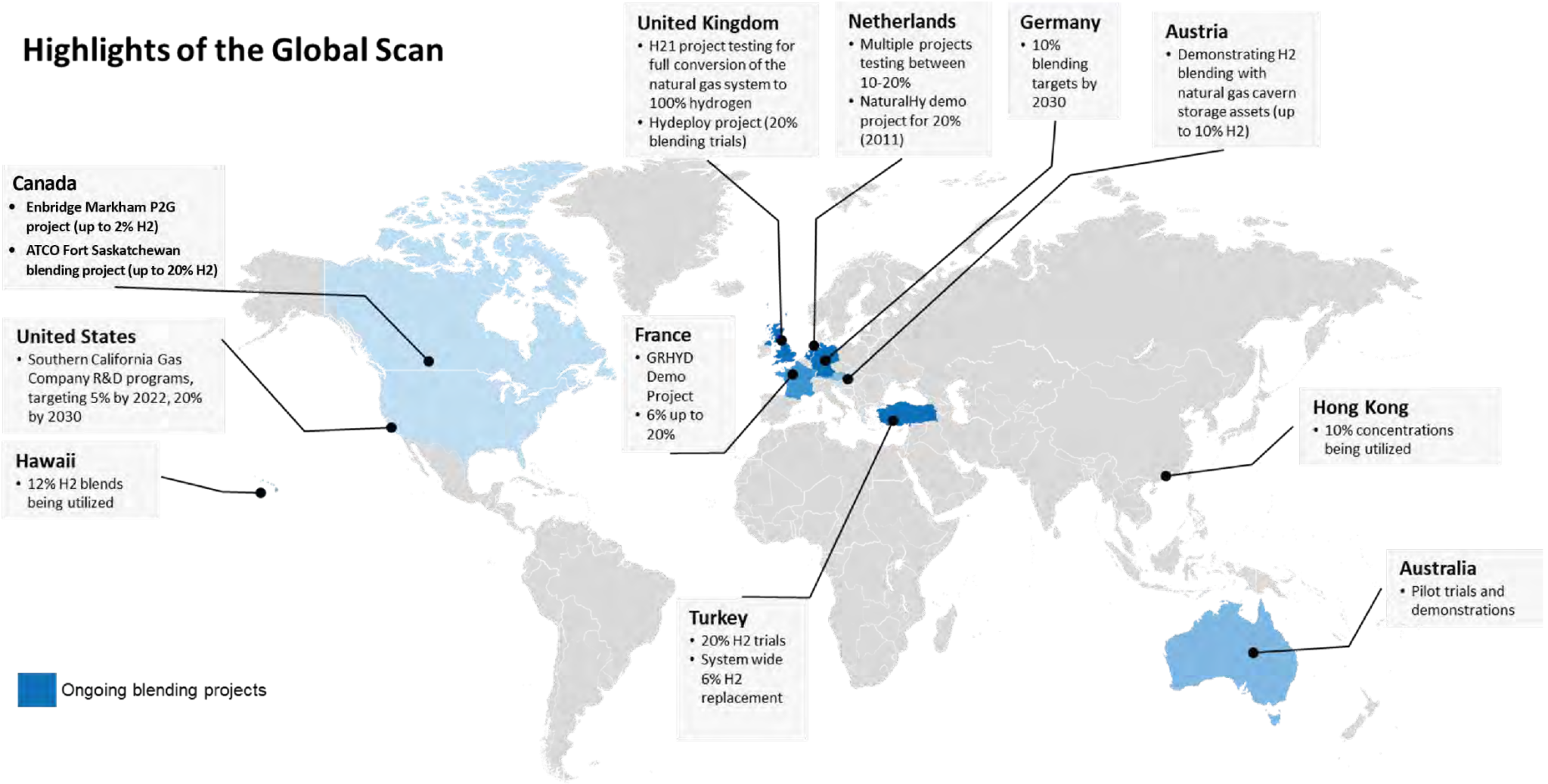
Highlights of the Global Scan



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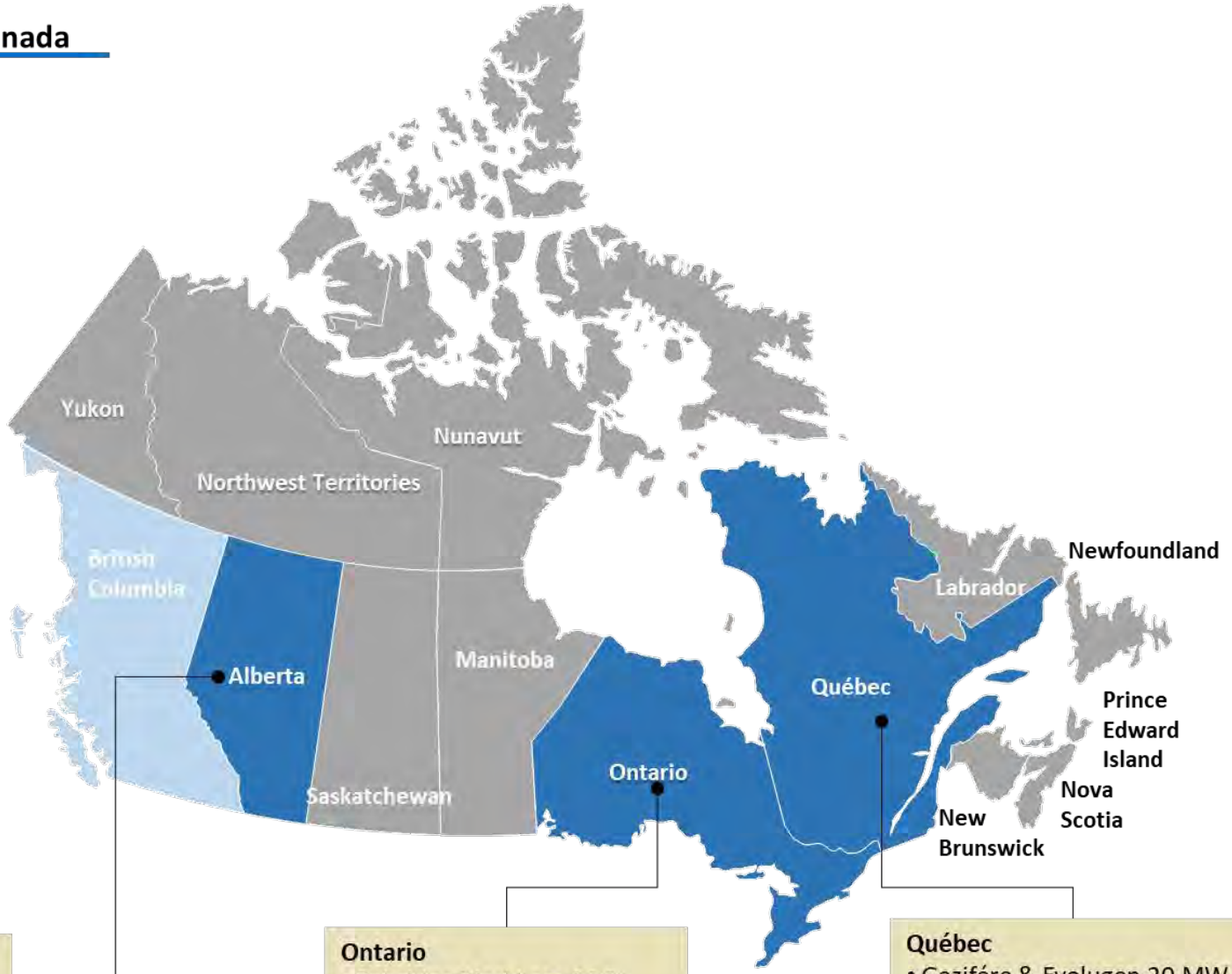
Hydrogen Blending Activity in Canada



Ongoing Blending Projects

Established Blending Policies

Alberta
- ATCO Fort Saskatchewan Blending Pilot

Ontario
- Enbridge Markham P2G project

Québec
- Gazifére & Evolugen 20 MW electrolyzer blending project

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Natural Gas Distribution System: Highlight of Key Areas Impacted by Hydrogen Blending

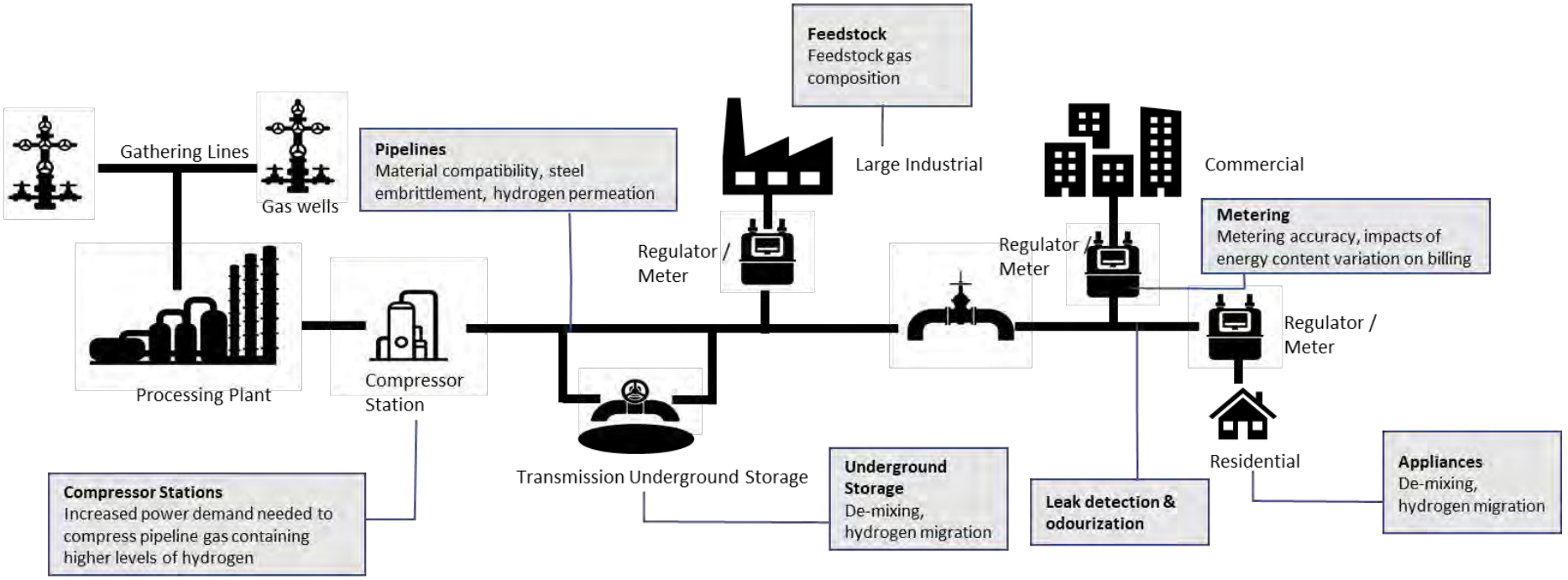

EXHIBIT G

UCI HYDROGEN BLENDING DEMONSTRATION SAFETY INFORMATION

Background

SoCalGas is filing an application with the California Public Utilities Commission (CPUC) to propose hydrogen blending demonstrations under live operational conditions. This application will consist of five (5) live demonstration project proposals coming from all four of California's Gas Investor-Owned Utilities (IOUs) - SoCalGas, SDG&E, Southwest Gas and PG&E.

The demonstration project being proposed by SoCalGas at UCI is part of a broader effort by the State and the utilities to inform the development of a statewide hydrogen blending standard - an important step in the process for the delivery of clean, renewable hydrogen to California. SoCalGas's proposed project intends to blend between 5-20% hydrogen into SoCalGas's infrastructure that will ultimately serve the Anteater Recreation Center (ARC) at UCI (Closed System Project).

The proposal to blend to the ARC was closely coordinated with UCI facilities personnel and was selected based on the facility's consistent gas load, location, ability to isolate from other campus buildings and residences, pipeline components, and end use equipment. The Closed System Project's details are subject to change during the application process or approval.

Safety & SoCalGas

At SoCalGas, safety is a core value and is at the foundation of everything we do. This commitment to safety is embedded in our culture and dedicated employees who work to safely and reliably operate the system to serve our customers.

SoCalGas focuses on safety through the lenses of public safety, infrastructure safety, employee safety, and contractor safety. This safety focus is the foundation of our business and helps to organize effort around our fundamental core safety value. The Company's tradition of safety spans more than 150 years and is the basis for company programs, policies, procedures, guidelines, and best practices.

SoCalGas Leadership in Hydrogen Safety

SoCalGas is an active member of the Center for Hydrogen Safety (CHS), a global non-profit dedicated to promoting hydrogen safety and best practices. SoCalGas' involvement includes chairing the hydrogen-natural gas blending working group within CHS, whose efforts include developing best safety practices of blending for industry.

SoCalGas is also working on a Joint Industry Partnership with DNV and Enbridge Gas Inc. to develop a hydrogen certification/training curriculum. The certification/curriculum would educate personnel on the fundamental role of hydrogen's role in the energy transition, the hydrogen value chain, and design, operations, and maintenance considerations for transporting hydrogen and hydrogen blended gas by pipeline.

UCI Hydrogen Blending Safety Protocols

SoCalGas's safety efforts to be taken before, during, and after the Closed System Project would include, but are not limited to:

- **Hydrogen safety education for personnel**: SoCalGas will work with local fire department and/or campus staff to provide educational briefings for hydrogen safety procedures, where needed.

- **Create hydrogen blending specific customer protocols and emergency response plans**: SoCalGas will work with UCI to develop any necessary emergency response plans.

- **Safety assessment for hydrogen storage and hydrogen components**: SoCalGas will conduct an independent safety review of all hydrogen storage and production components to evaluate any safety concerns prior to construction or implementation.

- **Survey end-use customer equipment to confirm behind-the-meter equipment present is free of leakage and operating safely**: SoCalGas will inspect end use equipment to confirm there is no leakage prior to the introduction of hydrogen, as well as regularly communicate with UCI staff on equipment condition.

- **Conduct pre-, during, and post-implementation leak surveys**: SoCalGas will conduct pre-injection leak surveys to confirm the system is free of any leakage. After the introduction of hydrogen, SoCalGas will perform monthly leakage surveys, which is 12 times the normal protocol of leakage inspection.

- **Install remote methane/hydrogen monitoring systems**: SoCalGas will have remotely monitored alarms for indoor areas where end use equipment is located, as well as surrounding hydrogen production, storage, and blending systems.

- **Mitigation measures to prevent hydrogen or hydrogen blends from reaching natural gas storage areas and electrical switching equipment**: The pipeline system will be isolated in a manner in which only the ARC receives the hydrogen/natural gas blend.

- **Conduct gas system operational tests and equipment tests**: Confirm the gas system and equipment are free of leakage and prepared to receive a hydrogen blend prior to the introduction of hydrogen.

EXHIBIT H

UCI Hydrogen Blending Demonstration Project
Safety Engineering and Data for UCI Advisory Committee
January 18, 2024

At SoCalGas, safety is a core value and is at the foundation of everything we do. As we continue collaborating with the University of California, Irvine (UCI) on the proposed hydrogen blending demonstration project, the data and research provided in this document highlights key safety protocols and measures that we currently expect to be in place. As the effort advances in its engineering design, we would invite further collaboration with UCI to enhance safety.

Background

Following the California Public Utilities Commission (CPUC) direct UC Riverside study regarding hydrogen blending, the CPUC directed SoCalGas, SDG&E, PG&E, and Southwest Gas (collectively, the Joint Utilities) to propose hydrogen blending demonstrations under live operational conditions. The proposed SoCalGas project at UCI is part of the broader effort by California, and the Joint Utilities, to inform the development of a statewide hydrogen blending standard. This is an important step in the process for the delivery of clean, renewable hydrogen to California and will ultimately support resiliency in the energy infrastructure system, consistent with the conclusions including the following:

- California Dispatchable Generation – EDF/Stanford's study on the need for long duration energy storage and dispatchable electric generation supported by hydrogen and clean fuels.
- CARB Scoping Plan– California Air Resources Board's (CARB) Scoping Plan which describes the need for low carbon fuels and hydrogen blending as one path towards GHG neutrality (see page 78).

SoCalGas's proposed project intends to blend between 5-20% hydrogen into SoCalGas's infrastructure that will ultimately serve the Anteater Recreation Center (ARC) at UCI.

The CPUC's directive follows and is consistent with similar efforts in other jurisdictions. Following are a few notable examples:

- Hawai'i Gas – Up to 15% hydrogen used in its fuel mix since the 1970s
- CenterPoint Energy (Minneapolis, USA) – up to 5% hydrogen blends to residential stoves and furnaces
- Dominion Energy Utah ThermH2 Phase 1– 5% hydrogen blend to the Training Academy test gas distribution system in Salt Lake City
- Dominion Energy Utah ThermH2 Phase 2 – up to 5% hydrogen blends to the live system of Delta and surrounding areas of Hinckley, Oasis and Deseret, serving approximately 1,800 customers
- HyDeploy Phase 1 Keele University (England) – up to 20% hydrogen blending into the University's existing natural gas network, feeding 100 homes and 30 faculty buildings
- HyDeploy Phase 2 Winlaton (England) – up to 20% hydrogen blending into homes in the village of Winlaton near Gateshead

- ATCO Gas (Canada) – 5% hydrogen blending into a subsection of the Fort Saskatchewan natural gas distribution system, serving about 2,100 customers. Planning to increase hydrogen blending to 20%.
- ATCO Gas (Australia) – 2% to 5% hydrogen blending into a portion of the natural gas distribution network around Calleya Estate, Treeby Estate and Glen Iris within the City of Cockburn, serving about 2,700 customers. Planning to increase hydrogen blending to 10%.
- Enbridge (Canada) – 2% hydrogen blend serving about 3,600 Enbridge Gas customers in Markham
- Hydrogen in natural gas on Ameland (Netherlands) – up to 20% hydrogen blends in the current existing Dutch natural gas distribution network
- Netze BW (Germany) – 8% to 30% hydrogen blends to households heating in town of Oehringen
- GRHYD France – up to 20% for a new 100-home including space heating, water heating and fuel
- Hydrogen Park South Australia – 5% renewable gas blend to more than 4,000 gas customers in Adelaide's south in the suburbs of Mitchell Park, Clovelly Park and parts of Marion, including households, businesses and schools

Safety Risk Analysis

Once the application is approved by the CPUC, SoCalGas will continue efforts to create detailed engineering designs for this project. There are multiple efforts planned for the project design to identify potential hazards and determine appropriate mitigative measures. To promote independent and impartial review, SoCalGas will hire experienced third-party engineering firms to conduct a minimum of three safety studies. SoCalGas subject matter experts along with third-party industry experts will participate in these risk assessments. SoCalGas welcomes experts at UCI participating in these safety reviews to provide engineering design and safety protocol input in every critical step of the design process.

- At the 30% engineering design phase two different safety analyses will be performed:
    - A Hazard Identification (HAZID) in which stakeholders will work with a third-party to identify any hazards that exist at the facility. External stakeholders will have the opportunity to participate, comment on mitigative measures, and review the documented design considerations.
    - A Quantitative Risk Assessment (QRA) will be performed by a third-party that specializes in risk assessments with hydrogen systems to provide a holistic system evaluation.
        - External stakeholders will participate in the QRA and review all the recommendations.
- An additional safety analysis will be conducted at the 60% engineering design phase:
    - A Hazard Operability Study (HAZOP) will be conducted, by the same third-party that performs the HAZID. This is intended as a more in-depth version of the HAZID and includes how the site will be operated. An exhaustive review of hazards will be evaluated at the site to determine how these risks will be managed.

SoCalGas would propose to do this work with firms/organizations such as:

- DNV-GL's process safety and hydrogen group - https://www.dnv.com/
- GTI / EPRI's – H2Edge Initiative - https://hydrogen.epri.com/en/h2edge.html

- WHA International - https://wha-international.com/ (part of the Center for Hydrogen Safety - https://www.aiche.org/chs)

The final site design must take into consideration all the items identified in the three risk assessments (HAZID, QRA, and HAZOP).

In addition to the scoping and engineering risk assessment, independent third parties will be engaged during the pre-commissioning process to review final design and commissioning safety protocols with SoCalGas and UCI facilities personnel (Pre-Startup Safety Review (PSSR)).

Pipeline Integrity Safety

SoCalGas will be injecting natural gas with a 5-20% by volume hydrogen blend into the ARC. SoCalGas will be installing new 3" steel distribution piping to connect into the existing 3" plastic pipe. The pipeline will be operating at pressures of 45 psig or less (approximately 1% of the specified minimum yield strength of the steel). There will be multilayer safety systems in place on the blending skid to mitigate the risk of overpressure. The net effect of a new steel pipeline manufactured to modern quality control standards combined with a minimal operating stress state will reduce the impact of material embrittlement to a negligible level, and this will be demonstrated as part of the comprehensive QRA.

Additionally, delivery pressure into the ARC facility is regulated down to 5 psig (an even smaller fraction of the specified minimum yield strength of the piping materials) at the meter set assembly. The existing plastic pipeline feeding into the ARC is leak tested annually by SoCalGas with the most recent survey conducted in April 2023, and the next survey scheduled for Q2 2024. SoCalGas publishes its leak/emissions data at the website below:

- Background: Methane Emissions Map | SoCalGas
- Map: Methane Emissions Map | SoCalGas

Additionally, SoCalGas has developed safety measures to be implemented before, during, and after the demonstration project on the UCI campus. These efforts include, but are not limited to:

- **Hydrogen Safety Education for personnel**: SoCalGas will work with local fire department and/or campus staff to provide educational briefings for hydrogen safety procedures, as needed.
- **Conduct pre-, during, and post-implementation leak surveys:** SoCalGas will conduct pre-injection leak surveys to confirm the system is free of any leakage. And after the introduction of hydrogen, SoCalGas will perform monthly leak surveys, which is 12 times the normal protocol of leakage inspection.
- **Mitigation measures to prevent hydrogen or hydrogen blends from reaching other areas:** The pipeline system will be isolated in a manner that only the UCI ARC building receives the hydrogen/natural gas blend. The supply of hydrogen blended gas to appliances occurs in the same manner as natural gas.
- **Create hydrogen blending specific customer protocols and emergency response plans**: SoCalGas will work with UCI to develop and tailor any emergency response plans.

Leak Detection and Process Safety

SoCalGas will be taking a proactive and conservative approach to safety and leak detection. There will be continuous monitoring of the process/production area, and within and around the ARC. Gas leak inspection of the pipeline will occur at least monthly if not more, twelve times more frequently than required by Title 49 of the Code of Federal Regulations § 192.723.

- **In the process area:**
  - SoCalGas will install leak detection equipment to completely monitor the production/blending facility. The gas detectors will be continuously monitoring the system for hydrogen, natural gas, and blended gas. If an alarm is triggered for a gas leak, the system will go into a shutdown mode, isolating equipment, stopping hydrogen production and returning the pipeline system to 100% natural gas. SoCalGas will be alerted immediately and will send out a technician to the site to fully remedy the issue before putting the site back into service.
- **On the pipeline:**
  - SoCalGas currently monitors the gas pipeline system at UCI annually. For this project, SoCalGas technicians will conduct leak surveys upon the introduction of hydrogen, and subsequently increase their pipeline leak detection activities to a monthly basis thereafter for the duration of the project. Leak surveys will also be performed prior to the introduction of hydrogen to confirm the pipeline is free of leakage before any hydrogen is introduced into the system. In addition to the added leak surveys, the blended gas will still contain an odorant that will make it easily detectable by smell if a leak were to occur. The public can report a gas leak in the area the same way that they do today.
- **In the ARC:**
  - SoCalGas will install leak detection equipment for indoor areas where end-use equipment is located. This equipment will have an audible alarm to alert ARC personnel. In addition, SoCalGas can remotely monitor this equipment if agreed to by UCI. SoCalGas will inspect end-use equipment to confirm there is no leakage prior to the introduction of hydrogen, as well as regularly communicate with UCI staff on equipment conditions. SoCalGas will perform leak and operational tests monthly to confirm the gas system and equipment are operational and free of leakage.

Equipment Safety Research

SoCalGas has been blending hydrogen to fuel equipment and appliances at its Engineering Analysis Center and Training Facility in Pico Rivera, California for decades. As part of that testing, technicians have been measuring the performance of stoves, heaters, and forced-air furnaces fueled with a blend of hydrogen and natural gas. Current results of testing appliances show that they are compatible with up to a 20% hydrogen blend. SoCalGas' findings are consistent with international research and lab testing.

- **More information about SoCalGas' results on hydrogen blending can be found here:** SoCalGas Among First in the Nation to Test Hydrogen Blending in Real-World Infrastructure and Appliances in Closed Loop System | SoCalGas Newsroom

In addition to household equipment, in 2021, SoCalGas conducted an evaluation of hydrogen-natural gas blending impacts (5, 10, 20 vol% H2) on commercial cooking appliances, including convection ovens, fryers, griddles, and underfired broilers.

Further, GTI Energy has studied the impact of 0–30% hydrogen blends by volume on the performance, emissions, and safety of unadjusted equipment in a simulated use environment, focusing on prevalent partially premixed combustion designs. The equipment was successfully operated with up to 30% hydrogen-blended fuels.

- **The report is publicly available here:** Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NOx Emission and Operational Performance

A study conducted by UCI assessed the impact of hydrogen injection into the natural gas pipeline infrastructure in a residential commercial oven burner. The evaluation covered various combustion performance aspects, including flashback limits, ignition performance, flame characteristics, combustion noise, burner temperature, and emissions (NO, NO2, N2O, CO, UHC, NH3). The findings suggest that adding 25% hydrogen to natural gas has minimal impacts.

- **The report is publicly available here:** Experimental assessment of the combustion performance of an oven burner operated on pipeline natural gas mixed with hydrogen - ScienceDirect

Finally, in addition to these studies, SoCalGas commissioned the [H2] Innovation Experience where we are blending up to 20% hydrogen into unmodified natural gas appliances including a range, tankless water heater, clothes dryer, barbeque, and an indoor and outdoor fireplace. The project was commissioned in January 2023 and has been operating at a 20% blend since that time. There have been no operational or efficiency issues with the appliances due to the introduction of the 20% blend.

- **More information about the SoCalGas [H2] Innovation Experience can be found here:** https://www.socalgas.com/sustainability/h2home

For the proposed UCI project, SoCalGas will have customer service technicians perform monthly operations and leak tests on all the gas appliances at the ARC. This includes testing of the appliances before hydrogen blending is introduced and while hydrogen blending occurs to ensure that the equipment is operating as it should. Testing the appliances monthly ensures that the appliances are checked throughout the hydrogen blending demonstration and whenever the hydrogen blending percentage is increased.

Data Collection

Various pieces of data will be collected to promote safety throughout the course of the demonstration project, as well as to provide meaningful data toward any impacts of blending hydrogen into live natural gas distribution systems. Below are various data points that are expected to be gathered through the course of the project life cycle:

Area	Objective	Frequency	Pre-Demo	During Demo	Post-Demo
Odorant sampling	Confirm hydrogen does not affect efficacy of current natural gas odorant	Monthly	✓	✓	
Leak surveys	Safety checks; repair any leaks prior to starting demo; determine if hydrogen blends affect leakage from fittings, valves, etc.	Monthly; And as needed for customer service calls	✓	✓	✓
Leak survey equipment	Evaluate performance of new leak survey equipment	Monthly; And as needed for customer service calls		✓	
Heating Value Measurement	Monitor and Analyze changes to heating value of gas supplied	Monthly	✓	✓	
Customer meters	Compare data from customer meters and blending skid data to evaluate accuracy	Monthly		✓	✓
Customer equipment evaluation	Confirm equipment is working properly; validate gas interchangeability	Monthly; And as needed for customer service calls	✓	✓	✓
Customer equipment checks for emissions	Perform measurement on emissions from heating and cooking equipment	Monthly	✓	✓	

Joint IOU Projects

Below is a snapshot of the projects that will be included in the application to the CPUC, including those from the other Joint Utilities. What makes the project at UCI different from the projects proposed is the mixed material of the pipeline system.

Utility	Pilot Location	Material	Blend %	End Use	Notes
SoCalGas	UC Irvine	Mixed (Steel & Plastic),Distribution	5-20%	Anteater Recreation Center	Isolated pipeline system, Coastal climate
SoCalGas	City of Orange Cove	Plastic, Distribution	0.1-5%	2,000 Residential meters, 85 Commercial	Blend into an "open portion" of SoCalGas distribution system
SDG&E	UC San Diego	Polyethylene plastic (PE), Distribution	5-20%	UCSD Fuel Cell System	Isolated pipeline system, Coastal Climate
Southwest Gas	Truckee, CA	Polyethylene plastic (PE), Distribution	5-20%	Select end users in Truckee	Isolated pipeline system, High elevation and extreme cold conditions
PG&E	Lodi, CA	Steel, Transmission	5-20%	N/A	Isolated transmission level blending

Memorandum of Understanding (MOU) and Final Agreement

In August 2022, SoCalGas and UCI signed a non-binding MOU to conduct the H2 blending project at another on-campus location. The MOU was attached to the H2 Blending Application filed with the CPUC in Sep. 2022. The MOU provides that SoCalGas and UCI would collaborate on the proposed H2 blending project, which depends on the CPUC's approval. A revised MOU was prepared noting the ARC as the new location, and it is pending UCI's signature. If approved, SoCalGas and UCI would later negotiate a binding agreement based on mutually acceptable terms and conditions. Such terms would include indemnity provisions that would address liability in case there is an event or condition that damages UCI's equipment.

Appendix

Project Process and Schedule

Below is a proposed sequence and schedule of events for the regulatory process and necessary technical reviews for the project to unfold. Please note that these dates are estimates, and many of these dates will be greatly impacted by the time it takes the CPUC to review and approve the project submissions.

Pre-Filing- Activities up to March 2024

- Preliminary Project Scope Preparation (completed)
    - With Input from UCI facilities and engineering
    - 10% engineering design
    - Stakeholder Engagement
- Amended Application Preparation
    - Executing Memorandum of Understanding (MOU) with UCI on revised project proposal
    - SCG Executive Review Pre-Filing

Application Filing – March 1, 2024

CPUC Review and Intervenor Comments Period - 12-18 Months

Post-Approval Activity

Phase 1 [Planning, Design, Construction, and Commissioning] - 12-18 Months

- Contract Negotiations with UCI
    - Negotiate Indemnification Provisions
- Preliminary Engineering Design
    - 30 % Engineering Design Package
        - Leak detection and full analysis of the existing UCI pipeline
        - QRA
        - HAZID
- Detailed Engineering Design
    - 60% Engineering Design Package
        - HAZOP
        - Develop Emergency Response Plan with UCI
    - 90% Engineering Design Package
        - Review design with all safety assessments
    - Issued for Construction (IFC) Package
- Construction
    - Fire Marshall Review
- Commissioning
    - Conduct Pre-Startup Safety Review (PSSR)
    - Fire Marshall Approval

Phase 2 [Demonstration] - 18 months

- Asset Inspection
    - Baseline the demonstration area (end use equipment and pipeline system) with natural gas with 3 months prior to introduction of hydrogen to check if systems are operational and free of leakage

- Blending Demonstration and Data Collection
    - Blend from 5% hydrogen to 20% hydrogen, increasing blend percentages as SoCalGas checks for safety and collects data

- Asset Validation
    - End of demonstration inspection

Phase 3 [Decommissioning] - 6 months

- Restore site to its original state

Phase 4 [Data Analysis and Results] - 9 Months

- Independent Review of Data
- Report development

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EXHIBIT I

Draft 3
Dec 26/2023

Questions for Jack Brouwer

1. Prior to any beta testing, it is standard practice that an in depth study is conducted to ensure that a feasibility study has been carried out addressing the main issues of concern. In this regard, was a study carried out studying the blending of hydrogen 5% and up to 20% in a variety of different steel pipes, and specifically with the pipes that are installed in ARC?

2. What is the state of the pipes in ARC now? Has a thorough inspection been conducted for leakage and integrity before even getting into the question of using it as a test site?

3. Hydrogen embrittlement is an issue in steels. What insurances are provided that the pipes will not be degraded and fail due to hydrogen embrittlement?

4. Hydrogen gas is a small molecule compared to other gaseous molecules. What assurances are taken to address the propensity of hydrogen leakage in existing ARC infrastructure/pipes that have been built years ago without hydrogen in mind?

5. The SoCal gas plan is to blend 5 - 20% H2 into the natural gas pipeline supplying the Anteater Recreation Center (ARC). The 2022 UCR CPCU study (https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-issues-independent-study-on-injecting-hydrogen-into-natural-gas-systems) advises caution for H2 added above 5%. From their report:
    a. "Hydrogen blends of up to 5 percent in the natural gas stream are generally safe. However, blending more hydrogen in gas pipelines overall results in a greater chance of pipeline leaks and the embrittlement of steel pipelines."
    b. "Hydrogen blends above 5 percent could require modifications of appliances such as stoves and water heaters to avoid leaks and equipment malfunction."

6. Question: In advance of the start of this study, will the equipment in ARC, and the connecting pipes, be tested to ensure compatibility with H2 mixing ratios above 5%?

7. Is it anticipated that "modifications" to the equipment in ARC, mentioned in this report, will be required?

8. Who external entity would monitor and report (to whom?) any issues as the project evolves? How is the increase from 5% to up to 20% be decided and what is the safety/decision protocol?

9. What is there for UCI to be a test site? Research advances or just collecting data for SoCalGas?

10. What are the other 5 test sites mentioned in the project summary? It would be good to know what other universities/entities have agreed to be a "test site" for this project.

11. Has a response to the letter been prepared and submitted?

EXHIBIT J

Draft 2
Jan 15 2024

Questions for SoCal

1. What is the state of the pipes in ARC now? Has a thorough inspection been conducted for leakage and integrity before even getting into the question of using it as a test site?

   How can we even talk about this beta testing, if the pipes at ARC and possible leakage have not been already assessed to start with? When will this be done and who (independent agent) will oversee this?

   Question: In advance of the start of this study, will the equipment in ARC, and the connecting pipes, be tested to ensure compatibility with H2 mixing ratios above 5%?

2. Hydrogen embrittlement is an issue in steels. What insurances are provided that the pipes will not be degraded and fail due to hydrogen embrittlement?

Studies have shown serious concerns about embrittlement of steel pipes (like in ARC) above 5% hydrogen. How will the plan to go from 5% to 20% be decided, who will monitor impacts (independent agency?), to whom these will be reported?, and who will be liable and pay for any damage to equipment (heating, cooking) and other risks?

SEE:

"Natural gas has been a pathway for our nation's energy independence; it is our nation's abundant energy source, 32.1% compared to solar at 1.04% and wind at 2.74% [2]. We depend on about 2 million miles of gas pipelines for distribution of our natural gas throughout the nation. Unfortunately, 3% of these pipes as well as in gathering systems are legacy pipes in that they are made of either cast or wrought iron pipes (60,000 miles long installed in the early 1800's), and about 100,000 miles of bare steel pipes, which were installed in the 1930's [3, 4]. Moreover, of all the leaks and failures that occur in gas pipelines, a disproportionate number occur in the legacy pipes. Though some of the legacy pipes have been replaced over time at great cost, there still remains over 20,000 miles of cast and wrought iron pipes, and about 40,000 miles of bare steel pipes [5]. This aging infrastructure creates a significant safety issue as well as an economic challenge. Excavating and restoring legacy pipes are not cost-effective; the solution needs to be an intelligent engineered approach to full-scale gas pipeline inspection, rehabilitation, and validation. "
From D. Apelian – proposal to DOE titled REPAIR.. authred by D. Apelian et al 2021

[3] Office of Energy Policy and Systems Analysis, "Natural Gas Infrastructure Modernization Programs at Local Distribution Companies: Key Issues and Considerations," Washington, DC 20585, 2017.
[4] "Cast and Wrought Iron Inventory | PHMSA." [Online]. Available: https://www.phmsa.dot.gov/data-and-statistics/pipeline-replacement/cast-and-wrought-iron-inventory. [Accessed: 02-May-2020].
[5] "Bare Steel Inventory | PHMSA," 2020. [Online]. Available: https://www.phmsa.dot.gov/data-and-statistics/pipeline-replacement/bare-steel-inventory. [Accessed: 02-May-2020].

3. Why are we doing this on a university campus and not at a site that excludes human beings... an industrial site without personnel on site?

4. The SoCal gas plan is to blend 5 - 20% H2 into the natural gas pipeline supplying the Anteater Recreation Center (ARC). The 2022 UCR CPCU study (https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-issues-independent-study-on-injecting-hydrogen-into-natural-gas-systems) advises caution for H2 added above 5%. From their report:
    a. "Hydrogen blends of up to 5 percent in the natural gas stream are generally safe. However, blending more hydrogen in gas pipelines overall results in a greater chance of pipeline leaks and the embrittlement of steel pipelines."
    b. "Hydrogen blends above 5 percent could require modifications of appliances such as stoves and water heaters to avoid leaks and equipment malfunction.

5. Who external entity would monitor and report (to whom?) any issues as the project evolves? How is the increase from 5% to up to 20% be decided and what is the safety/decision protocol?

6. What are the other 5 test sites mentioned in the project summary? It would be good to know what other universities/entities have agreed to be a "test site" for this project.

EXHIBIT K

Questions for Jack Brouwer

1. Prior to any beta testing, it is standard practice that an in depth study is conducted to ensure that a feasibility study has been carried out addressing the main issues of concern. In this regard, was a study carried out studying the blending of hydrogen 5% and up to 20% in a variety of different steel pipes, and specifically with the pipes that are installed in ARC?
    a. The current pipes that that deliver natural gas to the ARC are plastic and are known to be able to safely deliver hydrogen in the 5% to 20% range. SoCalGas will install a new steel pipe from the production site to the current plastic pipe that serves the ARC. The feasibility of using both of these sets of pipeline materials in this range of hydrogen concentrations has been thoroughly studied and proven feasible in other jurisdictions (e.g., Hawaii gas network which has been distributing 12-15% hydrogen through its system for more than 50 years). Additionally, should the project be approved by the CPUC, SoCalGas will conduct various hazard analyses performed by an independent third party during the detailed engineering design phase to identify potential hazards for the specific project scope. I expect that UCI experts, like those in the Clean Energy Institute, will be able to work with the independent third party and SoCalGas to review, critique, and contribute to the evaluation.

2. What is the state of the pipes in ARC now? Has a thorough inspection been conducted for leakage and integrity before even getting into the question of using it as a test site?
    a. While leakage and integrity of the pipes in the ARC are good and safe for delivering natural gas, a thorough special inspection for this hydrogen injection project has not yet been conducted. The team plans to conduct a thorough inspection for leakage and integrity of all pipes and equipment in the ARC prior to implementing any new infrastructure or injecting any hydrogen.

3. Hydrogen embrittlement is an issue in steels. What insurances are provided that the pipes will not be degraded and fail due to hydrogen embrittlement?
    a. Correct. Hydrogen does embrittle many types of pipeline steels. Note that the phenomena of embrittlement and enhanced fatigue crack growth rate occurs most rapidly under circumstances of high pressures and pressure fluctuations (dynamics) that are not present in the current parts of the natural distribution system in question. These conditions are mostly present in the natural gas transmission system. In addition, the period of time for this demonstration (2 years) is very short compared to the durations required for embrittlement. The

distribution pipeline will be operating at pressures of 45 psig or less, which is approximately 1% of the specified minimum yield strength of the steel. Note also that the existing pipes serving the ARC are plastic. Pipes within the ARC building itself are steel and will be evaluated for any impacts on leakage that hydrogen injection may induce. In addition, SoCalGas has stated that they will agree to standard University of California indemnification and insurance terms and conditions language in the contract that will govern the project implementation at UCI. These terms and conditions will be negotiated at a later date; however, they should produce appropriate assurances and insurance to replace any infrastructure that may be damaged in the demonstration project.

4. Hydrogen gas is a small molecule compared to other gaseous molecules. What assurances are taken to address the propensity of hydrogen leakage in existing ARC infrastructure/pipes that have been built years ago without hydrogen in mind?
    a. There will be extra monitors installed and operated and special measurements taken throughout the ARC and near all infrastructure delivering blends to the ARC for the entire duration of the demonstration project. For example, SoCalGas will install leak detection equipment for indoor areas where end-use equipment is located. Also, SoCalGas will install continuous and remote monitoring surrounding the hydrogen production, storage, and blending equipment. Lastly, SoCalGas will perform leak surveys of the distribution line (upstream of the ARC meter) and within the ARC on a monthly basis to regularly check for leakage.
    b. Yes, under some circumstances, hydrogen can leak faster than methane (e.g., during fully developed laminar or turbulent flow and by diffusion). On the other hand, recent research suggests that low pressure natural gas infrastructure leaks hydrogen at the same rate as it leaks methane (https://www.sciencedirect.com/science/article/pii/S0360319919347275). Regardless of whether hydrogen will leak faster than methane, the extra monitoring that will be accomplished should lead to greater safety margins. In addition, measurements with best available measurement technology to assess whether leakage in concentrations much lower than those of interest for safety reasons (e.g., those that can be used for climate impacts assessment) will be included in the demonstration project.

5. The SoCal gas plan is to blend 5 - 20% H2 into the natural gas pipeline supplying the Anteater Recreation Center (ARC). The 2022 UCR CPCU study (https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-

issues-independent-study-on-injecting-hydrogen-into-natural-gas-systems) advises caution for H2 added above 5%. From their report:

   a. "Hydrogen blends of up to 5 percent in the natural gas stream are generally safe. However, blending more hydrogen in gas pipelines overall results in a greater chance of pipeline leaks and the embrittlement of steel pipelines."

   b. "Hydrogen blends above 5 percent could require modifications of appliances such as stoves and water heaters to avoid leaks and equipment malfunction."

6. Question: In advance of the start of this study, will the equipment in ARC, and the connecting pipes, be tested to ensure compatibility with H2 mixing ratios above 5%?
   a. Some of the equipment at the ARC has already been tested in the UCI Combustion Laboratory (UCICL) for mixtures up to 100% hydrogen. The plan is to test all of the equipment at the ARC in the UCICL laboratory setting for concentrations of hydrogen in the demonstration project range (5% - 20%) and higher before the demonstration project begins.

7. Is it anticipated that "modifications" to the equipment in ARC, mentioned in this report, will be required?
   a. It is anticipated that no (zero) modifications to the equipment in the ARC, mentioned in this report, will be required. This expectation is based upon measurements at the UCICL that show no adverse performance impacts (or safety concerns) for all equipment at concentrations up to 50% hydrogen mixed with natural gas.

8. Which external entity would monitor and report (to whom?) any issues as the project evolves? How is the increase from 5% to up to 20% be decided and what is the safety/decision protocol?
   a. I do not know who SoCalGas may contract with to independently monitor the safety and impacts of the project, but, I understand that SoCalGas is required by the CPUC to contract with an independent third party to gather data collected and disseminate results accordingly. The independent third party will be selected after the CPUC application is approved. Over the years SoCalGas has engaged (contracted with) several independent contractors, experts and researchers to assure safety and performance in many hundreds of projects. I do not know to whom (besides those required by the CPUC) the independent entity would report. I suggest that they should report to the UCI Provost office and include reporting to energy experts on campus (e.g., those of us in the Clean Energy Institute) for independent review and evaluation.

9. What is there for UCI to be a test site? Research advances or just collecting data for SoCalGas?
    a. UCI is currently recognized for its leadership in advancing the science, engineering and implementation of renewable and clean hydrogen energy solutions. The implementation of this demonstration project on our campus will enhance and build upon this reputation. In addition, we will be able to evaluate the project, acquire data, analyze data, compare to models and publish papers that will be some of the first in the world to analyze such. Most importantly, every objective analysis for decarbonizing and depolluting everything has identified important roles for hydrogen for which there is no known alternative (e.g., shipping, aviation, steel). These hydrogen demands will require delivery via pipeline systems to achieve the necessary costs for widespread use. Our demonstration project will provide early information and results necessary for technologists and policy makers to do the work necessary to enable such hydrogen use.

10. What are the other 5 test sites mentioned in the project summary? It would be good to know what other universities/entities have agreed to be a "test site" for this project.
    a. I know that one of project test sites is a San Diego Gas and Electric (SDG&E) project on the University of California San Diego campus and another one is a Pacific Gas and Electric (PG&E) project in the Stockton/Lodi area, which is a closed loop transmission pipeline. SoCalGas will also be performing a demonstration of up to 5% hydrogen blends in an open portion of the distribution system in the City of Orange Cove. Lastly, Southwest Gas will be performing a demonstration of 5-20% hydrogen blends in a portion of their distribution system in the city of Truckee, which will provide data on blending hydrogen at high elevations and cold climates.

11. Has a response to the letter been prepared and submitted?
    a. Several workshops have been conducted in which I (Jack Brouwer) have responded to concerns, for example, from our UCI students (in a special ASUCI meeting that included a discussion of this demonstration project), responded to concerns by discussions with some of the signatories of the letter, discussed the project in a City of Irvine City Council meeting, and discussed the project and hydrogen features and regional hydrogen hub project in a separate meeting with staff from the City of Irvine.