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California Energy Commission
Commissioners Karen Douglas and Andrew McAllister
1516 9th St
Sacramento, CA 95814
Docket Number 21-IEPR-05

RE: Pacific Gas and Electric Company Comments on the Integrated Energy Policy Report (IEPR) Commissioner Workshop on Hydrogen to Support California's clean Energy Transition (Docket Number 21-IEPR-05)

Dear Commissioner McAllister and Commissioner Douglas:

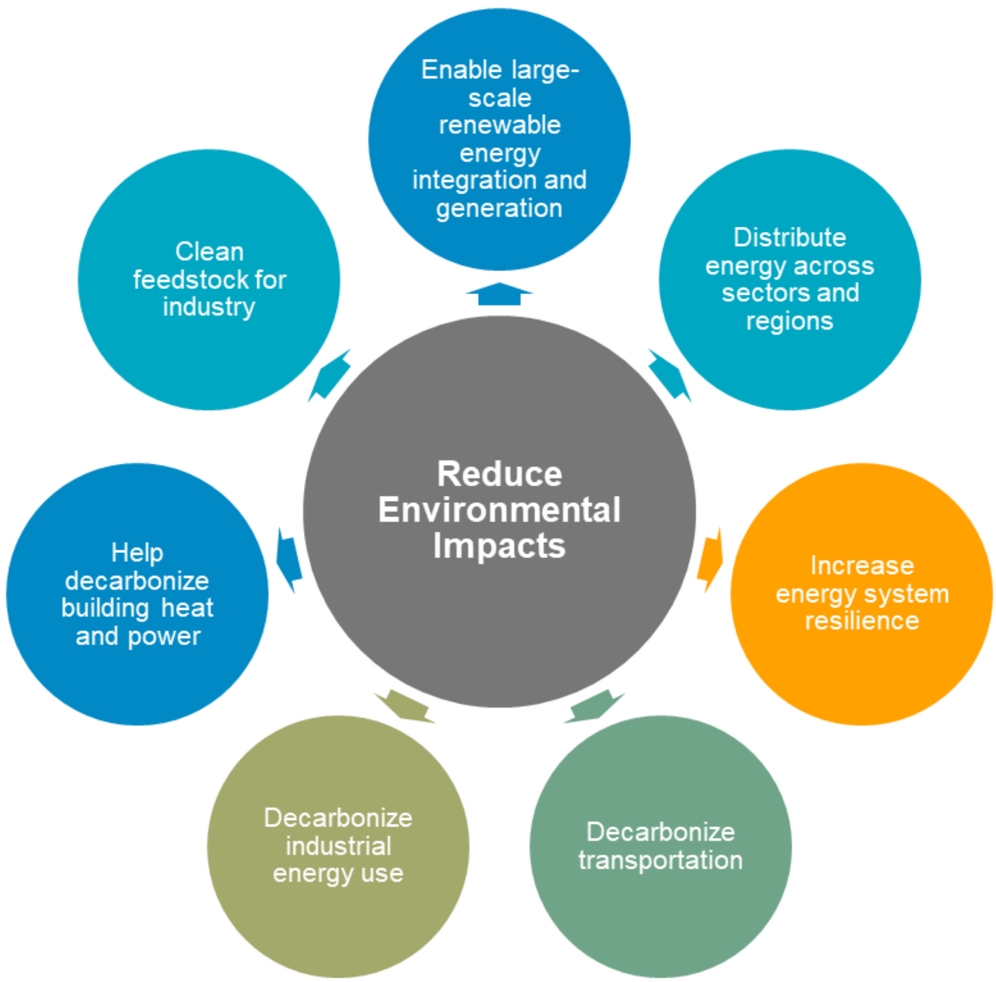
Pacific Gas and Electric Company (PG&E) appreciates the opportunity to comment in response to the California Energy Commission's (CEC) 2021 Integrated Energy Policy Report (IEPR) Commissioner workshop on hydrogen to support California's clean energy transition held on July 28, 2021.

PG&E applauds the CEC's efforts in organizing this workshop. The presentations were well delivered and represented a good mix of information about the hydrogen economy both domestically and internationally. PG&E is submitting these comments to expand the CEC's awareness of our progress with hydrogen. We also invite the CEC staff and other stakeholders to review PG&E's renewable natural gas (RNG) and hydrogen research and development (R&D) roadmap, which includes a high-level overview of the R&D work that PG&E is participating in related to the production of hydrogen, the transportation of it using the natural gas system, and the utilization of hydrogen by customers.

Role of Hydrogen in the Energy Sector

PG&E believes hydrogen will play a critical role in California's decarbonized future. PG&E sees hydrogen as one piece of a multi-faceted solution that incorporates many technologies using both clean electrons and molecules to meet the State's greenhouse gas (GHG) emission reduction targets and make a meaningful impact toward climate change.

Figure 1 Role of Hydrogen in Energy Transition



As shown in Figure 1, hydrogen has the potential to reduce environmental impacts in a multitude of ways. Specifically, hydrogen may contribute to the energy sector in the following ways:

1. Decarbonize the gas system;
2. Supply hard-to-electrify sectors to reduce their carbon footprint;
3. Enable large-scale renewable energy integration and generation;
    - Power to Gas (P2G) is a mechanism to capture and store renewable electricity integrating the existing electric and gas systems;
    - Long duration storage technologies, such as electrolysis and underground storage of hydrogen, could potentially provide storage for long-term seasonal storage of currently curtailed renewable electricity;
4. Distribute energy across sectors and regions;
    - Hydrogen can be transported and distributed across various sectors and regions to supply energy/fuel for multiple purposes (industrial, transportation, electric generation, etc.);
    - The natural gas system provides existing infrastructure that can be leveraged to transport and distribution;

5. Increase energy system resilience;
    - Hydrogen provides an opportunity for long-duration storage beyond the capabilities of batteries and hydro and pumped air storage;
    - Storing energy as hydrogen will improve resilience through the seasons by shifting supply from one season to another.

Leveraging the Natural Gas System

PG&E's natural gas system is a significant part of California's energy ecosystem and there is benefit in leveraging the gas system in the clean energy transition. PG&E's gas system is an existing pipeline infrastructure with sufficient capacity to meet the energy needs in PG&E's service territory. On an annual basis, the natural gas system delivers 3.5 times the energy compared to the electric grid and is an excellent way to store energy for both gas and electric fuel sources.

In addition to decarbonizing the gas system, blending hydrogen with natural gas in the natural gas system is one of many promising innovations that could enable PG&E and other companies to offer hard-to-electrify sectors ways to reduce their carbon footprint. Once downstream, the hydrogen could be separated out from the natural gas to be used as fuel for vehicles for transportation purposes or remain as a blend to be delivered to end-use customers.

Using hydrogen in this way allows us to leverage the nature of our integrated natural gas and electric business to explore several applications for hydrogen as part of California's push to achieve carbon neutrality by 2045 and reduce greenhouse gas (GHG) emissions by 80% from 1990 levels by 2050.

The development of a California hydrogen injection standard depends on closing gaps in knowledge about the impact of blends of hydrogen and natural gas on the gas system transmission assets, whose safety, integrity, and reliability are essential to deliver power. PG&E's hydrogen R&D roadmap is in its early stages and we will continue to support R&D around the impact of hydrogen-natural gas blends on gas system assets and customer equipment. This includes limitations on the amount of hydrogen that can be blended into the system and modifications needed to ensure the safety, integrity, and reliability of the gas system. A few examples of PG&E's R&D work in progress is attached for CEC's awareness. PG&E would welcome a conversation with the CEC to discuss these projects and the hydrogen R&D roadmap.

PG&E plans to continue efforts to inform the California Public Utilities Commission (CPUC) and stakeholders on an appropriate hydrogen injection standard that will shape how the utilities' pipeline systems use hydrogen in the Biomethane Rulemaking (R.13-02-008), despite the Joint IOU's application A.20-11-004 (filed on November 20, 2020 regarding hydrogen-related additions or revisions to the Standard Renewable Gas Interconnection Tariff) being dismissed by the CPUC in July 2021.

Emissions Reduction Potential for the Natural Gas System

Table 1 below provides the carbon dioxide emissions reduction potential for PG&E's natural gas system. Hydrogen's lower heating value is 244 kilo joules per molecule (kJ/mol). Natural gas is composed primarily of methane and methane's lower heating value is 802 kJ/mol, which is about 3.3 times larger compared to hydrogen. Consequently, the methane emissions reduction is equal to the amount of blended hydrogen divided by 3.3. This number is then converted into carbon dioxide equivalent.

On the other hand, blending hydrogen in natural gas reduces the head loss by friction allowing faster flows in our pipelines to compensate for the reduction of energy per unit of volume. However, leveraging this property would require important modifications of our compression facilities so it is not considered here.

Table 1 Carbon Dioxide Emissions Reduction Potential for the Natural Gas System[1]

			5%	10%	20%	50%	80%	100%	Amount of H2 injected
			1.52%	3.04%	6.08%	15.21%	24.34%	30.42%	Reduction of methane for same energy
Category	**2020 Emission Total (Mscf)**	**2020 Emission Total (MT CO2eq)**	**Emission Reduction impact by injecting hydrogen (MT CO2eq)**						
Transmission Pipeline	164038	73687.54	72566.61	71445.67	69203.81	62478.21	55752.62	51268.89	
Transmission M&R Stations	634065	284828.45	280495.65	276162.85	267497.24	241500.43	215503.62	198172.41	
Transmission Compressor Stations	86527	38868.81	38277.54	37686.27	36503.72	32956.10	29408.47	27043.39	
Distribution Pipeline	537339	241378.15	237706.31	234034.47	226690.80	204659.78	182628.75	167941.41	
Distribution M&R Stations	9703	4358.69	4292.38	4226.08	4093.47	3695.64	3297.82	3032.60	
Meter Set Assemblies	250607	112575.22	110862.72	109150.23	105725.25	95450.31	85175.36	78325.40	
Underground Storage Facilities	98268	44142.99	43471.48	42799.98	41456.98	37427.97	33398.96	30712.95	
Total	**1780547**	**799839.84**	787672.70	775505.56	751171.28	678168.44	605165.60	556497.04	
			12167.14	**24334.28**	**48668.56**	**121671.40**	**194674.23**	**243342.79**	**Emission Reduction (MT CO2eq)**

Electric System Evolution and the Use of Hydrogen for Increased Reliability and Resiliency

PG&E's electric system is also an essential part of California's energy ecosystem and continues to evolve to help support the transition to clean energy. Part of this evolution could include the use of hydrogen to increase resiliency and reliability in the electric grid. Locating large-scale electrolytic hydrogen production in regions with excess renewable electricity could provide an opportunity to leverage the cheaper renewable production that would otherwise be curtailed.

PG&E's electric portfolio in 2020 procured 31% renewable electricity and 84% GHG-free electricity (as shown in Figure 2 below). As the portfolio of renewable electricity increases over time, there will be greater opportunity to use excess renewable energy sources within PG&E's service territory for electrolytic hydrogen production.

[1] The 2020 emission total (mscf) data is from the 2021 Natural Gas Leak Abatement Emissions Report

Figure 2 PG&E 2020 Power Source Disclosure Annual Report[2]

2020 POWER SOURCE DISCLOSURE ANNUAL REPORT SCHEDULE 3: POWER CONTENT LABEL DATA For the Year Ending December 31, 2020 Pacific Gas and Electric Company Base Plan		
Instructions: No data input is needed on this schedule. Retail suppliers should use these auto-populated calculations to fill out their Power Content Labels.		
	Adjusted Net Procured (MWh)	**Percent of Total Retail Sales**
Renewable Procurements	10,949,002	30.6%
Biomass & Biowaste	936,029	2.6%
Geothermal	919,982	2.6%
Eligible Hydroelectric	436,466	1.2%
Solar	5,680,204	15.9%
Wind	2,976,322	8.3%
Coal	-	0.0%
Large Hydroelectric	3,636,234	10.1%
Natural gas	5,892,170	16.4%
Nuclear	15,349,591	42.8%
Other	-	0.0%
Unspecified Power	-	0.0%
Total	**35,826,997**	**100.0%**
Total Retail Sales (MWh)		35,826,997
GHG Emissions Intensity (converted to lbs CO_2e/MWh)		160
Percentage of Retail Sales Covered by Retired Unbundled RECs		2.0%

California currently has regions of renewable electricity production that is being curtailed during certain times of the year; more than 1,500 Gigawatts hour (GWh) of renewable electricity was curtailed in 2020.[3] With the installation of solar and wind production projected to increase significantly over the next decade, solutions to smooth out the intermittent production of these energy resources will need to be implemented. Given that, there is an opportunity to create affordable zero-carbon hydrogen when

[2] 2020 Power Source Disclosure Annual Report for year ending December 31, 2020 filed to the California Energy Commission June 1, 2021.
[3] CAISO curtailment history: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx

renewable production prices drop, and renewable production exceeds the electric grid demand and energy storage capacity.

In PG&E's bundled portfolio, renewable resources have seen increasing curtailment since 2015, driven largely by local congestion. The counties where curtailed renewable resources are located are likely to continue to have excess renewable generation in the future, specifically during the spring when net load is low.

The following regions are forecasted to experience curtailments of renewable electricity production in the near future.

Table 2 Renewable Electricity Curtailments by County[4]

County	2020-2021 Curtailment (MWh)
Riverside	100,043
San Luis Obispo	80,010
Kings	28,677
San Bernardino	25,847
Santa Barbara	19,674
Kern	13,722

The California Independent System Operator (CAISO) interconnection queue also contains several resources planned for Kings, San Bernardino, San Luis Obispo, and Tulare counties. These new projects could potentially introduce more excess generation in these areas and increase congestion and curtailment in the future.

Science, Innovation Needs and Challenges

The CEC should fund research efforts on the feasibility and practical implications of injecting hydrogen at various levels into existing high and low-pressure natural gas pipelines. It is critical to ascertain hydrogen's potential impact on gas facilities and operations. Experimental testing at a laboratory scale is required for gas pipeline assets, equipment, methods, and procedures that are better suited for evaluation in a controlled laboratory environment prior to deploying them in a demonstration project (such as mechanical analysis, chemical analysis, leak testing, welding, flaring, etc.).

Specific examples of experimental testing include, but are not limited to[5]:

- Evaluate embrittlement, cracking and corrosion of vintage carbon steel pipeline.
- Determine permeation rates through seals, gaskets, and plastic pipes.
- Understand swelling, rapid decompression and other effects on elastomers.
- Develop a hydrogen odorant compatible with end-use equipment.

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[4] PG&E bundled renewable energy procurement portfolio data

[5] K. Domptail, S. Hildebrandt, G. Hill, D. Maunder, F. Taylor and V. Win, "PR-720-20603-R01 Emerging Fuels - Hydrogen SOTA Gap Analysis and Future Project Roadmap," Pipeline Research Council International, Chantilly, 2020. https://www.prci.org/Research/Measurement/MEASProjects/MEAS-15-02/178529/202786.aspx

- Develop measurements to monitor and control emissions (i.e. oxides of nitrogen (NOx) emissions, air-fuel ratio controls) for engines, turbines, gas burners and other combustion equipment, considering the facilities operated by the network operators.
- Evaluate precision of metering under changing/fluctuating gas admixtures/response of meters to changing composition.
- Advance live gas composition and calorific value analysis to accurately respond to hydrogen blending.
- Evaluate the effect of hydrogen on the equipment that regulates pressure, the impact to relief systems and other over-pressure protection.
- Assess injection and blending technologies, such as shear, jet, etc.
- Test compressor performance by assessing equipment commonly used in transmission networks.
- Evaluate the effect of potential increased flow and pressure inside the pipes due to the presence of hydrogen on the mechanical integrity of In-Line Inspection (ILI) tools.
- Evaluate integrity of repair sleeves commonly used in transmission pipeline systems.
- Assess separation technologies, providing clear energy and financial balance.
- Assess impacts of hydrogen blending on capillary threshold pressure.
- Evaluate tightness of the cements used for underground gas storage wells (e.g., class G cements).

Hydrogen Future can be Informed by Demonstration Projects

In addition to laboratory testing, demonstration projects will help inform future hydrogen blending injection standards. Demonstration projects will:

- Allow the creation of comprehensive transmission and distribution system testing grounds;
- Create a standardized hydrogen blending and injection skid, and
- Allow testing of components of a gas transmission and distribution system in a large-scale environment, including:
    - Testing compression and regulation at scale at various hydrogen blend percentages and pressures;
    - Testing measurements and analyzer capabilities and accuracy, and
    - Testing both current and historical aspects of the gas system.

Key technical, operational and safety questions will be answered to inform a future hydrogen blending injection standard. Demonstration projects will also allow for the validation of literature and experimental research on material compatibility with hydrogen natural gas blend. Ultimately, demonstration projects prove out research for hydrogen natural gas blends in a real-life environment.

Further details are below on what data from demonstration projects can provide:

I. Standardized skid configurations:
    - Develop a standardized hydrogen-natural gas blending skid.
    - Test multiple configurations of blending skid to allow complete mixing of various hydrogen-natural gas blends.
    - Connect pure hydrogen production to downstream hydrogen-natural gas system.
    - Assess impact of hydrogen stratification on piping design to accept stratified flow (that is, some piping will flow 100% hydrogen at or downstream of injection into a hydrogen-natural gas system).

II. Hydrogen-natural gas isolated system:
- Feed gas system with hydrogen-natural gas blend from blending skid at varied pressures.
- Install and test various new and vintage transmission pipe materials and components (such as fittings, valves, flanges, O-rings, etc).
- Design redundant feeds to maximize testing and data collection.
- Demonstrate system reliability and flexibility.

III. Compression:
- Install and test standard natural gas compressors (turbine or reciprocating).
- Evaluate and quantify the impact of hydrogen-natural gas blends on compressor emissions.
- Size gas system for sufficient compression run times to simulate real-world compression scenarios.
- Configure gas system to test multiple types of compression units in redundant runs to maximize testing.
- Configure gas system to bypass compression to feed downstream pipes.

IV. Regulation:
- Design redundant regulator runs with various equipment and pressure control devices to maximize testing and determine equipment compatibility with hydrogen-natural gas blends.

V. Maintenance and operations:
- Test measurement and control devices.
- Assess inspection and maintenance processes and procedures.
- Implement leak survey best practices with proven technology for testing for hydrogen and natural gas.
- Assess impacts on current methods and procedures.
- Install cathodic protection devices.

VI. Hydrogen fueling stations:
- Hydrogen successfully separated from the gas holder using hydrogen separation technology and the hydrogen production system will feed hydrogen fueling stations.

VII. CNG fueling stations:
- Natural gas successfully separated from the gas holder using hydrogen separation and the natural gas supply will feed compressed natural gas (CNG) fueling stations (either via direct piping or tank truck).

VIII. Electric generation:
- Electric generation facility designed to accept hydrogen-natural gas blends up to 10% hydrogen.
- Hydrogen-natural gas system to supply electric generation facility.
- Hydrogen-natural gas blend to be metered on delivery.
- Metered volumes to be compared to upstream natural gas and hydrogen meter inputs to hydrogen-natural gas system.
- Continuous operation for consecutive months is ideal to maximize testing and simulate a real-world gas system environment.

IX. Alternative end-use option

- Hydrogen-natural gas system requires an end-user to off-take gas to increase load and flow through the hydrogen-natural gas system for testing of compression and regulation.
- Alternative end-use options may need to be considered to provide continuous flow and operation of the system.
- Alternatives include cement plants or other end use that can accept varying blends of gas without impact to operations.

X. Underground gas storage
- Evaluate microbial activity and hydrogen sulfide (H_2S) formation.
- Determine if stratification of hydrogen and natural gas occurs.
- Measure for any additional leaks and losses of hydrogen natural gas blends.
- Operate the system within maximum and minimum storage pressures to determine if changes are needed.
- Assess impacts on underground storage (UGS) well integrity.

Scientific User Facilities or Computational Tools

Table 3 below provides an excerpt of current hydrogen microgrids or tests in pilot facilities. There may be an opportunity for PG&E to utilize the microgrids or test facilities for conducting R&D projects to provide the required innovations or resolve the remaining challenges.

Table 3 Examples of Hydrogen Microgrid and Test Facilities

Project Name / Location	Description
The French Alternative Energies and Atomic Energy Commission (CEA) Hydrogen and Storage (source)	The objective of the hydrogen production and storage platform is to develop innovative hydrogen production, conversion, and storage processes so that hydrogen can be effectively used as a source of energy. The platform develops and tests demonstrators of significant size in partnership with manufacturing companies.
University California, Irvine (UCI) campus hydrogen microgrid (USA) (source)	In December 2016, UCI injected renewable hydrogen into their campus power supply. UCI engineers implemented the first power-to-gas hydrogen pipeline injection project in the United States, demonstrating the use of excess clean electricity (wind and solar energy) that would otherwise go to waste.
The Australian Renewable Energy Agency (ARENA) hydrogen microgrid at Clean Energy Innovation Hug (Australia) (source)	Green hydrogen from on-site solar using electrolysis, fueling a range of gas appliances, and blending into the natural gas pipeline. Planned for 2019.
Sustainable Powering of Off-Grid Regions (SPORE) (Semakau's Island off Singapore) by ENGIE and Schneider Electric (source)	SPORE's key element is a "hydrogen brick" designed to store surplus energy in gaseous form and match energy generation to demand, thereby increasing the grid's flexibility. Hydrogen is used to complement batteries. Hydrogen is also used by vehicles on site.
Enel Green Power (Antofagasta region in northern Chile)	The microgrid comprises a 125 Kilowatt hour (kWh) solar PV facility combined with a hybrid energy storage system including 450kWh of hydrogen storage and 132kWh of lithium-ion storage.

Project Name / Location	Description
H-Mat: Hydrogen Materials Consortium (source)	H-Mat is composed of Sandia National Laboratories, Pacific Northwest National Laboratory, Oak Ridge National Laboratory and Argonne National Laboratory. The Consortium is a framework for cross cutting early stage R&D on hydrogen materials compatibility. The laboratories have capabilities to study hydrogen interactions with materials.
National Renewable Energy Laboratory (NREL) (source)	The hydrogen infrastructure testing and research facility (HITRF) at NREL's Energy Systems Integration Facility (ESIF) consists of hydrogen storage, compression, and dispensing capabilities for fuel cell vehicle fueling and component testing.
DNV GL (source)	DNV GL has several laboratories and test sites worldwide. Services include corrosion testing, failure analysis and failure investigation, flow testing and flow calibration, full-scale testing and materials testing and qualification.
Research & Innovation Center for Energy (RICE), GRTGaz (source)	The main research themes of the center will focus on industrial security and operation excellence as well as on renewable gases (bio-methane and hydrogen). Efforts are focused on developing specifications regarding the quality of the gas required for injection in gas infrastructure. It will also contribute to the deployment of the first reverse flow stations, equipment which will enable surplus bio-methane to be carried from the distribution networks to the transport networks when local production exceeds demand.
FenHYx (source)	FenHYx is a first demonstrator on a European scale to test hydrogen and decarbonized gases in the networks. The FenHYx platform in particular aims to reproduce the features of gas networks and especially those of the gas transmission networks compression, expansion, measurement, analysis, injection loop, etc. The opening up of this platform to other operators will contribute to the emergence of the hydrogen sector.
University of British Columbia, Clean Energy Research Centre (CERC) (source)	This research aims to design a methodological framework for the sustainable development of the hydrogen supply chain (HSC) in British Columbia for a 30-year time frame, i.e., minimize costs and environmental impact.

PG&E appreciates the opportunity to comment on this IEPR workshop and to share our learnings and insights on hydrogen's potential in the clean energy transition. We would welcome further discussion with the CEC to further discuss the role of hydrogen and the synergies it can create between the gas and electric energy systems.

Sincerely,

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[Attachment - PG&E Hydrogen R&D Efforts]