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PREPARED DIRECT TESTIMONY OF

DANIELLE MARK

ON BEHALF OF PACIFIC GAS & ELECTRIC COMPANY

(PG&E'S HYDROGEN BLENDING DEMONSTRATION PROJECT)

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

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CHAPTER 5

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I. PURPOSE

The purpose of my prepared direct testimony on behalf of Pacific Gas & Electric Company (PG&E) is to provide the justification and context for PG&E's proposed Hydrogen Blending Demonstration Project (Project). My testimony will focus on a description of the Project and how it will help close operational data gaps while supporting Southern California Gas Company (SoCalGas), San Diego Gas & Electric Company (SDG&E), PG&E, and Southwest Gas Corporation's (Southwest Gas) (collectively, the Joint Utilities) focus on safety, system integrity, and reliability. Project cost estimates will be provided in this application.

My testimony will (1) discuss the Project's structure from a holistic view, including each Research, Development and Demonstration (RD&D) Facility; (2) how the demonstration and data collected will address key technical, operational, and safety gaps to support a future hydrogen injection standard; (3) how the Project will validate existing literature and research; and (4) how PG&E will collaborate with University of California (UC), Riverside and other investor-owned utilities (IOUs) to integrate data from the demonstration projects and to prevent duplicative efforts.

The gap we are seeking to close is a lack of operational data on the effects of hydrogen blending at transmission pressure on our natural gas infrastructure. There have been numerous desktop and laboratory studies that have provided us analytical data, giving us fundamental knowledge of the theory and science behind hydrogen flow behavior and interaction with materials.

However, analytical data has limitations and is only a piece of the puzzle due to its small scale and inability to replicate operational variations. Specifically, laboratory experiments are capable of testing only a couple of feet of pipe (or a small handful of equipment simultaneously) with pure hydrogen, pure methane, or a mix of those two gases, in a static and relatively stable environment. This is why field pilots and demonstrations (on miles of pipe and equipment simultaneously) are needed to provide us with crucial operational data from real-life environments with variations in (1) temperature and humidity from changes in our climate, (2) pressure fluctuations due to changes in supply and demand on a daily/weekly/monthly/annual basis, (3) volume fluctuations from changes in supply and demand, and (4) true gas quality representations as traditional and renewable natural gas contain more than just methane (including heavier hydrocarbons and other impurities).

PG&E thoughtfully designed our Project to complement what SoCalGas (Chapter 1-2), SDG&E (Chapter 3) and Southwest Gas (Chapter 4) are proposing. We also wanted to make sure that we were not duplicative of other global efforts.

The resulting solution, our Project, will focus on a large-scale and long-term (10-years) field demonstration, with a new and stand-alone high pressure (720 psi) gas transmission system in PG&E's service territory. The transmission equipment and pipe (new and vintage) that we will utilize in our Project will be representative of those found in our existing natural gas system.[1] It will serve as an open access testing ground and knowledge sharing platform, not only for all of California, but the global industry.

Initial hydrogen blend levels for the system will start at 5%, followed by stepwise increases to 10%, 15%, and finally up to 20% in the high-pressure gas transmission system, with the potential for higher levels in the future to accommodate blending into a nearby power plant or other future research needs. Our Project will close gaps by providing California (and the nation) long-term operational data (e.g., operations and maintenance, integrity, gas quality and measurement, fluid hydraulics, and safety) on the impacts of hydrogen blending in natural gas transmission pipeline systems. Beyond the 10-year demonstration, we intend to leave the equipment in place as an operating asset provided that we can show (through the operational data) that hydrogen blending can be safely and reliably done in the natural gas system without any impacts to system integrity.

Due to the nature of our gas transmission system, it is not feasible to create an isolated system for such testing from existing operational assets. There is not a process to control the flow of hydrogen to keep it only within the existing gas transmission system since it is interconnected and flows directly into our gas distribution system and to our customers. In addition, choosing only a single portion of our gas transmission system would provide a very small data set containing a limited variety of pipe and equipment.

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[1] PG&E defines our gas transmission system as gas pipelines with operating pressures above 60 psi and consisting mostly of steel, PG&E Terms and Definitions, available at: Gas Industry Glossary | Pipe Ranger (pge.com) (accessed Jan. 16, 2024).

PG&E's standalone and custom-built facility will offer a comprehensive representation of pipes and equipment, delivering a singular, all-encompassing demonstration for California in a single location and project.

The Joint Utilities will conduct the necessary safety and reliability research and demonstrations covering most of the infrastructure found in California's natural gas systems, helping California to progress toward achieving the safe and optimal delivery of renewable hydrogen in existing gas infrastructure.

II. BACKGROUND

a. Global Perspective

In developing the Project, PG&E has reviewed global hydrogen blending projects and continues to learn from involvement with international consortiums[2] focused on hydrogen blending in transmission systems. Several European countries, Australia, and Canada are leading hydrogen blending research projects and demonstrations.

On the steel transmission side, Snam (an Italian energy infrastructure company) completed a trial in 2019 blending 10% hydrogen into a steel pipeline that serves a pasta factory and bottled water company.[3] Since the early 1970's, Hawaii Gas has been operating their transmission and distribution pipelines with synthetic gas created from naptha that naturally contains a 10-12% blend of hydrogen.[4]

A comprehensive review of global transmission pressure hydrogen pipeline projects reveals that North America does not yet have such a project. Table 1 below is a summary of notable projects at transmission pressure that PG&E is aware of. All projects are located in Europe, therefore this proposed demonstration project fills a major gap in North America's efforts to support blending of hydrogen at transmission pressures. Another meaningful contribution of this Project is its long duration of 10-years or more

[2] Including the Pipeline Research Council International Emerging Fuels Institute, NYSEARCH, and Gas Technology Institute (GTI Energy).

[3] See Baker Hughes, Snam and Baker Hughes Successfully Complete First Trial for the Use of Hydrogen as Fuel in a Gas Compression Station (Dec. 6, 2022), available at: Snam and Baker Hughes Successfully Complete First Trial for the Use of Hydrogen as Fuel in a Gas Compression Station | Baker Hughes (accessed Jan. 16, 2024); Snam, Snam: Europe's first supply of hydrogen and natural gas blend into transmission network to industrial users (Apr. 1, 2019), available at: Carta Intestata (snam.it) (accessed Jan. 16, 2024).

[4] Issuu, Hawai'i Gas, 2021 Sustainability Report (Dec. 2022), p. 18, available at: HAWAIʻI GAS | 2021 Sustainability Report by hawaiigas5 - Issuu (accessed Jan. 18, 2024). PG&E understands that Hawai'i Gas' transmission system is 22 miles and operates at ~350-450 psi.

offering continuous learning and knowledge sharing; the European projects are much shorter in duration.

Table 1 – Summary of high-pressure transmission hydrogen blending projects

Project Name	Project Location	Project Summary
MosaHYc[5]	Germany, France, Belgium	Retrofitted gas pipelines (70 km) for 100% H_2. Project will transport 20,000 m^3/hr.
FenHyx[6]	France	Project aims to reproduce features of gas networks for studying impacts of H_2 blends and 100% hydrogen in new test facilities.
Jupiter 1000[7]	France	1 MWe power to gas (green hydrogen and methane utilizing captured CO2 with methanation). Project trials to be completed in 2023.
HyNTS Future-Grid[8]	United Kingdom	Hydrogen-NG blending trials in isolated system with decommissioned assets over 7-month period, at 2%, 20% and 100% hydrogen ending in 2024.
Snam Contursi[9]	Italy	10% hydrogen blend supplied to 2 customers. Testing completed in 2019.
H21[10]	United Kingdom	100% hydrogen testing on isolated portion of existing system. Short-term trials (several months) to validate operation and maintenance activities.

HyNTS Future-Grid is most similar in scope to the Project since it will evaluate hydrogen blends at 2%, 20% and 100% hydrogen in an offline test loop consisting of decommissioned gas transmission pipeline assets over a 7-month period.[11] The Project

[5] Entsog, available at: MosaHYc (Mosel Saar HYdrogen Conversion) | ENTSOG (accessed Jan. 17, 2024).

[6] Entsog, available at: FenHYx | ENTSOG (accessed Jan. 17, 2024).

[7] Jupiter 1000, First Industrial Demonstrator of Power to Gas in France, available at: English | Jupiter1000 (accessed Jan. 17, 2024).

[8] National Gas, Future Grid, available at: FutureGrid | National Gas (accessed Jan. 17, 2024).

[9] See Baker Hughes, Snam and Baker Hughes Successfully Complete First Trial for the Use of Hydrogen as Fuel in a Gas Compression Station (Dec. 6, 2022), available at: Snam and Baker Hughes Successfully Complete First Trial for the Use of Hydrogen as Fuel in a Gas Compression Station | Baker Hughes (accessed Jan. 16, 2024).

[10] H21, Pioneering a UK hydrogen network. Led by Northern Gas Networks, available at: H21 (accessed Jan. 17, 2024).

[11] National Gas, Future Grid, Building a Hydrogen NTS, available at: PowerPoint Presentation (nationalgas.com) (accessed Jan. 17, 2024).

will be an expansion to include all transmission pipeline asset classes representative of California and much of the US and be operational for at least 10-years.

The projects above provide a good knowledge foundation and proof of concept for hydrogen blending into pipelines as a viable decarbonization pathway, but the operational data gaps must be addressed before widescale hydrogen injection can occur in existing transmission assets operating at high pressure and higher blend percentages. In alignment with the U.S. National Clean Hydrogen Strategy and Roadmap, which calls out the need to address barriers to using existing infrastructure for clean hydrogen deployment,[12] the Project seeks to address the operational data gaps through continued research and development.

Unlike the other Joint Utilities' distribution projects which are in the pre-development stages, this Project is currently in the early engineering stages and will focus on transmission pressure assets due to a scarcity of projects focusing on high pressure steel systems at blend percentages over 12%. PG&E views conversion of existing natural gas transmission assets to support hydrogen blending as key to a cost-effective net zero carbon gas system. For this reason, the Project will implement a Full-Scale Online Testing Facility containing a test loop where knowledge required to inject hydrogen safely and confidently into the existing system will be gathered over time.

Through this testing, the Project will enable a knowledge-based fitness-for-service assessment for compatibility with hydrogen blends up to 20% and potentially higher to accommodate future blending into a nearby power plant or other future research needs, with an operating pressure of approximately 720 psi. The Project will be carried out over many years to enable critical maintenance and in-service construction cadences and practices to be validated over longer duration than what is currently available from other projects. In addition, training sessions can be held on-site to transfer this knowledge to PG&E and the utility workforce, ensuring that they have the required expertise should hydrogen blending and injection be widely deployed in California.

To ensure that the RD&D goals align with and supplement current academic research, the Project is consulting with national laboratories and research universities.

[12] U.S. National Clean Hydrogen Strategy and Roadmap, p. 3, available at: U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov) (accessed Jan. 17, 2024).

The expertise of these organizations will strengthen test data fidelity that will be summarized and presented in annual reports to the Commission and at industry conferences.

b. Collaboration with Stakeholders

In developing the Project, PG&E is collaborating with various stakeholders who are actively researching hydrogen blending in the natural gas system. Descriptions of collaborations beyond the University of California, Riverside (UCR) Study and CEC GFO-21-057 project, which are discussed in the Application (A.22-09-006), are provided below.

i. Pipeline Hazardous Materials and Safety Association (PHMSA)

In April 2022, PHMSA issued several research announcements. For research announcement #693JK32210004POTA – Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends[13] – the objective is to "investigate the … impact of hydrogen injection on leakage dynamics and … the effect of hydrogen on existing leak detection equipment."[14] PG&E is part of a Technical Advisory Panel (TAP) on the project team led by the Gas Technology Institute (GTI) and SENSIT Technologies. The results will provide for a proof-of-concept hydrogen detection scheme to fill knowledge gaps identified during the project.

PG&E is also part of a project team led by Engineering Mechanics Corporation of Columbus for research announcement #693JK32210013POTA– Review of Integrity Threat Characterization Resulting from Hydrogen Gas Pipeline Service.[15] The objective is to identify and describe "possible changes to the ASME B31.8S threat assessment process" for integrity management of

[13]PHMSA, Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends, available at: Research & Development Program: Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends (dot.gov) (accessed Jan. 17, 2024).

[14] *Ibid.*

[15] PHMSA, Review of Integrity Threat Characterization Resulting from Hydrogen Gas Pipeline Service, available at: Research & Development Program: Review of Integrity Threat Characterization Resulting from Hydrogen Gas Pipeline Service (dot.gov) (accessed Jan. 18, 2024).

hydrogen service in new or existing pipelines.[16] The results will inform PHMSA and the industry of appropriate changes to the threat assessment process conventionally used for natural gas transmission, with a focus on time-dependent threats, resident threats, threat interactions, potential impact radius, and other consequence aspects, and to the methods used to set (re-)assessment intervals.

The results from the PHMSA studies (2022 – 2025) will provide valuable analytical data for California. Similar to the UCR and CEC study, the Project will provide the needed supplemental operational data, as there will be no hydrogen blending in live pipelines in the PHMSA studies.

ii. Department of Energy (DOE) Pipeline Blending CRADA (HyBlend)

DOE's Hydrogen and Fuel Cell Technologies Office (HFTO) launched the Pipeline Blending CRADA (HyBlend) collaboration in 2021 and coordinates related work through the DOE Hydrogen Program.[17] "The HyBlend initiative aims to address technical barriers to blending hydrogen in natural gas pipelines."[18]

"Key aspects of HyBlend include materials compatibility R&D [from laboratory testing], techno-economic analysis, and life cycle analysis that will inform the development of publicly accessible tools that characterize the opportunities, costs, and risks of blending."[19] "This effort supports DOE's H2@Scale vision for clean hydrogen use across multiple sectors in the economy."[20] HyBlend has a $15M R&D portfolio with over 20 partners, with PG&E being one of them through our membership at Operations Technology

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[16] *Ibid.*

[17] DOE, HFTO, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines (HyBlend Opportunities for Hydrogen Blending), available at: HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines | Department of Energy (accessed Jan. 18, 2024).

[18] DOE, HFTO, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines Technical Summary (HyBlend Technical Summary), available at: HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines (energy.gov) (accessed Jan. 18, 2024).

[19] DOE, HFTO, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines Technical Summary (HyBlend Technical Summary), available at: HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines (energy.gov) (accessed Jan. 18, 2024).

[20] HyBlend Opportunities for Hydrogen Blending.

Development (OTD), and 6 national labs.

The results from HyBlend (2021 – 2023) will be leveraged for the Project's FEL-3/Detailed Engineering study described in Section III below. The Project synergizes with HyBlend by providing real-life data from a full-scale operational environment:

- To complement laboratory scale data, furthering scientific understanding to ensure safety of piping and pipelines for hydrogen service.
- To further development of representative pipeline case studies in the Pipeline Preparation Cost Tool (PPCT), informing future potential blending scenarios.
- To fill the emissions data gap on NG/H2 transportation, improving Life Cycle Assessment and emissions analysis.

iii. Research Consortia/Joint Industry Projects

Below is a table that presents a snapshot of PG&E's research and development (R&D) collaborations. Though not an exhaustive list, it illustrates the breadth of our R&D work to close technical knowledge gaps through either a desktop study, laboratory study, or pilot. The data from our R&D work has laid the foundation for progressing towards California's and the United States' first large-scale and long-term hydrogen blending demonstration in our new and standalone high-pressure natural gas transmission system.

Table 2 – PG&E R&D Collaborations

Research Consortia	Project Title
Pipeline Research Council International Emerging Fuels Institute (PRCI EFI)	• Hydrogen state-of-the-art study[21] • Hydrogen underground gas storage state-of-the-art study[22] • Change Management for Introducing Hydrogen at Compressor Stations • Guidelines for integrity management of hydrogen pipelines
NYSEARCH	• Blended hydrogen natural gas impact on elastomers • Hydrogen natural gas dispersion in a residential building • Local distribution company decarbonization gap analysis
Operations Technology Development (OTD)	• Accuracy of hydrogen analyzers and leak survey instruments • Gap identification between hydrogen and natural gas pipeline standards and practices • State-of-the-art study on hydrogen deblending technologies
Utilization Technology Development (UTD)	• Hydrogen blended gas in residential / commercial combustion equipment • Heavy duty hydrogen vehicle deployment
Other	• HyReady guidelines for hydrogen blending • Gas Technology Institute/DOE: Hydrogen Storage for Load-Following and Clean Power: Duct-firing of Hydrogen to Improve the Capacity Factor of Natural Gas Combined Cycle Plants

III. PROJECT DESCRIPTION

The Project focuses on blending and transportation of hydrogen at transmission pressure in PG&E's stand-alone and new natural gas transmission system. The Project's planned location is in Lodi, California where the Northern California Power Agency (NCPA) power generation plant, Lodi Energy Center (LEC), is situated. LEC has an existing gas fired turbine that can currently accept up to a 45%[23] hydrogen blend by volume. NCPA plans both to provide hydrogen (produced using renewable electricity) to the Project and to consume it downstream in its power generation plant. Provisions may

[21] Domptail, et al., PR-720-20603-R01, Emerging Fuels – Hydrogen SOTA Gap Analysis and Future Project Roadmap, DOI: https://doi.org/10.55274/r0011975 (accessed Jan. 22, 2024).

[22] Hamilton, et al., PR-244-21700-R01 Underground Storage Define and Refine Scope for Hydrogen (May 9, 2022). DOI No. https://doi.org/10.55274/R0012223 (accessed Jan. 22, 2024).

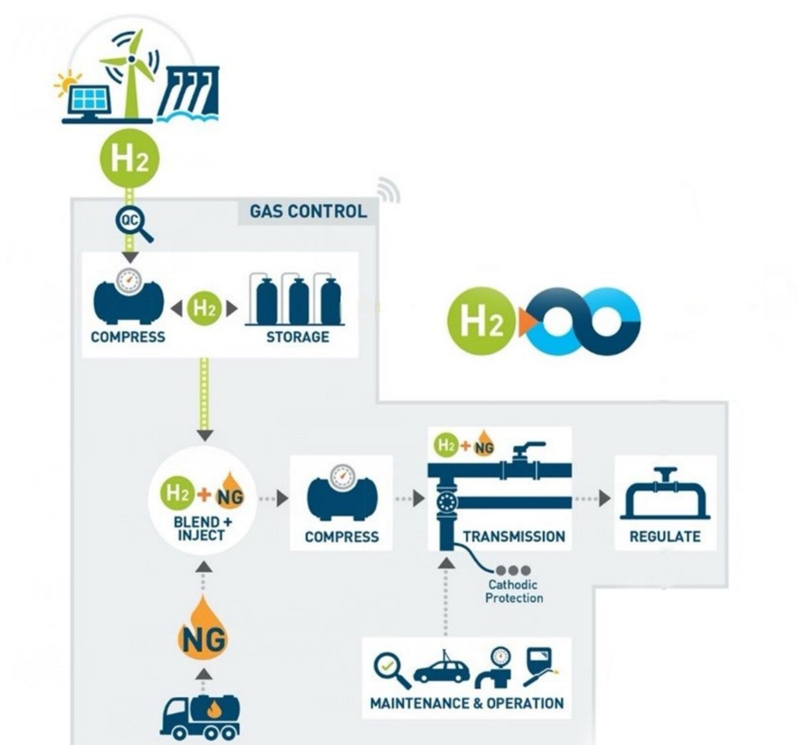
[23] NCPA, Press Release, California's Alliance for Renewable Clean Hydrogen Energy Systems Awarded Hydrogen Hub Funding by the U.S. Department of Energy (Oct. 13, 2023), p. 2, available at: NCPA-Press-Release-ARCHES-Decision-10132023.pdf (accessed Jan. 19, 2024).

be made in the Project to accommodate a future blend of up to 45% when NCPA is ready to accept the blend via pipeline.

Upon PG&E's receipt of hydrogen, it will travel to an above ground storage facility that will be used for load balancing of the closed-loop transmission system to ensure a consistent supply. It will then travel to a blending and interconnection skid to combine with the natural gas provided by pipeline or tube trailers. Once blended, the hydrogen natural gas blend will travel through the stand-alone gas transmission system (consisting of pipe, fittings, valves, compressors, regulators, meters, and so on) that are representative of the existing PG&E gas transmission system. In the future, the hydrogen natural gas blend may be provided by pipeline to the LEC for power generation.

PG&E is also partnering with UCR and their Center for Environmental Research and Technology (CE-CERT) to leverage the results of their study (mentioned in the collaborators section above) and expertise to support the design of the PG&E demonstration facility. UCR is acting in an advisory role to ensure that the Project's testing protocols are consistent with their rigorous protocols.

Figure 1 – Hydrogen Blending Project Demonstration Concept



The following components are currently in scope for this application:

- Natural gas supply from the PG&E gas system via interconnection or tube trailers
- Hydrogen-natural gas blending skid with incremental blending steps of 5% up to 20% by volume
- Hydrogen-natural gas transmission pipeline test loop with compression and regulation

The following components are currently out-of-scope for this application:

- Hydrogen production, which is anticipated to be undertaken by NCPA
- Interconnection pipeline to NCPA's power generation plant
- Distribution mains and services as these are addressed by SoCalGas, SDG&E and SWG's Projects
- End-use residential, commercial, and industrial customers as these are addressed by SWG's Project, CEC GFO-21-507 study and our R&D work with UTD

Expected Project Deliverables

- External white paper detailing results
- Internal technical report to help PG&E engineers make decisions backed by facts and data with regard to hydrogen-natural gas blends
- Long-term (10+ years) large-scale demonstration site
- Internal and external virtual workshop presentations
- Internal and external on-site tours and learning sessions

Outside the scope of this application, future expansion of the Project may include the following, provided there is no opportunity to leverage existing facilities:

- A **Full-Scale Offline Testing Facility** to enable testing of full-scale equipment compatibility, leak testing, and full-scale materials and integrity testing. This facility could fill gaps recognized by the gas industry in scaling up laboratory research.
- A **Laboratory** to include testing laboratories and workshops. It will enable laboratory-scale testing to support research and testing programs ahead of full-scale and live testing programs. It can also support investigations and

inspection of equipment and samples before, during, and after the full-scale testing.

- An **Education and Training Facility** to include dedicated classrooms and additional training areas for knowledge dissemination and safety/operations training for the utility workforce.
- A **de-blending area** testing de-blending technologies to separate the hydrogen-natural gas blend and demonstrate achievable purities for vendor technologies and sensitive customer equipment. This would feed a pure hydrogen supply into a Hydrogen Fueling Station (with on-site compressed storage) which could cater to heavy duty, light duty, and bus fleet vehicles.

A. PHASE 1: Planning, Design, Construction, and Commissioning

1. Planning

The proposed project site is owned by the City of Lodi and consists of approximately 1,100 acres of land. Roughly 300 acres are accounted for via existing facilities and proposed future uses already under consideration and planning prior to Project development. The remaining is used for City of Lodi agricultural production via wastewater effluent.

Figure 2 Aerial view of proposed Project site

The Project is intended to establish a world-class research, development, and demonstration facility respective to hydrogen blending within utility-grade transmission systems. Considered a 'green field' project within the City of Lodi's property in western San Joaquin County, it contains minimal existing site development and connection potential to existing utilities and facilities. Figure 2 above shows a proposed site development layout that provides purpose, functionality, safety, and longevity of the Project facilities.

2. Design, Construction, and Commissioning

The **Full-Scale Online Testing Facility** is in the form of a large transmission test loop with testing areas attached to allow long-term exposure in a dynamic flow environment. The long-term testing will enable the Joint Utilities to develop an understanding of the changes in operations and maintenance requirements for transmission equipment in hydrogen service and train operators in modified operating procedures on live equipment. It allows the demonstration and assessment of new technologies and materials expected to emerge in support of the decarbonized energy transition over the coming decade and beyond.

The proposed test loop will include a minimum 1-mile length of "piggable" steel pipeline with multiple test areas within (or attached to) the test loop for long-term pipeline materials, transmission equipment, and hydraulic performance testing.

The test loop is proposed to operate over multiple years to allow monitoring of the pipeline and transmission equipment performance, integrity, and operations and maintenance changes due to extended exposure to hydrogen blends. The test loop design will allow for ongoing online monitoring, provisions for equipment and materials to be removed for detailed examination and validation, and non-destructive and destructive testing to assess for changes in equipment properties over the research program. Training for operations is integrated into the Full-Scale Online Testing Facility.

Transmission equipment and pipe samples will be representative of those found in PG&E's existing natural gas system.[24] Beyond this, the Full-Scale Online Testing

[24] PG&E defines our gas transmission system as gas pipelines with operating pressures above 60 psi and consisting mostly of steel, PG&E Terms and Definitions, available at: Gas Industry Glossary | Pipe Ranger (pge.com) (accessed Jan. 16, 2024).

Facility will serve as an open access testing ground and knowledge sharing platform for California and the industry. Eventually, utilities, vendors and other stakeholders with transmission equipment and pipe who are looking to obtain operational data in a real-life hydrogen blending environment might connect to this test loop through their active participation and commitment. Inclusion of third-party equipment in the test loop would be self-funded by those entities.

The control center facility will contain an onsite control room to monitor and control the test loop that will be supervised from the PG&E Gas Control Center in San Ramon.

Consistent with industry best practices for the design, implementation, and control of gas and liquids pipelines, it is presumed that the test loop will be modelled to ensure equipment is sized and specified based on planned process conditions.

There will also be a small building containing a classroom area for public education. Members of the public will be invited to learn about the value of gas network decarbonization, the challenges to be overcome, career opportunities in the transition to a cleaner energy system, and PG&E's leadership in RD&D.

The proposed Project site is assumed to require a separate building for storage of equipment, materials, consumables, and items that otherwise require cover within a building for both security and protection from the elements. The asset storage facilities will have space for racking of storage vertically as well as a facility to store provisions for ongoing site operations and long-term maintenance. It will also have an integrated gantry, bridge, girder, or other appropriately designed overhead crane to handle and transport larger equipment and materials throughout the warehouse.

Materials for services such as building structure maintenance, mechanical and HVAC servicing, energy and water management, lighting, fire safety, plumbing and site stormwater drainage, and provisions specific to environmental, health, and safety for the entirety of the site, would be included in these asset storage warehouse and maintenance facilities. The maintenance facility will also house and store provisions for soft services, including overall site cleaning, pest control, waste disposal and recycling, and general grounds management.

3. Project Schedule

The Project plan starts with the Front-End loading (FEL) approach. FEL is a staged development process that should provide PG&E with enough information to make technical and business decisions, reduce risk, and maximize the Project's success. The FEL approach is a progressive design approach, wherein the defining of project scope, schedule, and budget allows PG&E and associated stakeholders to address key risks at critical stage-gate milestones. Generally, FEL is broken up into 3 primary design iterations, with detail engineering on the back end. Table 3 provides a summary of key considerations and level of detail for each FEL stage.

Table 3 – FEL Stages

	FEL-1	**FEL-2**	**FEL-3**
Project Stage	Planning / Conceptual Design	Feasibility Design	Preliminary Engineering
Project Definition	2% - 5%	10% - 30%	30% - 60%
Cost Estimate Class (AACE)	Class 5	Class 4	Class 3
Cost Estimate Accuracy	Low - -20% to -50% High +30% to +100%	Low - -15% to -30% High +20% to +50%	Low - -10% to -20% High +10% to +30%
Basis of Estimate	Parametric models, figures, experience & judgement	Budgetary quotes, factors, Architectural & Engineering estimates	Semi-detailed unit costs, key contract vendor quotes.

The 3 common stages of FEL are described in more detail below:

1. **FEL-1** is a conceptual stage that starts a project. The purpose of this step is to conceptualize the project idea and define alternatives. Working with experienced independent third-party groups, including GHD Inc. and UCR, PG&E completed a FEL-1 and made significant progress on a FEL-2 study in 2022.

   This FEL-1 stage developed the concept for the Project. Primary considerations focused on development and preliminary design of the test loop and site requirement upgrades for the parcels and land area in consideration.

For the process design specific to infrastructure associated with the long-term blending demonstration facilities, Process Flow Diagrams (PFDs) have been created that assist in identifying key equipment, principal process lines, and main control elements (instrumentation and other related actuated control valves). This level of detail lends itself to a higher level of cost estimating accuracy and is the precursor to subsequent design stages.

The Project site presents a multitude of benefits with regards to the availability of land in a semi-remote location, access to a variety of resources (including the City of Lodi's recycled water), and the co-location of the existing natural gas fired turbine plant. However, the site is currently operated as an agricultural production field, and thus, lacks several utilities and infrastructure elements necessary for the successful implementation of the proposed blending demonstration program.

The FEL-1 stage identified and created a preliminary design of key infrastructure to support the program. These include site grading and earthwork improvements, stormwater handling, a new water supply, treatment and conveyance system, fire and life safety systems, improvements to the adjacent country road for site access, and general site layout ingress and egress parameters. All design considerations in this stage will be reevaluated as new data and studies are performed in subsequent design stages (e.g., geotechnical report, topographical survey data, groundwater quality assessment, etc.).

FEL-1 deliverables include:

- Identification and assessment of process alternatives
- Selection of a single process concept to move forward with preliminary analysis
- Determination of the funding needs for the remaining stages of the Project
- Development of staged gate project plan with timelines to consider critical path through the start-up stage

2. **FEL-2** is the next step where alternative designs are evaluated and the best technical solution is developed for a cost estimate. The blending demonstration PFDs created during FEL-1 will transition to Piping and Instrumentation Diagrams (P&IDs) to further refine the process design. Initial site investigatory studies will commence to create the basis of design for all site infrastructure and civil engineering improvements. Site architectural planning pertaining to the general site flow and spatial relationships will occur during this stage, which is necessary to establish and define ultimate facility goals in conjunction with site use requirements and safety codes and standards. More refined understanding of project phasing regarding construction and implementation will be developed during FEL-2 studies. The level of project definition, engineering design, cost estimation, and public outreach at the FEL-2 stage typically provides sufficient detail to commence project permitting, regulatory approvals, and ultimately CEQA and NEPA documentation. This stage is also referred to as Pre-Front-End Engineering Design (**Pre-FEED**). The outcome is used as the design basis for the next stage.
3. **FEL-3** [also referred to as Front-End Engineering Design (**FEED**)] is the last step prior to final approval for a project to proceed into detailed engineering and construction. The outcome is used as the basis for the bidding and execution stage of the project. The level of project definition at the FEL-3 stage typically provides sufficient design and specification detail to begin the requests for proposals (RFP) and solicitation process with design-build or Engineering, Procurement, and Construction (EPC) contractors for program elements that lend themselves to these styles of project delivery. The outcome is used as the basis for the bidding and execution stage of the project, with a definitive cost estimation basis and a project execution plan.

The steps following FEL commonly consist of the following, all of which are coordinated and scheduled with overlap and activities generally occurring in parallel to one another:

4. **Detailed Engineering** includes final design respective to all the studies prior to construction, such as extraction of essential information from the FEED, specifications, 3D modelling and so on. Engineering definition is progressed to 60% to 90%, cost estimate class upgrade to Class 2, and detailed quantity take-offs with unit costs from quoted contracts are utilized for final budgetary approval.
5. **Procurement** includes acquiring the necessary products, materials, or services from suppliers/vendors. Procurement may occur in parallel to other engineering and construction activities.
6. **On-site/Off-site Fabrication** involves the assembly of parts or systems (e.g., pipeline components and accessories for this Project) and connecting the different pieces for the installation stage.
7. **Construction** assembling the different elements together by following the detailed design plan and installation drawings from the detailed engineering study.
8. **Erection/Installation** cleaning and preparing the place of installation of a new machine or equipment and pipeline followed by connecting the different parts of the system (e.g., through welding, mechanical fittings, etc.).
9. **Pre-commissioning** cleaning, flushing, drying, leak testing, hydro-testing of equipment, piping system and other components.
10. **Commissioning** verification process to confirm that a facility and system has been designed, procured, fabricated, installed, tested, and prepared for operation per the design drawings and specifications.
11. **Start-Up** the entire system goes live following the successful completion of commissioning.

Once hydrogen blending goes live, the overall demonstration is expected to last around 10 years.

An estimated project schedule is below in Table 4.

Table 4 – Project Schedule

	2022	2023	2024	2025	2026	2027
FEL-1 + FEL-2 (Pre-FEED)	■					
FEL-3 (FEED)			■			
Detailed Engineering				■		
Land / Permits, Approvals, Legal				■		
Construction					■	■

B. PHASE 2: Testing and Demonstration

Preliminary testing information for the Full-Scale Online Testing Facility are listed below in Sections III B.1 – B.3.

1. Asset Inspection

The Full-Scale Online Testing Facility test loop pipeline will be representative of existing transmission facilities and designed and tested to the requirements of ASME B31.12 - Hydrogen Piping and Pipelines,[25] while end of line metering and regulation facilities will be designed in accordance with ASME B31.3 - Process Piping. PG&E specific design standards will be applied where applicable. One hundred percent of girth welds will be subject to non-destructive examination for future record. All test materials and equipment will be attached to offtakes from the pipeline that can be monitored, controlled, and isolated as required for safe operation.

Fracture toughness and production testing requirements (including hardness and hydrogen compatibility of the line pipe) shall be in accordance with minimum requirements of ASME B31.12. The test loop construction will include hot formed bends that shall be qualified in accordance with the requirements of ASME B31.12. Cold field bends are to be minimized,[26] long term exposure trials are to be considered for hot and cold formed bends for assessment of impact of residual stresses, wall thinning, and development of revised cold form bend construction guidelines.

[25] The test loop pipeline will be designed and tested to the requirements of other ASME standards, consensus engineering documents, etc. that are established in the future.

[26] The performance of cold field bends and impacts of work hardening and thinning from forming are to be evaluated as part of long-term pipe exposure trials.

The details of asset inspection will be determined in the FEL-3 and Detailed Engineering design stages of the Project.

2. Live Hydrogen Blending, Data Collection, and Analysis

The test loop in the Full-Scale Online Testing Facility will support the following research streams:

- Fluid Mechanics and Pipeline Hydraulics;
- Gas Quality, Measurement and Control;;
- Operations and Maintenance;
- Risk and Safety and
- Equipment and Materials Integrity.

The loop will operate by hydraulic gradient created by flow from a compressor through the pipeline loop to a metering and pressure reduction facility back to a low pressure (LP) inlet that feeds the compressor inlet. The test loop will include inlet pressure flow control valve that will allow simulation of daily and seasonal pressure fluctuations in conjunction with the facility bypass valve. The load profile will be controlled by the test loop HMI (human-machine interface) based on a demand load profile representative of PG&E assets. Thermal load and additional management requirements in the system will be assessed during test loop design.

The test loop is expected to operate over a period of 10 years at a constant hydrogen blend composition. The test loop will include a blending skid that allows make-up gas to be added as gas is consumed due to system use and compression duty.[27] The loop will initially operate on 100% natural gas with blending up to the target long-term blend composition undertaken in steps during which the system integrity, equipment operation and flow hydraulics are monitored, informing potential operations and maintenance (O&M) and system changes as blend composition changes. Blending steps are expected to take 3-6 months at 5% increments, meaning up to 2 years to reach target long-term blending composition of 20% hydrogen. Provisions may be made in the test

[27] The blending skid will allow for future testing requirements outside the current project scope being capable to blend up to 100% hydrogen.

loop to accommodate higher blends should NCPA become ready to accept the blend via pipeline or other future research needs.

The test areas attached to or fed by the test loop include the following:

- In-line inspection tool trials;
- Welded high strength fittings and sleeves test area;
- Live welding and repair test area;
- Pipe and coating long term exposure trials;
- Transmission equipment long term trials;
- Compression equipment long term trials;
- Blending and odorant injection trials; and
- Leak testing trials.

Provisions will be made in the loop design for future technology trials for compression—for testing the integrity and impacts to operations for compressor technology. The compressor built into the test loop will be selected as a hydrogen-ready unit up to the proposed long-term blending composition, but provision is to be made to allow for future testing and research with existing natural gas compression technology. Connection points will be included to allow alternate compressors and technologies to be connected and tested on the test loop.

The details of data collection and analysis will be determined in the FEL-3 and Detailed Engineering design stages of the Project.

3. Asset Validation

The test loop pipeline will contain typical pipeline assemblies and will be monitored continuously for performance, reliability and integrity changes during the long-term exposure trial including:

- Inline inspection launcher and receivers;
- Insulation joints or insulation flanges;
- Pig-signal – external mount with remote monitoring;
- Main line valve – manual and actuated; and
- Auto Shut Off Valve.

Additional instrumentation will be included to monitor the system performance including:

- Thermocouples for pipeline temperature monitoring;
- Pressure transmitters at each pipeline assembly; and
- Acoustic and vibration monitoring at assemblies.

There will be sections of redundant pipe runs, each composed of various vintage pipe materials, that will be decommissioned at different time intervals (e.g., 1 year, 3 year, 5 year, 7 year, etc.) for in-depth laboratory analysis.

The full research and testing program will be defined in subsequent engineering stages and will align with recommendations from industry experts, including national laboratories.

C. PHASE 3: Decommissioning, Equipment Removal, and System Restoration

Beyond the 10-year demonstration, we intend to leave all RD&D Facilities in place as an operating asset provided that we are able to show through the operational data that hydrogen blending can be safely and reliably done in the natural gas system.

IV. PROJECT GUIDANCE

A. API RP 1173 Pipeline Safety Management System

API Recommended Practice (RP) 1173 provides pipeline operators with safety management system requirements that, when applied, provide a framework to reveal and manage risk, promote a learning environment, and continuously improve pipeline safety and integrity. PG&E's commitment to gas safety excellence is recognized through certification to APR RP 1173 for Safety Culture.

The Project utilizes API RP 1173 Plan-Do-Check-Act (PDCA) life cycle to drive continual improvement. PG&E is currently in the "Plan" stage to design the Full-Scale Online Testing Facility test loop and prepare for its safe operation. PG&E intends to engage with the American Institute of Chemical Engineers (AIChE) Center for Hydrogen Safety for input on the safe handling and use of hydrogen in the Project. The Project will move to the "Do" stage when the test loop becomes operational and data collection starts. The Project leads into the "Check" stage where continuous monitoring will be done through the onsite gas control facility to measure pressure, flow rate, and gas quality of the test loop for safe and reliable operation 24/7. The "Act" stage includes analyzing the collected data to inform improvements on how we operate and maintain the test loop and for knowledge sharing.

B. Overarching Safety Case

PG&E is committed to reaching a net zero energy system by 2040 - five years ahead of California's current carbon neutrality goal. In support of this effort, we are exploring new technologies and cleaner fuels, including hydrogen.

To validate hydrogen's role in our clean energy delivery system, the Project will determine the required factors needed for safe use of existing infrastructure for long-distance transmission of hydrogen-natural gas blends.

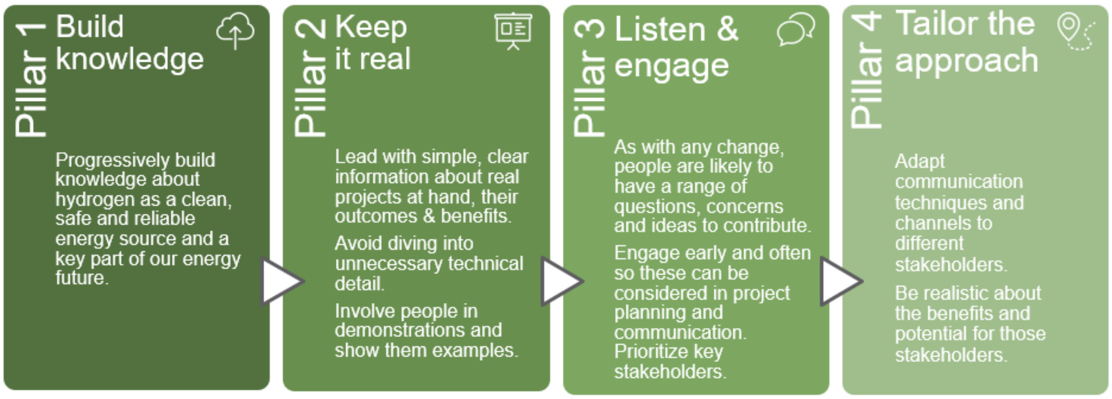
PG&E's test loop is a standalone and custom-built facility, separate from our existing natural gas system. This ensures the safe testing of live hydrogen blending in a controlled large-scale environment. The appropriate design and construction standards and operating the test loop within designed parameters will minimize the risk of hydrogen leakage. Combustion equipment will comply with CARB emission requirements that will be specified during the Detailed Engineering design study. There will be fixed, continuous monitoring of the entire facility to detect any leaks that may occur. Several instrumentations will be used to monitor the system performance, including thermocouples for pipeline temperature monitoring, pressure transmitters at each pipeline assembly, and acoustic and vibration monitoring at assemblies. The onsite control center facility will monitor and control the Full-Scale Testing Facility from the PG&E Gas Control Center in San Ramon.

The Project will offer a comprehensive representation of pipes and equipment, delivering a singular, all-encompassing demonstration for California in a single location and attempt. This should provide the needed operational data on our high-pressure gas transmission system so that a hydrogen injection standard can be developed and deployed to ensure the long-term safety of the California pipeline.

C. Stakeholder Engagement & Reporting

Community engagement for a project of this magnitude is a priority. PG&E is developing a holistic communication and engagement plan for the rollout of the Project to take the community on a journey from awareness to acceptance. Consistency of key messaging and listening to community feedback will develop familiarity and trust in the Project and Project partners.

Change takes time, and this journey will take several years. The figure below presents four pillars for hydrogen communication and engagement.



PG&E has already started community engagement efforts with a series of meetings in the cities of Lodi and Stockton. Three events were held in October 2023, and one event was held in November 2023. The forums include the San Joaquin Disaster Council meeting, San Joaquin Office of Emergency Services meeting, Stockton Environmental and Legislative Committee, and a local community meeting in the City of Lodi.

Additional community engagement meetings will be held in 2024 as follow-ups to the initial meetings in 2023. This will ensure that:

- We understand the priorities of the residents in Lodi and neighboring communities;
- We have heard people's concerns and questions and have properly addressed their concerns regarding safety, societal, economic, technological impact, and other issues that are raised; and
- We reiterate the safety measures and benefits of hydrogen blending.

Input received during these engagement meetings will be brought to the Project's experienced independent party, to consider incorporation into the design of the test loop.

Additional outreach activities (with residents and city officials in the cities of Lodi and Stockton) may include the following:

- An in-person meeting following the completion of the FEED study to present the results;
- An in-person meeting following the completion of the Detailed Engineering study to present the results; and
- For Project stages after Detailed Engineering until the Project goes live, written communications, with annual in-person meetings, will occur to inform people on Project progress and to address concerns.

During the demonstration period, there will be knowledge sharing in the form of whitepapers, technical reports, presentations, and/or public tours of the demonstration facility.

Beyond engagement and reporting, the Project will consider the impacts to disadvantaged communities by:

- Learning how to encourage the use of hydrogen as a decarbonization pathway, which in turn may reduce greenhouse gas emissions that may disproportionately affect disadvantaged communities;
- Providing options for skilled workers in disadvantaged communities to receive training and education in hydrogen blending pipeline operations, such as PG&E's Power Pathway program. Opportunities to be considered as part of the new workforce needed to operate and maintain the Project facilities will be given; and
- Using the Project as a model for community-based energy solutions, inspiring them to explore hydrogen and other renewable energy options to meet their needs.

V. ORDERING PARAGRAPH COMPLIANCE

The Ordering Paragraphs from Decision 22-12-057 outlined several key requirements for the hydrogen blending demonstration projects. Below is a detailed accounting of how PG&E will be complying with each order through this Project.

1. **OP 7a:** *"Ensures the long-term safety of the California pipeline, the prevention of hydrogen leakage, the inclusion of hydrogen monitoring, the consideration of the dilution rate, and the monitoring and reporting of all mechanical characteristics of hydrogen blends in the natural gas pipeline stream"*

Ensures the long-term safety of the California pipeline: PG&E's test loop is a standalone and custom-built facility, separate from our existing natural gas system. This design ensures the safe testing of live hydrogen blending in a controlled large-scale environment. The Project will offer a comprehensive representation of pipes and equipment, delivering a singular, all-encompassing demonstration for California in a single location and attempt. This should provide the needed operational data on our high-pressure gas transmission system so that a hydrogen injection standard can be developed and deployed to ensure the long-term safety of the California pipeline.

Prevention of hydrogen leakage: The Full-Scale Online Testing Facility test loop pipeline will be representative of existing transmission facilities and designed and tested to the requirements of ASME B31.12[28] Hydrogen Piping and Pipelines, while end of line metering and regulation facilities will be designed in accordance with ASME B31.3 - Process Piping. PG&E specific design standards will be applied where applicable. One hundred percent of girth welds will be subject to non-destructive examination for future record. All test materials and equipment will be attached to offtakes from the pipeline that can be monitored, controlled, and isolated as required for safe operation.

Fracture toughness and production testing requirements (including hardness and hydrogen compatibility of the line pipe) shall be in accordance with minimum requirements of ASME B31.12. The test loop construction will include hot formed bends that shall be qualified in accordance with the requirements of ASME B31.12. Cold field bends are to be minimized,[29] and long-term exposure trials are to be considered for hot and cold formed bends for assessment of impact of residual stresses, wall thinning, and development of revised cold form bend construction guidelines.

Utilizing the appropriate design and construction standards and operating the test loop within the designed parameters will minimize the risk of hydrogen leakage.

[28] The test loop pipeline will be designed and tested to the requirements of other ASME standards, consensus engineering documents, etc. that are established in the future.

[29] The performance of cold field bends and impacts of work hardening and thinning from forming are to be evaluated as part of long-term pipe exposure trials.

Inclusion of hydrogen monitoring: There will be fixed, continuous monitoring of the entire facility to detect any leaks that may occur. Several instrumentations will be used to monitor the system performance, including thermocouples for pipeline temperature monitoring, pressure transmitters at each pipeline assembly, and acoustic and vibration monitoring at assemblies. The onsite control center facility will monitor and control the Full-Scale Testing Facility supervised from the PG&E Gas Control Center in San Ramon.

Consideration of dilution rate: Gas quality analyzers and metering equipment will be located on the hydrogen blending and injection skid to measure the composition and quantity of the hydrogen and natural gas. This will ensure that the hydrogen is properly diluted to the desired blend percentage prior to injection into the test loop.

Monitoring and reporting of all mechanical characteristics: The test loop pipeline will contain typical pipeline assemblies and will be monitored continuously for performance, reliability, and integrity changes during the long-term exposure trial including:

- Inline inspection launcher and receivers;
- Insulation joints or insulation flanges;
- Pig-signal – external mount with remote monitoring;
- Main line valve – manual and actuated; and
- Auto Shut Off Valve.

Additional instrumentation will be included to monitor the system performance including:

- Thermocouples for pipeline temperature monitoring;
- Pressure transmitters at each pipeline assembly; and
- Acoustic and vibration monitoring at assemblies.

There will be sections of redundant pipe runs, each composed of various vintage pipe materials, that will be decommissioned at different time intervals (e.g., 1 year, 3 year, 5 year, 7 year, etc.) for in-depth laboratory analysis.

All data collected from the instrumentation, through manual inspection and the in-depth material analysis, will be kept as records and summarized in annual reports to the Commission.

2. **OP 7b:** *"Prevents hydrogen from reaching natural gas storage areas and electrical switching equipment directly or through leakage"*

The Project is an offline facility that is completely separate from natural gas storage areas and electrical switching equipment.

3. **OP 7c:** *"Avoids end user appliance malfunctions"*

The Project does not currently have an end user. However, should NCPA become ready to accept a blend via pipeline, and a methodology is established for assessing hydrogen blending in existing pipelines, NCPA may become an end user. NCPA's electric generation facility has a "fast-start" gas fired turbine. Siemens Energy is the provider of the gas turbine, which can currently accept up to a 45%[30] hydrogen blend by volume.

4. **OP 7d:** *"Evaluates hydrogen injection at blends between 0.1 and five percent and five to twenty percent; such evaluations must adhere to approved monitoring, reporting, and long-term impact study in accordance with the approval of the pilot project application, and must include validation programs to confirm performance"*

SoCalGas' Open System Blending project will evaluate hydrogen injection blends between 0.1 and five percent. This Project will evaluate blends at 5-20%, with the potential for higher levels in the future to potentially accommodate NCPA when it is ready to accept the blend via pipeline or other future research needs. The Project will adhere to approved monitoring, reporting, and long-term impact study, and will contain validation programs to confirm performance. These details will be developed in the FEL-3 and Detailed Engineering design studies.

5. **OP 7e:** *"Specifies the amounts of funding necessary to complete all aspects of the proposal and proposes testing durations adequate to draw meaningful conclusions"*

Refer to Section VI for detailed cost estimates. Blends of 5% through 15% will be held at their respective levels for 6-months to validate safe and stable operation. Once validated, the blend will be increased at an increment of 5%. After a 20% blend is

[30] NCPA, Press Release, California's Alliance for Renewable Clean Hydrogen Energy Systems Awarded Hydrogen Hub Funding by the U.S. Department of Energy (Oct. 13, 2023), p. 2, available at: NCPA-Press-Release-ARCHES-Decision-10132023.pdf (accessed Jan. 19, 2024).

achieved, it will be maintained for the remaining ~8 years of operational testing. This duration is required to provide adequate data on long-term operational performance.

6. **OP 7f:** *"Is consistent with all directed courses of action specified in this decision relevant to leakage, reporting, heating value, system safety, environmental considerations, end-use emissions, and all other elements enumerated in this decision"*

The Project is consistent with all directed courses of action specified in decision D.22-12-057. The details of how the Project addresses all courses of actions (organized by theme) has been discussed throughout Chapter 5 and cross-referenced below in Table 5.

Table 5 – Directed Courses of Action in D.22-12-057

Themes	**Recap of PG&E's Response**	**Cross-Reference(s) in Chapter 5**
Leakage	The Project will be designed to minimize and monitor leakage, as well as evaluate various leak detection technologies at different hydrogen blends.	Sections III.A.2, III.B.2, V.a, V.k.
Heating value	PG&E does not have a heating value requirement in its gas quality tariff and does not currently have an end-user.	Section V.a (dilution rate)
Blending limitations	The Project will evaluate hydrogen blending between 5% and 20% by volume (with the potential for higher levels in the future to accommodate NCPA when it is ready to accept the blend via pipeline or other future research needs) in a closed system that is a mock-up of a real-world system using typical equipment and materials found in California gas infrastructure. The Project is focused on ensuring the long-term safety of the California pipeline.	Section I, III
Measurement, monitoring, and reporting requirements	The Project will be carried out over 10 years to study long-term impacts (including delayed undetected efforts) and enable maintenance and in-service construction cadences and practices to be validated. Status updates will be reported to the CPUC annually.	Section I, II.a, III.A.2, III.B.2, III.B.3
Additional testing requirements	The Project's testing program will be informed by the UC Riverside Study and the R&D projects identified in Section II, plus any new projects that are initiated after the filing of this application. UCR is one of the Project partners, acting in an advisory role, to ensure that the Project's testing protocols, which details will be developed in the FEED and Detailed Engineering studies, are consistent with their testing protocols.	Section II, V
Cost and environmental considerations	The Project will produce important information about the potential for carbon reductions if a system-wide hydrogen injection standard is adopted. Environmental impact to customer and communities is considered as part of our stakeholder engagement activities.	Section IV.C, VI

Appropriate next steps	The Project considers the UC Riverside Study, existing and ongoing hydrogen research, development, and demonstration activities, and stakeholder feedback.	Section II, IV.C
Additional considerations	Chapter 5 makes explicit reference through Section V how the Project complies with the directives of decision D.22-12-057.	Section V

7. **OP 7g:** *"Proposes rigorous testing protocols consistent with the UC Riverside Study"*

Scientific rigor means that other people can replicate the test(s) and understand clearly what steps were taken during the test(s). Number of tests, randomization, how to collect the data to avoid unrecognized bias, handling of outliers and so on will follow the protocols used the UC Riverside Study and be expanded to apply to a large-scale testing environment. UCR is one of the Project partners, acting in an advisory role, to ensure that the Project's testing protocols, which details will be developed in the FEED and Detailed Engineering studies, are consistent with their testing protocols.

8. **OP 7h:** *"Takes into account parties' comments and further stakeholder input and includes the opportunity for compensation for parties and for community-based organizations"*

Refer to Section IV.C for details. PG&E will have a communication and engagement plan for the Project. This will ensure that parties' comments and further stakeholder input are incorporated as we progress through each stage of the Project (described in Section III.A.3). PG&E is actively pursuing collaboration opportunities with a broad range of entities, which includes parties and community-based organizations. PG&E met with the Environmental Defense Fund (EDF), on February 5th. EDF provided thoughtful feedback on leak detection testing that we will bring to the Project's experienced independent party, to consider for incorporation into the design of the test loop. PG&E intends to hold additional community engagement meetings beyond the events in October and November, to:

- Understand the priorities of the residents in the Lodi and neighboring counties;
- Listen to people's concerns and questions; addressing their concerns regarding safety, societal, economic, technological impact and other issues that are raised;

- Provide educational materials and information sessions to disseminate knowledge on the technology, safety measures, and benefits of hydrogen blending; and
- Keep them informed about Project progress.

PG&E's Core Fixed Cost Account (CFCA) and Noncore Customer Class Charge Account (NCA) record and recover intervenor compensation and other compensation granted to community-based organizations.

9. **OP 7i:** *"Proposes a methodology for performing a Hydrogen Blending System Impact Analysis that can ensure that any hydrogen blend will not pose a risk to the common carrier pipeline system"*

This System Impact Analysis would be consulted for Joint Utilities and potential third parties connecting to the gas system to use to ensure the common carrier pipeline system will remain safe should a hydrogen injection standard be established.

The Joint Utilities propose developing a methodology for performing the Hydrogen Blending System Impact Analysis upon completion of the projects. The proposed methodology will provide a framework to ensure hydrogen blends do not compromise gas system integrity, safety, or impact end-use equipment.

The methodology will benefit from using the data collected from the demonstration Projects. The proposed methodology for hydrogen blending will follow a similar framework as a biomethane interconnection agreement.

The framework will include, but will not be limited to:

- Identification of downstream systems.
- Potential materials.
- Operating pressures.
- Equipment (e.g., valves, meters, etc.).
- Review of pipeline history and end-use equipment.
- Any further analysis that is deemed necessary by the interconnecting utility.

10. **OP 7j:** *"Includes new or revised heating values and discusses whether heating values would be modified through the use of propane or other means and whether such modifications to heating value can be done safely"*

PG&E's gas quality tariffs do not specify heating value of the gas. We use the Wobbe number to ensure a consistent blend for our customers, which indirectly correlates to a heating value. Propane will not be used to supplement heating values. We will monitor the calorific value of the blend at the blending and injection skid at the point of entry to the Full-Scale Online Testing Facility test loop. The test loop will be 1-2 miles in length, and at such a short distance, it is not expected that the gas quality properties of the blend will change. Furthermore, the Project does not currently have an end user.

11. **OP 7k:** *"Demonstrates the ability to reliably detect leakage of any hydrogen, methane, or hydrogen/methane blends and describes rigorous hydrogen leak testing protocols that are consistent with leak testing and reporting elements identified in the University of California at Riverside's 2022 Hydrogen Blending Impacts Study, identifies and addresses the comments presented by parties in this proceeding regarding leak issues, and identifies and addresses the comments presented by workshop stakeholders in this proceeding regarding leak issues"*

There will be fixed, continuous monitoring of the entire facility to detect any leaks that may occur. There will be a leak testing area that will contain remote actuated shut down valves, gas metering, and pressure regulation to allow different leak pressures to be trialed to represent different pipeline operating pressures. There will be a pressure indicating transmitter with a wireless connection to the onsite Control Center Facility. The aboveground test area will have flanged connections, typical piping fittings, and equipment for leak testing and training. Controlled leaks can be created along the test easement with different combinations of leak rates (controlled by instrument vales) at different pressures and different burial depths / backfills. Both ground (handheld and vehicle mounted etc.) and airborne (drone) leak detection technologies will be trialed with different hydrogen blends (up to 100% hydrogen will be possible). The location will be separated sufficiently from the facility boundary and public areas to ensure small leak releases during testing have sufficiently dissipated. A windsock will be used for wind monitoring during test activities.

Furthermore, a fibre optic leak detection system is proposed to be installed as part of the test loop to ascertain the suitability for hydrogen pipelines. The system will be vendor supplied and installed at the time of construction of the test loop to vendor specifications. The system will be monitored by the onsite control room. Installation of a trial section within the leak test area will be discussed with vendors during the vendor engagement process in FEED. The selection of leak detection system, technology, and provider, or multiple systems, will be made during FEED.

12. **OP 7l:** *"Contains an independent research plan for assessment, measurement, monitoring, and reporting through an independent party, which must be engaged in such activities during the development, construction, operational life, and decommissioning of the pilot project."*

Working with experienced independent third-party groups, including GHD Inc. and UCR, PG&E completed a FEL-1 and made significant progress on a FEL-2 study in 2022. For subsequent stages outside of the Joint Industry Project (see Section VI for details), PG&E will partner with the Joint IOUs to issue an RFP to solicit competitive bids for an independent party to complete the independent research plan. One entity will oversee the overarching plan, with two or more entities being contracted to lead the gas distribution and gas transmission independent research plans. Due to the large differences in the IOUs' five demonstration projects, it will be left up to the bidders to propose a reasonable budget to complete the independent research plan. The cost for this independent research plan will be tracked through an administrative memorandum subaccount and recorded in the PG&E Hydrogen Blending Demonstration Project Balancing Account (HBDPBA) described in Chapter 9.

13. **OP 22:** *"Pacific Gas and Electric Company shall submit its Hydrogen to Infinity project reports and findings to the Service List in Order Instituting Rulemaking 13-02-008, or its successor proceeding, to provide an opportunity for parties to comment on the project."*

The available details of PG&E's Hydrogen-to-Infinity project have been outlined in this application. The Project in this application is the same as the Hydrogen-to-Infinity project. Parties will have the opportunity to review and comment on the Project through this application proceeding.

VI. COST ESTIMATES

The planning, design, procurement, construction, and operation of the Project will require significant capital investment (detailed in Section VI.b).

a. EXTERNAL FUNDING

PG&E began pursuing external funding in August 2021. PG&E has held meetings with several entities including the Department of Energy (DOE) Hydrogen Fuel Cell Technology Office (HFCTO) and the Loan Program Office (LPO), PRCI, PHMSA, Low Carbon Research Initiative (LCRI)/Electric Power Research Institute (EPRI), Breakthrough Energy, Hy24, and others. Although all have expressed interest in the Project, they have not offered funding.

PG&E also submitted the Project through the DOE's Unsolicited Proposal Program, but it was denied because it appeared overlap with the DOE's Hydrogen Hubs Program (DE-FOA-0002779). However, PG&E believes the rejection was in error because it is explicitly stated in the DOE Hydrogen Hubs solicitation (DE-FOA- 0002779) document that "H2Hub award funding may not be used for pilot-scale or earlier activities, such as research and development."[31] The Project is a pilot-scale activity in alignment with D.22-12-057.

PHMSA leadership was very engaged and understood the value of the Project. PHMSA stated that it has a modest R&D budget and is not able to provide funding without a legislative act. PHMSA committed to talking to the DOE about the Project and potential funding opportunities within the DOE. However, PHMSA leadership also made the following recommendations to PG&E:

- Lobby at the federal level to request legislation for full-scale transmission hydrogen blending demonstration be addressed nationally through the Project;
- Present the project at the PHMSA R&D Forum Oct. 31st, 2023;
- Engage with Canada Energy Regulator to request funding support;
- Request that the Commission take the Project to the National Association of Regulatory Utility Commissioners (NARUC) for funding across all US ratepayers;
- Engage with the California government to request state funding; and

[31] DOE, Office of Clean Energy Demonstrations, Bipartisan Infrastructure Law: Additional Clean Hydrogen Programs (Section 40314): Regional Clean Hydrogen Hubs Funding Opportunity Announcement (Sept. 22, 2022), p. 30, available at: DE-FOA-0002779 Full Funding Opportunity Announcement (accessed Jan. 28, 2024).

- Follow-up discussion with the PHMSA leadership to discuss progress on these items in December 2023. PHMSA reiterated their support and request for PG&E to lobby at the federal level.

PG&E has made significant effort trying to secure external funding for the Project. No funding has been granted thus far.

The Project benefits not only California, but all gas utilities and customers across the United States. Given that, PG&E will continue to pursue options to secure as much external funding as possible so that PG&E's customers do not have to pay for the entire Project (transmission test loop). PG&E requests the Commission's support to obtain external funding and urges the Commission to consider the following options:

i. Procure funding from the State of California;
ii. Propose this as a national project through NARUC and request that costs be spread over multiple US regulatory jurisdictions;
iii. Spread the costs across all California customers; and
iv. Provide letters of support for seeking external funding from both government and private entities

As PG&E continues to seek external funding, PG&E is attempting to initiate a Joint Industry Project in Q4 2023 to help fund and collaborate on the FEL-3 (FEED) and Detailed Engineering studies for the Full-Scale Online Testing Facility (test loop and associated control center). The estimated cost for these engineering studies is $2,289,062 (accuracy -50%/+100%). The initiation of the Joint Industry Project is contingent on receiving external funding that covers the entirety of the estimated costs. Collaborating with other utilities, national labs, technology developers, industry players, government organizations, etc. will ensure that the Project addresses the right operational data gaps and challenges with results benefitting the industry.

b. BREAKDOWN BY RD&D FACILITY

Tables 6 and 7 below show estimated CAPEX costs for the Project by RD&D Facility. Since only a preliminary feasibility study was completed thus far, these are Order of Magnitude cost estimates with low accuracy (+100%/-50%). Higher accuracy cost estimates will be available following the FEED and Detailed Engineering studies, which will occur after this application is submitted. As such, the actual costs for the Project, are expected to vary from the early estimated costs and will be recorded in the PG&E Hydrogen Blending Demonstration Project Balancing Account (HBDPBA) described in Chapter 9. Please see Exhibit 5A for the breakdown of Project cost estimates. The total estimated capital cost is $63,457,362 (accuracy +100%/-50%) and operating cost is $2,988,000 per year (accuracy +100%/-50%).

Table 6 – CAPEX Costs Distributed by Year for the Full-Scale Online Testing Facility

Year	2022	2023	2024	2025	2026	2027
FEL-1	$237,500					
FEL-2 (Pre-FEED)						
FEL-3 (FEED)			$1,069,531			
Detailed Engineering				$1,069,531		
Land / Permits, Approvals, Legal				$5,783,191		
Construction + O&P					$21,166,719	$21,166,719
AFUCD			-	-	$1,849,957	$1,849,957
Contingency			$2,225,440	$2,225,440	$2,225,440	$2,225,440
RD&D 1 Total by Year	$237,500[32]		$3,294,970	$9,078,161	$25,242,115	$25,242,115

[32] The 2022 cost is presented to show the overall project costs and is excluded from the PG&E Hydrogen Blending Demonstration Project Balancing Account (HBDPBA).

Table 7 – CAPEX Costs Distributed by Year for the Control Center and Public Education Facilities

Year	2022	2023	2024	2025	2026	2027
FEL-1						
FEL-2 (Pre-FEED)						
FEL-3 (FEED)			$75,000			
Detailed Engineering				$75,000		
Land / Permits, Approvals, Legal						
Construction + O&P					$900,000.00	$900,000
AFUCD						
Contingency			$112,500	$112,500	$112,500	$112,500
RD&D 1 Total by Year			$187,500	$187,500	$1,012,500	$1,012,500

VII. CONCLUSION

A large-scale and long-term hydrogen blending demonstration in the natural gas transmission system is the next critical step to develop a hydrogen injection standard for California. This Project will provide the necessary operational and material data to support such a standard for using high pressure gas transmission systems to transport hydrogen blends. PG&E is looking forward to taking this next step to help California achieve its decarbonization goals.

This concludes my prepared direct testimony.

VIII. QUALIFICATIONS

My name is Danielle Mark. I am employed at PG&E as an Expert Gas Engineer in the Greenhouse Gas and Emission Strategies organization. I am responsible for Gas Operations' hydrogen blending initiatives. I joined PG&E in April 2014 as a Gas Operations Engineer in the Gas Distribution Control Center and was responsible for leading the development and deployment of the Gas Distribution Control Center's Emergency Response and Management Process. From 2016 – 2022, I was a Senior Gas Engineer in the Gas R&D team leading our gas decarbonization R&D efforts.

Prior to joining PG&E, I was an Engineering Project Leader at Enbridge Gas Distribution in Toronto, Canada.

I hold a Bachelor of Applied Science in Chemical Engineering from the University of Waterloo and a Professional Engineers license in the State of California.

I have not previously testified before the Commission.

CHAPTER 5

EXHIBIT 5A

BREAKDOWN OF PROJECT COST ESTIMATES

October 3, 2023

PG&E Hydrogen Demonstration Project Work Paper 1 (WP-1)

To	PG&E Hydrogen Team	**Contact No.**	707.273.8784
Copy to	Jamie Randolph, Danielle Mark, Kevin Pease (PG&E)	**Email**	ryan.doyle@ghd.com
From	Ryan Doyle (GHD Inc.)	**Project No.**	12567161
Project Name	Hydrogen Blending Demonstration Program		
Subject	Class 5 Cost Estimate Basis – Online Test Loop Blending Demonstration Facilities		

1. Order of Magnitude Cost Estimate Basis

1.1 General

The estimating deliverable for the PG&E's Direct Testimony Draft Document of work is an Order of Magnitude Total Installed Cost (TIC) estimate. The estimate was developed utilizing a combination of budgetary vendor pricing, engineering discipline issued information, and estimates derived from preliminary drawings. The information provided to the estimating team was developed based on client design input, client standards, and good engineering and design practices. The estimating team used the information to obtain quantities, general sizes, and relevant project pricing experience to develop the total cost. Where applicable, GHD contacted vendors to obtain equipment and material quotes and input this information into the estimate.

This Basis of Estimate (BOE) explains in detail the applicable key components of the project estimate including quantity development, material costs, equipment costs, indirect costs, engineering and architectural design costs for future design phases, environmental compliance and permitting, vendor representatives, and contingency costs. All assumptions, clarifications and exclusions that were made in development of the estimate are listed herein.

While detailed information has been supplied as part of the Project Definition Report and FEL-1 design development, these estimates take a high-level view of the prescribed testing facility. The intent of this level of estimate to capture all major scoped infrastructure elements that serve the purposes of the PG&E Hydrogen Blending Demonstration Project goals and criteria. For an order of magnitude cost basis, this translates to conservative quantities and unit costs, and subsequent contingencies, with the goal of providing the order of magnitude capital cost expenditures to be expected. In subsequent phases of design, refinements of design parameters, unit costs, and quantities will ultimately lead to finer granularity of detail, high confidence, and greater levels of certainty with respects to the ultimate project to be constructed.

The estimates provided should be considered as 'order of magnitude' and are subject to revision as information becomes available. Assume an accuracy in the region +100% / -50%.

1.2 Scope and limitations

GHD has prepared the preliminary cost estimates set out in this memorandum ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Cost Estimate has been prepared for the purpose of supply PG&E with a basis for their upcoming California Public Utilities Commission Testimony for their proposed Hydrogen Blending Demonstration Project and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. No preliminary or detailed quotations have been obtained for actions identified in this report. GHD does not represent, warrant, or guarantee that the Hydrogen Blending Demonstration Program can or will be undertaken at a cost which is the same or less than the cost estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

This technical memorandum has been prepared by GHD for PG&E. It is not prepared as, and is not represented to be, a deliverable suitable for reliance by any person for any purpose. It is not intended for circulation or incorporation into other documents. The matters discussed in this memorandum are limited to those specifically detailed in the memorandum and are subject to any limitations or assumptions specially set out.

2. Capital Expenses

2.1 Assumptions

In the absence of project specific costing from potential technology suppliers, estimates have been based on available information from several sources;

- in the public domain (vendor websites),
- through verbal consultation with vendors in the course of the project or,
- utilising industry knowledge/experience by GHD staff based on the general scale and technology required.

The costs assume all site development, improvements, equipment installation, services, and construction of facilities are available on site using established typical construction methodologies.

Costs associated with civil infrastructure (grading, stormwater runoff, structural foundations, groundwater quality, etc.) are based on knowledge/experience by GHD staff in lieu of site-specific data required for detailed design (survey, geotechnical report, groundwater sampling, etc.).

2.2 Exclusions

The following list details a number of known exclusions from the cost estimate basis.

- Hydrogen production and delivery infrastructure / mechanisms
- Modifications to any end-users of blended gas (e.g., NCPA's Lodi Energy Center)
- Taxes
- Licensing Fees
- Pre-production and production costs for equipment

2.3 Inclusions

A detailed list of inclusions can be found in Appendix A for this Order of Magnitude estimate for all elements of the Online Testing Loop. The project and associated cost estimates are referenced to June 2022, when developed under the FEL-1 study. This Basis of Estimate has been updated in September 2023 for use in PG&E's application A.22-09-006 Chapter 5; utilizing a California Construction Cost Index[1], the total cost is benchmarked to the September 2023 index.

[1] DGS California Construction Cost Index CCCI

2.4 Contingency

An allowance of 30% for contingency is included in the Estimate. Contingency is defined as a special monetary provision in the project budget to cover uncertainties or unforeseeable elements of time/cost within the scope of the project under GHD's control. Contingency typically covers risk of cost increases resulting from lack of scope definition, lack of particular experience, omissions, underestimation, technical problems, nonspecific schedule slippage, and like items. Scope changes are specifically excluded from contingency and considered an Owner cost.

Contingency is included in the cost estimate as a provision for unknown project costs that cannot be identified for estimating purposes due to the lack of complete, accurate and detailed information. An estimate's contingency is an amount added, for a defined scope, to allow for items and/or conditions, for which the state, occurrence, and/or effect are uncertain. Experience shows these items will likely result in additional costs outside of the current assumptions captured in the assembly of the estimate and as outlined in the previous sections of this document. The contingency is expected to be expended by the end of the project. A contingency of 30% of the direct and indirect costs was included in the estimate.

The contingency aims at capturing the following risks associated with the project estimate:

- Estimate errors and omissions
- Quantitative growth above assumed growth allowances captured due to design development
- Material cost fluctuations associated with market forces and shop loadings
- Labor cost fluctuations related to quantitative growth, performance and availability, wage, etc.
- Schedule slippage related to engineering, material and equipment delivery, weather-related delays, etc.

3. AFUDC

Allowance for funds used during construction, commonly called AFUDC, is a regulatory method of compensating a utility for the financing costs it incurs during construction of new facilities. This is considered critical for utilities because their business is capital-intensive, and it often takes significant capital and time to build large facilities. Since typical utility regulation does not allow the utility to put the cost of a new facility into rates until it is in service, AFUDC offers a way for the utility to recover its pre-operational financing costs.

PG&E provided a Microsoft Excel calculation tool to GHD which uses the Capital Cost Subtotal line item to determine the AFUDC financing costs. At the time of this Cost Basis development, the annual AFUDC rate of 7.34% was used over a project duration of 24 months for the Project.

4. Operating Expenses

The CPUC Testimony requires an estimate of annual operating expenses (OPEX). As the current basis of design is lacking in detail with regards to process loads and equipment sizing, a percentage of capital per year-based approach will be used at this stage for estimating those costs. The level of accuracy is defined similarly with the CAPEX estimate of +100% / -50%.

When estimating OPEX costs using this method, the percent range typically varies between 1.5% and 5% per year of the overall capital cost total. Given the complexity of the Hydrogen Blending Demonstration Program, an anticipated 5+ full time employees estimated to be staffed on-site full time, and various power and consumables demands, this estimate assumes a higher than typical 5% of element specific direct costs per year.

OPEX costs for the Full-Scale Testing Facility are approximately $2,988,000.

5. Cost Estimate Breakdown

The following table presents a breakdown of cost per phase in September 2023 dollars.

Table 1 H2Infintiy Cost Breakdown

	Online Testing Facility	Control Center & Public Education Building
Equipment	$10,448,827	
Piping	$13,098,831	
Civil	$2,767,069	
Steel	$48,232	
Instrumentation	$3,379,291	
Electrical	$2,092,565	
Insulation	$38,715	
Paint	$405,875	
Other – Building *		$1,500,000
Direct Totals	*32,279,405*	*1,500,000*
Construction Equipment & Indirects	$4,801,946	$150,000
Construction Management, Staff, & Supervision	$1,637,125	$75,000
Material Taxes	$1,814,961	$75,000
Engineering	$2,139,061	$150,000
Contingency	$8,901,759	$450,000
Permits / Approvals / Land	$5,783,191	--
Indirect Totals	$25,078,043	$900,000
Total by Element	**$57,357,448**	**$2,400,000**
AFUDC **	**$3,699,914**	

* Building required for test loop control center and preliminary education and training facilities, assumed 7,500 square feet at $200 per square foot.

** AFUDC includes capital costs for both Test Loop and Control Center & Public Education Building

Costs for quantities and assessments of site-wide requirements for grading, additional facilities for operations, maintenance, and storage are to be spread throughout each RD&D facility relative to their complexity and size.

5.1 Distributed CAPEX by Year Through Commissioning

The following table presents an estimate of the major cost considerations throughout the project implementation lifecycle per phase.

Table 2 Full-Scale Online Testing Facility CAPEX Costs Distributed by Year

Year	2022	2023	2024	2025	2026	2027
FEL-1	$237,500					
FEL-2 (Pre-FEED)						
FEL-3 (FEED)			$1,069,531			
Detailed Engineering				$1,069,531		
Land / Permits, Approvals, Legal				$5,783,191		
Construction + O&P					$21,166,719	$21,166,719
AFUCD			-	-	$1,849,957	$1,849,957
Contingency			$2,225,440	$2,225,440	$2,225,440	$2,225,440
RD&D 1 Total by Year	$237,500		$3,294,970	$9,078,161	$25,242,115	$25,242,115

Table 5 Public Education Building CAPEX Costs Distributed by Year

Year	2022	2023	2024	2025	2026	2027
FEL-1						
FEL-2 (Pre-FEED)						
FEL-3 (FEED)			$75,000			
Detailed Engineering				$75,000		
Land / Permits, Approvals, Legal						
Construction + O&P					$900,000.00	$900,000
AFUCD						
Contingency			$112,500	$112,500	$112,500	$112,500
RD&D 1 Total by Year			$187,500	$187,500	$1,012,500	$1,012,500

6. Accuracy

The actual costs for the Program, are expected to vary from the early estimated costs and will be recorded in the PG&E Hydrogen Blending Demonstration Project Balancing Account (HBDPBA) as detailed design progresses.

Regards,

Ryan Doyle
Design Manager

Ryan.doyle@ghd.com

707.273.8784