

**DOE Hydrogen Program
Response to RFI #DE-FOA- 0002529**

To: DOE Hydrogen Program

From: Green Hydrogen Coalition

with support from the following individuals and organizations:

Green Hydrogen Coalition Initiative, HyDeal LA: Advisors

- *Jack Brouwer, Director, National Fuel Cell Research Center, University of California, Irvine*
- *Michael Colvin, Director of Legislative and Regulatory Affairs, California Energy Program, Environmental Defense Fund*
- *Tyson Eckerle, Deputy Director, Zero Emissions Vehicle Market Development, Governor's Office of Business and Economic Development*
- *Rachel Fakhry, Senior Policy Analyst, Natural Resources Defense Council*
- *Jeffery Preece, Senior Program Manager, Low-Carbon Resources Initiative, Electric Power Research Institute*
- *Keith Wipke, Laboratory Program Manager, Fuel Cell & Hydrogen Technologies, National Renewable Energy Lab*

Green Hydrogen Coalition Initiative, HyDeal LA: Funders

- *174 Power Global*
- *Los Angeles Department of Water and Power*
- *Mitsubishi Power*
- *Southern California Gas Company*
- *8minute Solar Energy*
- *Clearway Energy Group*
- *Fortis BC*
- *Hydrogen Pro*
- *Phoenix Hydrogen*
- *SPEC Services*

Green Hydrogen Coalition Initiative, HyDeal LA: Key Implementation Partners

- *Clifford Chance*
- *Corporate Value Associates (CVA)*
- *Cranmore Partners*
- *Energeia*
- *Marathon Capital*
- *Sheppard Mullin*
- *Strategen*

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Contact:

Janice Lin

President and Founder

Green Hydrogen Coalition

2150 Allston Way, Suite 400, Berkeley, CA 94704

jlin@ghcoalition.org

O: +1 (510) 665-7811 x101

M: +1 (415) 595-8301

www.ghcoalition.org

Executive Summary

HyDeal LA: Architecting a Scalable Model for Green Hydrogen Hubs, Starting with Los Angeles

HyDeal Los Angeles represents a unique opportunity for DOE to establish and advance US leadership in the development of clean hydrogen clusters to support the new clean energy economy.

In May 2021, the [Green Hydrogen Coalition](#) (GHC), a 501(c)(3) non-profit organization supported by a number of green hydrogen off-takers, gas and electric infrastructure utilities, clean energy project developers, integrators, equipment manufacturers, investors, environmentalists, and advisors launched [HyDeal Los Angeles](#) (HyDeal LA), an initiative to overcome the biggest barrier to the green hydrogen economy — its high cost — by developing a commercial green hydrogen cluster at scale in Los Angeles, California.

The HyDeal LA initiative aims to achieve \$1.50/kilogram at-scale delivered green hydrogen to off-takers across the LA basin by 2030. HyDeal LA is architecting the green hydrogen ecosystem by qualifying and aggregating multi-sectoral green hydrogen off-takers including power generation, oil refining, hydrogen fueling stations for on road transport, alternative fuel for maritime goods movement, aviation, and ultimately for international export of green hydrogen and/or green ammonia from the ports of Los Angeles and Long Beach.

Hydeal Los Angeles Initiative Advisors include leaders from:



Funders of the Hydeal Los Angeles Initiative include:

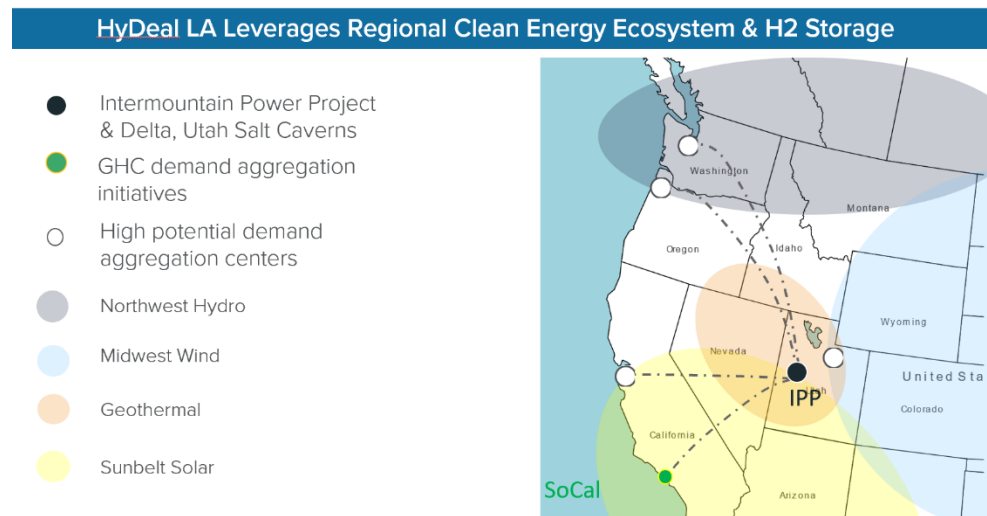


Key implementation partners include:



HyDeal LA represents the first and most bold vision and execution of its kind in the United States - a hub where green hydrogen produced from abundant domestic renewable resources provides affordable, reliable, carbon-free fuel to achieve a clean energy economy across multiple sectors. With the goal of leveraging diverse clean energy resources from across the West, massive hydrogen storage capacity from salt caverns in Delta, UT, and existing right-of-ways, HyDeal LA may incorporate many resources and support the development of other Western Hydrogen Hubs, potentially including Salt Lake City, Seattle, Portland, and California's Bay Area (*Figure 1*).

Figure 1: HyDeal LA Leverages Regional Clean Energy Ecosystem and H2 Storage



Los Angeles is the first envisioned hydrogen hub because it has many of the ingredients for success as a first mover: visionary municipal leadership, forward-thinking utility partners, major off-takers committed to a low-carbon future by 2035 including power generation, industry, ports, airports, and heavy transit, and abundant renewable energy resources for green hydrogen production. HyDeal LA can serve as a model for many other hydrogen hubs in the US to come.

Deployment benefits of HyDeal Los Angeles include development of a new green energy industry that supports skilled, well-paying new jobs, increases equity, supports energy diversity, vastly improves energy resiliency, reduces and avoids energy sector air pollutants and carbon emissions, and provides affordable, equitable hydrogen fuel supply for all residents of the Los Angeles basin, and in particular, underserved communities and priority populations that have been most impacted by poor air quality for decades.

The HyDeal LA initiative is actively creating an innovative and expanding vendor and development community to help catalyze the supply chain needed to achieve large-scale, low-cost green hydrogen power supply for Los Angeles.

HyDeal LA has already identified and validated major off-takers for green hydrogen including Los Angeles Department of Water and Power's four in-basin generating facilities: Harbor,



Haynes, Scattergood and Valley Generation Station. Independent studies, including the recently completed Los Angeles 100% Renewable Energy Study developed by the National Renewable Energy Lab (NREL), point to the need for renewably fueled in-basin generation to achieve reliable 100% renewable electricity for LA. HyDeal is also working to validate renewable energy requirements needed to supply electrolytic green hydrogen. HyDeal LA participants are also interested to investigate pathways to convert the 89,000 tons of waste per day generated in LA to clean hydrogen, and to partner with DOE to study the technologies, safety, and emissions profiles related to these alternative pathways for generating green hydrogen.

HyDeal LA benefits from another significant initiative around green hydrogen for LADWP, which is acting as project manager and the largest power purchaser from IPP Renewed. IPP Renewed is replacing an 1800 MW coal fueled electricity generating station at the Intermountain Power Project in Delta, Utah with new natural gas fueled generators designed to utilize a 30% green hydrogen blend at start-up in 2025, increasing to 100% by 2045. IPP Renewed is also expected to catalyze commercial-scale development of long term green hydrogen storage in a geologic salt dome located immediately adjacent to the power plant.

HyDeal LA is part of HyDeal North America, a platform launched by the Green Hydrogen Coalition, a 501(c)(3) educational nonprofit organization dedicated to facilitating policies and practices to advance the production and use of green hydrogen at scale to accelerate multi-sectoral decarbonization. HyDeal LA is modeled after HyDeal Ambition, a similar project launched in 2020 in Europe which committed to producing and purchasing 3.6 million tons of green hydrogen per year for the energy, industry, and mobility sectors at €1.5/kilogram (kg) before 2030.

Advisors to the HyDeal LA initiative include leaders from the Environmental Defense Fund, the National Renewable Energy Lab (NREL), Natural Resource Defense Council (NRDC), California Governor's Office of Business and Economic Development (GO-Biz), University of California, Irvine, and the Electric Power Research Institute (EPRI).

Funders of the HyDeal LA initiative include the nation's largest municipal utility, the Los Angeles Department of Water and Power, the nation's largest gas utility, Southern California Gas Company (SoCalGas), Mitsubishi Power, 8minute Solar Energy, 174 Power Global, Phoenix Hydrogen, SPEC Services, Fortis BC, Clearway Energy Group, and Hydrogen Pro.

It is important to note that HyDeal Los Angeles and the goal of achieving \$1.50/kg delivered green hydrogen at scale to the LA Basin is a vision that many diverse parties are collaborating towards. HyDeal Los Angeles is not yet a contracted or engineered project and no commitments have been made. It represents a big vision that is in pre-feasibility phase. The assumptions made in our RFI may have a 50% margin of error, but they are our group's best estimates based on months of interviews, research, and collaboration with parties in the LA Basin and beyond.

With federal support, we believe this vision could become a reality for Los Angeles and that the HyDeal North America approach and platform can be replicated for many other regions in the United States to accelerate the development of low-cost green hydrogen ecosystems at scale.

Our vision for HyDeal Los Angeles encompasses the following key elements:

- **Target Location:** Los Angeles Metro Area, having a population of 18.9 million, a gross metropolitan product of \$998 billion as of 2020, exceptional diversity, and a strong demand for renewable hydrogen, renewable energy development, and environmental justice for all communities.
- **Utility Scale Hydrogen Supply:** Leverage vast renewable power resources in Southern California and the Western Region to meet potential demand of 1-10+ million metric tons of green hydrogen consumption in the region. It should be noted that HyDeal LA Phase 1 is focused on electrolytic pathways to produce green hydrogen, and funding permitting, intends to also evaluate the potential use of agricultural and municipal waste for green hydrogen production during later phases of work.
- **Existing and Expanded Transmission and Distribution Infrastructure:** SoCalGas already operates the region's most extensive pipeline transmission and distribution facilities, and these existing systems may be expanded or modified to support hydrogen transmission and distribution, subject to regulatory/legislative authority and right-of-way (ROW) and other diligence to be completed. Los Angeles is also already home to approximately 15 miles of hydrogen pipelines operated by Air Products, with multiple sources and sinks primarily supplying the refining industry.
- **Expansive Storage:** Taking advantage of remote storage, the vision has the potential to optionally leverage available salt cavern storage capacity in southwestern Utah and Nevada, as well as future potential development of other alternatives for hydrogen storage. More research and development on bulk hydrogen storage will likely be required.
- **Power Plant Conversions:** The HyDeal Los Angeles vision centers on converting in-basin natural gas thermal plants to initially operate on a blend of green hydrogen with natural gas and eventually to operate on 100% green hydrogen, supporting clean burning and renewable / low carbon operation. Power plants are an ideal initial target off-taker because of their ability to rapidly scale green hydrogen demand and leverage existing infrastructure. Once scaled, the availability of low-cost green hydrogen in the LA basin will help to accelerate demand for green hydrogen in other sectors, including transportation, industrial maritime, aviation and export.
- **End Users:** The Los Angeles region has long been an early adopter of low pollution, green solutions for energy and fuels. The region has been the national leader in deployment of light duty and commercial hydrogen powered vehicles, compressed natural gas use as a fuel for transit systems, and the transition to other clean burning solutions. The green hydrogen end user market is vast and rapidly expanding, and ultimately is expected to include major industrial and utility end users as well as commercial and heavy duty transportation, ports, buildings, and industry.
- **Waste-to-Hydrogen:** Los Angeles produces a significant amount of organic waste every day – some portion of the 89,000 tons of municipal waste produced every day is a candidate for green hydrogen production, either through anaerobic digestion/reformation or thermo chemical conversion processes. This consistent and predictable feedstock can provide an important and potentially low-cost source of green hydrogen for multi-sectoral off-takers in the LA Basin, and will be an area of focus for future HyDeal LA study phases.

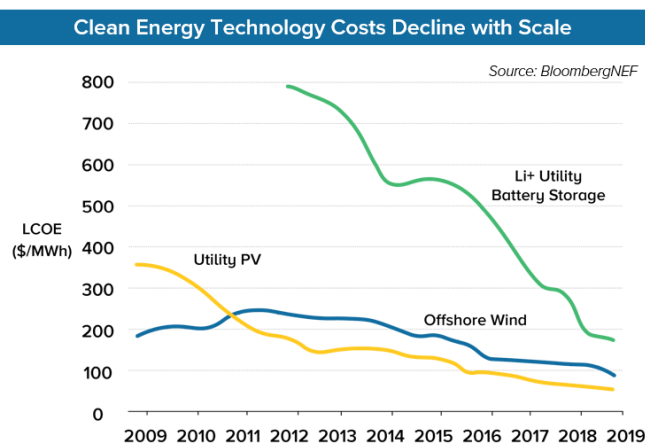
- **Export and Economic Development Opportunities:** Finally, the green hydrogen ecosystem and related infrastructure proposed for LA and the Ports will serve as a beachhead for future export of low-cost green hydrogen to Japan and other interested global importers.
- **Environmental Justice:** HyDeal LA is focused on prioritizing the transformation of LADWP’s four power generating facilities, as well as improving air for all Angelenos, including disadvantaged communities. Three of these generating stations are located within close proximity to the Port of LA – an area that is also subject to the emissions of many thousands of diesel-powered trucks, ship pollutants, and port operations equipment, including significant quantities of short-lived climate pollutants. The availability of low-cost green hydrogen to displace diesel transportation fuel will dramatically improve air quality for the surrounding communities who have suffered most.

The GHC appreciates the US Department of Energy’s leadership in advancing the hydrogen economy and launching the Hydrogen Earthshot. There are a number of areas where DOE and federal government leadership can significantly accelerate progress for HyDeal LA and other green hydrogen hubs nationally:

I. Incentive Funding for Initial Project Development

HyDeal LA represents a unique opportunity to demonstrate multiple pathways for at scale green hydrogen production to serve multiple large scale off-takers, including electrolytic as well as waste to energy production pathways. While experts around the globe agree that electrolytic pathways are poised for rapid cost reduction, learning from other clean energy applications, we know the first projects will be higher cost, and that costs will fall steeply over time, by 2-4X, with scale (Figure 2). Federal incentive funding to help offset the higher costs of early adopter, “first mover” projects at scale like HyDeal LA will be critical. For example, HyDeal LA will require an estimated 20 gigawatts of electrolysis capacity. Incentive funding to help pay for the electrolysis equipment will be incredibly helpful to jumpstart ecosystem and project development at an affordable price point.

Figure 2: Clean Energy Technology Costs Decline with Scale



II. Federal Leadership to Investigate and Perform Techno-Economic Assessment of Dedicated Hydrogen Pipeline Networks to Serve Hydrogen Hubs

DOE and Federal government leadership is essential to investigate and understand how to connect potential future secure hydrogen demand centers across the U.S. – which may include industrial clusters and potential hubs for interstate trucking corridors- and undertake a techno-economic assessment of- and potentially support- the buildout of dedicated hydrogen pipeline networks to serve those demand centers. Such initial no-regret pipeline corridors could then be expanded if and when the emergence of new hydrogen demand warrants such an expansion.

Not all regions are at the same stages of hydrogen market development. In California, federal support of a dedicated hydrogen pipeline infrastructure network would greatly help the state and HyDeal LA accelerate hydrogen adoption by increasing its accessibility across the state. This can include new pipeline infrastructure or repurposing old methane pipelines for 100% hydrogen transport. HyDeal LA system modeling work to date shows that pipeline transport is the lowest cost means of moving mass quantities of green hydrogen from areas of low-cost production to areas of concentrated demand, including potential exports via the Port of LA. To achieve the \$1.50/kg delivered cost target, a 100% hydrogen pipeline and underground geologic storage infrastructure in California (and requisite legal and regulatory framework for their operation) is absolutely required. Additionally, pipeline transport of hydrogen is both the most cost-effective and safest way to transport large quantities of hydrogen.

III. Research, Demonstration, and Deployment of Bulk Underground Hydrogen Storage

Even with the establishment of a network of hydrogen pipelines, the ability to locally store bulk quantities in low cost, underground geologic storage facilities will aid the management of peak demand and contribute to lower overall system cost and increased resiliency. Hydrogen storage in salt caverns is already well established, but these formations are rare and limited. Further research and demonstration of repurposing other forms of geologic storage, including retired oil fields, natural gas caverns, and aquifers would be very helpful for HyDeal LA as there are no known nearby salt dome formations in Southern California.

IV. Assistance to Develop Green Ammonia or Hydrogen Export from the Port of LA

The Western United States possesses abundant renewable feedstocks to produce globally competitive low-cost green hydrogen as a potential new export commodity. The vision for HyDeal LA includes development of needed port infrastructure to facilitate mass quantities of low-cost green hydrogen exports from the Port of LA and/or Port of Long Beach. The first implementation of this export infrastructure, and related maritime shipping fueling operations with green hydrogen or green ammonia will require federal assistance. HyDeal LA is well situated to be the first such demonstration as the Port of LA is the largest port in North America, Japan has expressed an interest to import low-cost green/decarbonized hydrogen from California and there are many disadvantaged communities near the Port of LA. Further, development of mass-scale green hydrogen-

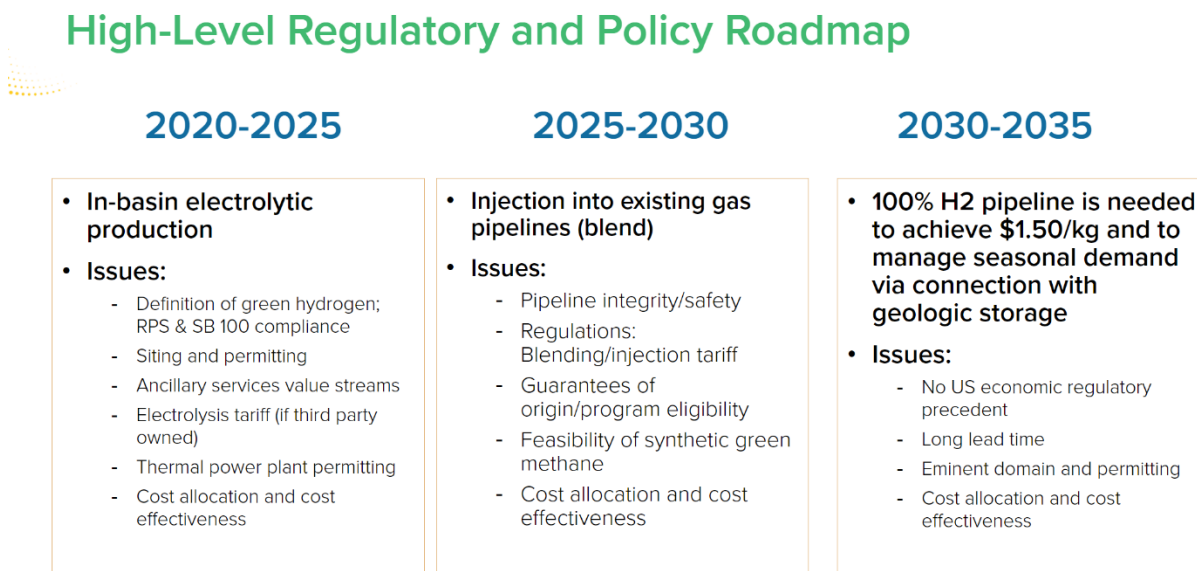
based green ammonia can also be used to supply fertilizer producers in California and the broader California agricultural markets.

V. Green Hydrogen Policy and Regulatory Market Design

Finally, the GHC would like to work closely with DOE and the Federal government to advance a myriad of necessary policies and regulations that will support the establishment of green hydrogen hubs across the United States. For example,

- a. There is no clear intrastate or interstate regulatory authority for the economic regulation of hydrogen pipelines or the hydrogen itself. Lack of clarity here will significantly impede project development.
- b. As noted in the high-level roadmap below (Figure 3), GHC believes that initially, use of existing gas pipelines will be critical to physically and cost effectively transport green hydrogen molecules. The DOE's HyBlend initiative will be game changing for all regions to better understand technical and safety limitations of hydrogen injection into existing methane pipelines. It is important to note that although the below roadmap envisions use of blending and injection and ultimately 100% green hydrogen pipelines in the 2025-2030 and beyond timeframe, the work to enable all of these potential infrastructure pathways needs to start now.

Figure 3: High-Level Regulatory and Policy Roadmap, Green Hydrogen Coalition



- c. In parallel, methods for tracking, validating, and retiring green hydrogen and guarantees of origin need to be developed. There is a need to confirm that the feedstocks and energy sources used to produce the green hydrogen are indeed green. Ideally, this could be done consistently with international standards and regionally across the US.
- d. Even if we collectively achieve \$1/kg production cost, progress will be hampered if transport and storage costs are not similarly reduced. Ultimately, hydrogen

pipelines will be necessary to achieve very low delivered cost, ie \$1.50/kg. This will take many years. Help from DOE to identify ways to accelerate this infrastructure investment will be essential to achieving the DOE's \$1/kg production cost target within the decade. For example, in Germany, new legislation has just been adopted that automatically extends existing methane pipeline permits to hydrogen pipelines, enabling a much faster transition of Europe's natural gas network to a clean hydrogen-based network.

- e. Finally, cost reduction is only half of the equation to achieving the green hydrogen economy. GHC recommends that DOE invest in market design frameworks to assist system planners, particularly gas and electric system infrastructure planners, to recognize, quantify and value all the benefits that a green hydrogen project and related infrastructure can provide. Without an appropriate legal and regulatory framework that enables compensation for these benefits, green hydrogen projects will always struggle to obtain financing as compared to their status quo fossil based competitors. Such benefits can include but are not limited to, for example, carbon reductions, other emissions reduction, ancillary services market participation, reliability, resiliency, capacity and resource adequacy, other waste stream reduction (e.g., diversion of waste from landfills) economic development, job creation and energy resource diversity. Consistent and transparent access to even a subset of these benefit streams is essential to achieving a bankable value proposition for green hydrogen projects regardless of their application.

HyDeal LA is a unique opportunity for the DOE to establish and advance US leadership in the development of clean hydrogen clusters to support the new clean economy. The Los Angeles region represents the premier and front-running location for DOE's proposed investment. California leads the country in direct state-level investment and buildout of clean, renewable technologies. Much of the end-use development, policy alignment, and political will needed to deploy an ambitious program such as HyDeal LA is already in place or underway.

Hydrogen is perfectly positioned to be a scalable clean molecule that can complement already abundant clean electrons and a world-class renewables resource base in California. The Los Angeles region—as the major US metropolitan area with significant manufacturing capacity—is uniquely positioned for the development of a net-zero industrial hub. Here, hydrogen will play a key role in decarbonizing those target / high priority industries that are characteristically difficult or impossible to decarbonize with electricity alone, including industrial heat, power generation, heavy duty transportation, refinery/chemicals production, and ports and the maritime industry. Hydrogen in California fits remarkably well into both the supply and demand sides of the energy equation. DOE's investment here will drive the global leadership, jobs development, industry invigoration, decarbonization, recognition, and green economy development targeted by the current administration.

We are grateful to the US Department of Energy for opening this Request for Information and for recognition of the value of hydrogen via this Hydrogen Earthshot. The GHC would be happy to further discuss any part of this RFI response in a follow up meeting.

RFI Response

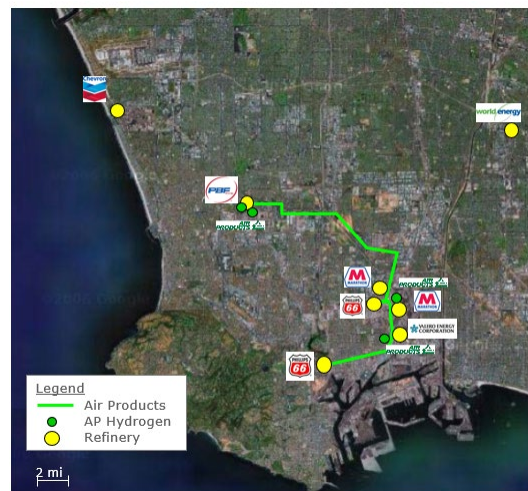
1. Regional Hydrogen Production, Resources, and Infrastructure

1a & 1b. Existing Infrastructure is Available to be Repurposed and Expanded to Produce Green Hydrogen at Scale

The Los Angeles region offers multiple categories of existing infrastructure, including facilities that currently use or support hydrogen, and facilities that are considering or planning to repurpose and/or upgrade to incorporate green hydrogen to decarbonize their operations.

- Hydrogen Production:
 - Gray hydrogen production: Los Angeles currently supports production of over 200 metric tons of gray hydrogen per day, or over 0.073 million metric tons (Mt_{H_2}) per year, mainly to serve the area's oil refineries. In theory, these production facilities could be converted to create green hydrogen by switching their hydrogen feedstocks from natural gas to biogas in existing SMR facilities.
 - Green hydrogen production in-basin is currently very limited. In order to create the massive volumes of green hydrogen identified by HyDeal, both existing (curtailed) renewable energy in the region as well as purpose-built clean energy would be required. In California in 2019, the California Independent System Operator (CAISO) curtailed renewable production (solar + wind) in the amount of 961,343 MWh. With the conservative assumption that it requires 50 kWh of energy to produce 1 kg of hydrogen via electrolysis, **we can theoretically create 19.2 Mt_{H_2} of green hydrogen per year via electrolyzers powered solely by the state's curtailed renewable energy.**¹
- Pipelines:
 - LA Basin already has over 15 miles of dedicated hydrogen pipeline, operated by Air Products.
 - Existing methane transmission and distribution pipelines owned by SoCalGas to be examined for their suitability to support hydrogen transmission.
 - **A national hydrogen pipeline network should be considered.** In Europe, such efforts are already underway – European gas transmission operators launched the European Hydrogen Backbone Initiative. In Germany, a national, 130 km pipeline initiative called H2 Nukleus is set to

Figure 4: Air Products Hydrogen Pipelines in California



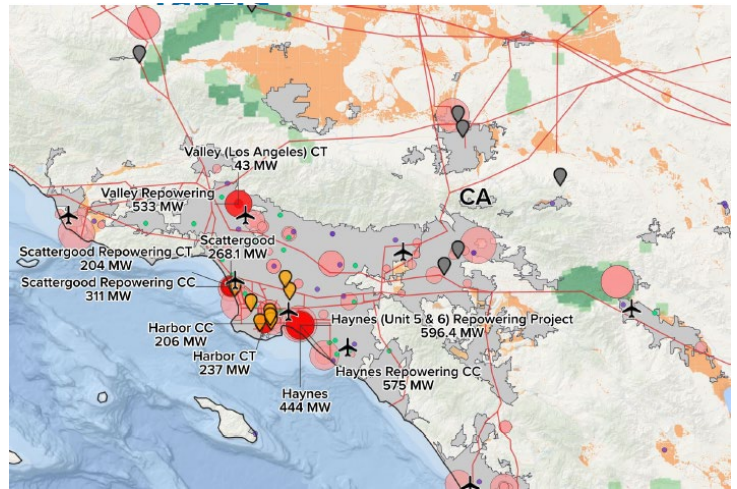
¹ California ISO, Wind and solar curtailment totals by month. <http://www.caiso.com/informed/Pages/ManagingOversupply.aspx>

come online in 2024, with non-discriminatory access and transparent prices.² There are many potential industrial decarbonized hydrogen hubs that would benefit greatly from a regional and ultimately national vision for building out shared infrastructure to connect areas of low-cost production with areas of high demand, including export hubs like the Port of LA.

- Power Plants:

- LADWP has four thermal, natural gas-fueled generating stations that are under consideration for repowering with green hydrogen: Scattergood (~800 MW), Haynes (~1580 MW), Valley (~600 MW), and Harbor (~450 MW).
- Owned by Intermountain Power Agency (IPA), Intermountain Power Plant is an 1,800 MW coal-fueled power plant serving serving public power purchasers in six states including major purchasers in the LA Basin. It is underway to be repowered to an 840 MW combined cycle gas turbine capable of using a blend of natural gas and 30% green hydrogen upon commissioning in 2025.

Figure 5: Map of existing facilities that serve as current and/or potential future off-takers for hydrogen for HyDeal LA



1c. Extensive Storage Resources

At the current planning stage, HyDeal LA has identified potential resources to support large, utility scale storage of hydrogen. Storage resources anticipated to be available and that could be leveraged include:

- Salt cavern storage in Delta, Utah: Salt caverns in Utah are already in commercial use for natural gas products storage. They are also anticipated to be feasible for use as hydrogen storage. Similar formations in Texas have been storing hydrogen safely for many years. The caverns in Delta have the capacity to store over 5,500 tons of hydrogen, the equivalent energy capacity of 150,000 MWh. To take advantage of this storage, a dedicated hydrogen pipeline between Utah and LA would have to be constructed.
- Potential geologic storage systems located elsewhere are still under the evaluation phase and will require additional research for full development.

² Open Grid Europe: <https://oge.net/en/us/projects/get-h2-nukleus>

1d. Existing and Planned Hydrogen Refueling and Liquefaction Infrastructure

The Port of Los Angeles (POLA) and Long Beach (POLB) are respectively the largest and fourth largest container ports operating in the US. These two ports carry direct access to markets in Asia, South America, and globally. Over the mid to long term, liquefied hydrogen, and ammonia made from green hydrogen, are under serious consideration as alternative maritime fuels. Moreover, our region's ports are one of the largest producers of greenhouse gas and air pollutant emissions. POLA and POLB have both committed to stringent and aggressive decarbonization and emissions reduction commitments and goals, including replacement of polluting cargo handling and transport equipment with zero emissions equipment. These investments represent additional targeted refueling demand for hydrogen end use.

1e. Environmental Benefits and Compliance

The proposed HyDeal LA initiative directly supports multiple environmental benefits, while helping to fulfill locally adopted plans and requirements for emissions reduction and clean energy deployment. From an environmental compliance perspective, the proposed infrastructure development will require — to the extent that it leverages federal funding — National Environmental Policy Act (NEPA) compliance, in addition to state level environmental compliance. Generally, California's environmental regulations and requirements match or are more stringent than applicable federal requirements. The team has structured the proposed effort to support as many environmental benefits as possible, while minimizing impacts through careful planning and mitigation. Key environmental benefits of HyDeal Los Angeles focus on emissions reduction, as well as significant environmental justice benefits (see below). With any infrastructure deployment project, environmental impacts are possible, particularly for large scale linear facilities or new centralized production or conversion facilities. However, HyDeal seeks to minimize these effects to the extent practicable, including through advanced techniques, the upgrading and replacement of existing equipment required, and the strategic use of existing brownfield sites, permits, and right-of-ways for entirely new infrastructure.

1h. Carbon Capture Opportunities

Our vision is based on green hydrogen and does not evaluate opportunities for carbon capture and storage (aka blue hydrogen).

1j. Site Demographics

Please see Figure 6 below for demographics of communities near four LADWP natural gas thermal plants that can be converted to be powered by green hydrogen.

Figure 6: Demographics of Communities near LADWP Thermal Plants that can be converted to hydrogen power

Potential Offtaker (all thermal power plants)	City and Zip Code	Socio Economic Data	Racial Demographics ³
Scattergood	El Segundo, 90245	<ul style="list-style-type: none"> • 5.9% in Poverty: • Median household income: \$109,577 	<ul style="list-style-type: none"> • 71% White • 3.7% Black or African American • 10% Asian • 16% Latino
Haynes	Long Beach, 90803	<ul style="list-style-type: none"> • 16.8% in Poverty: • Median household income: \$63,017 	<ul style="list-style-type: none"> • 51% White • 12% Black or African American • 13% Asian • 42% Latino
Valley	Alhambra City, 91352	<ul style="list-style-type: none"> • 12.7% in Poverty: • Median household income, \$61,384 	<ul style="list-style-type: none"> • 22 % White • 2.2% Black or African American • 51% Asian • 35% Latino
Harbor	Carson City, 90744	<ul style="list-style-type: none"> • 8.7% in Poverty • Median household income, \$82,305 	<ul style="list-style-type: none"> • 27% White • 23% Black or African American • 26% Asian • 37% Latino

2. End Users for Hydrogen in the Region and Value Proposition

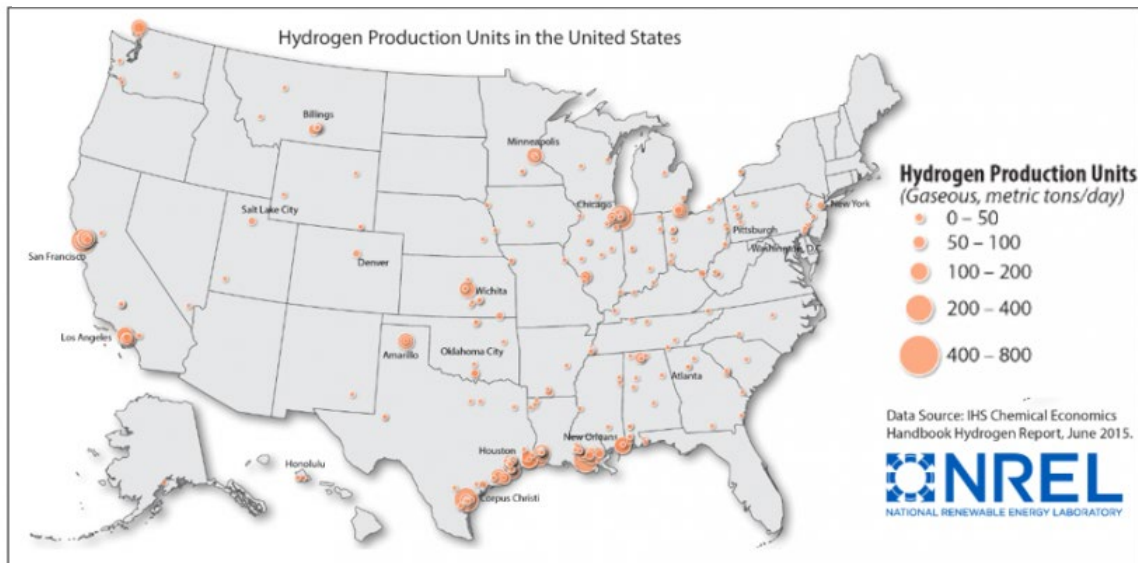
2a and b. Hydrogen End Users and Their Needs: Current and Future (2030)

The Los Angeles region has extensive existing and future hydrogen end users and off-takers. We consider “current” to be 2021, and “future” to be the target year of 2030. The ramp up between 2021 and 2030 is not yet well understood.

• Existing and Known Hydrogen Demand

- According to IHS, in 2015 the Los Angeles region produced over 200 metric tons of green hydrogen per day, or over 0.073 million metric tons (Mt_{H2}) per year. (Figure 6). Most of this hydrogen is produced to support refineries in the area.
- The Los Angeles region already has more hydrogen-powered passenger and commercial vehicles and more hydrogen refueling stations than anywhere else in the nation.
- California Executive Order N-79-20 requires 100% of all in-state sales of new passenger cars and trucks be zero-emission by 2035 and for medium and heavy-duty trucks by 2045. Hydrogen vehicles qualify as zero emission.
- The ports of Los Angeles and Long Beach, for example, are currently supporting development of and testing for innovative pilot projects that rely on hydrogen for drayage vehicles and other on-site usage.

Figure 7: 7 Hydrogen Production Units in the United States.



- **New Hydrogen Demand:**

HyDeal has identified over 2 million metric tons (Mt_{H_2}) of new hydrogen demand in the LA Basin by 2030. Of this amount, 0.6 Mt_{H_2} is considered “qualified” at this time, with an additional 1.7+ Mt_{H_2} identified as potential, but “unqualified,” additional off-takers. More aggressive targets can put LA demand at 10 Mt_{H_2} or more, especially if LA becomes an exporter of green hydrogen or green ammonia to countries like Japan. At this time, the amount of hydrogen required per day is not yet known.

“Qualified”, or probable off-takers, include LADWP thermal power plants Haynes, Valley, Scattergood, and Harbor, though commitments are not yet in place, and these off-takers are still in the evaluation phase.

Other unqualified off-takers may include oil refineries in the region, cement manufacturers who can use green hydrogen to as a thermal energy input to their energy intensive production processes, mobility fuels for heavy duty and other vehicles, fuel for mobility and aviation at airports, backup or distributed clean energy generation via fuel cells to support buildings, ports operations including the Port of LA and the Port of Long Beach, other industrial applications, and export opportunities for green hydrogen and green ammonia.

2c. Distribution Network and Geographical Footprint

Details on pipeline distribution network and geographical footprint are not currently available. However, DOE and Federal government leadership is essential to study, design and architect the connected network of clean hydrogen pipelines and storage facilities needed to serve multisectoral applications. A similar effort has been undertaken by European gas transmission operators called the European Hydrogen Backbone Initiative, and in Germany with the H2 Nukleus program. System modeling work completed for HyDeal Ambition in Europe as well as for HyDeal LA suggests a need for a network of hydrogen pipeline and storage infrastructure to achieve the \$1.50/kg delivered cost target. There are many potential industrial decarbonized

hydrogen hubs that would benefit greatly from a regional and ultimately national vision for building out shared infrastructure that will connect areas of low cost production with areas of high demand including export hubs like the Port of LA. A national hydrogen pipeline with non-discriminatory access and transparent prices will be critical to connecting low cost production with areas of high demand including export hubs like the Port of LA.

2d. Green Hydrogen Off-Taker Commitments

Currently, the main commitment for green hydrogen in LA is for LADWP to offtake power from Intermountain Power Project in Utah using a blend of 30% green hydrogen/70% natural gas by 2025. There could be commitments for other qualified and non-qualified off-takers as early as 2022 and 2023.

2e. Transportation Requirements

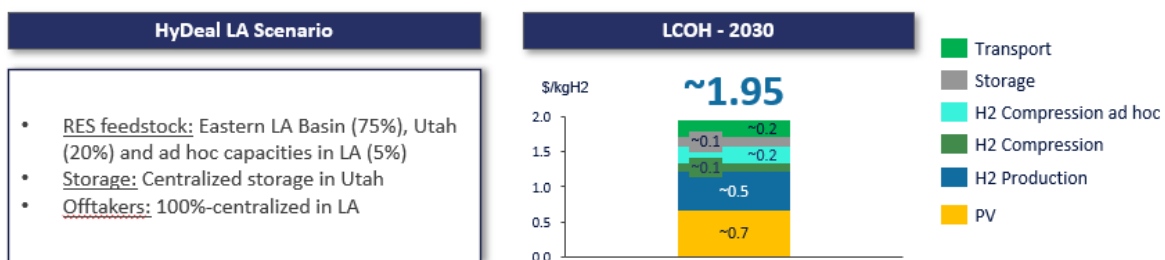
It is assumed that there will be modifications required to the pipelines to carry hydrogen at a blend higher than 10-20%, or when a dedicated hydrogen pipeline is required.

3. HyDeal Hydrogen Business Case

3a. Costs for all Stages of Hydrogen Use

In Figure 7, Levelized Cost of Hydrogen (LCOH) on a per kilogram basis is demonstrated based on HyDeal LA findings to date. Transport means pipeline, storage means bulk storage, compression refers to compression at the site of the electrolyzer, ad hoc compression refers to the energy required to compress hydrogen along the pipe, hydrogen production refers to the cost of the electrolyzers (up to 20 GW of capacity required) and PV refers to the purpose-built solar (photovoltaic) energy that will be required to provide electricity to the electrolyzers.

Figure 8: Typical Cost Scenarios for Green Hydrogen at Scale, Including Production, Storage, and Transport Based on Key Scenarios (Source: HyDeal Los Angeles courtesy of CVA)



Understanding the full CAPEX for a HyDeal LA or other regional green hydrogen cluster at scale will require details on the following major capital expenditures:

- Construction and land costs of new renewable power projects and related PPA prices
- Cost of any required transmission and permitting related to renewables for green hydrogen production
- Construction of hydrogen production facilities using electrolyzers
- Cost of electrolyzers
- Cost of repowering existing natural gas power production facilities to hydrogen, including price of new turbines and related equipment
- Cost of water and related water infrastructure

- Pipeline installation and upgrading
- Bulk hydrogen storage system development
- Energy storage systems to ensure stable hydrogen production from intermittent renewables
- Ammonia production: soft costs, CAPEX, OPEX, transport

3b. Anticipated Capital and Operational Costs

Capital costs for the proposed HyDeal LA project focused on achieving green hydrogen in basin at \$1.50/kg are in evaluation. If federal support is provided to cover costs of electrolysis, that would help reduce LCOH of hydrogen by 10-35 cents per kilogram.

3c. Local and Regional Policies to Support the Business Case

Currently there are some state policies to support the hydrogen business case in California:

- Low Carbon Fuel Standard for refineries and transportation
- Cap-and-Trade Cost of Carbon at \$100/ton for power plant producers

3d. Regional Trends and Commitments

There are many reasons that LA is leading the way in Green Hydrogen Momentum and Climate Action. The City of Los Angeles has already committed to an ambitious target of 100% renewable energy by 2045 under Mayor Eric Garcetti’s Green New Deal. During the Mayor’s Annual “State of the City” address in April, Garcetti announced that the city has accelerated that goal to 2035, and cited the critical role of green hydrogen for in-basin power plants.

Additionally, The LA 100 Study recently completed by NREL and LADWP found that hydrogen gas as part of renewably fueled combustion turbine is a “No Regrets Option” on the path to 100% renewable energy for the region.³

Figure 9: “No Regrets Options on the Path to 100% Renewable Energy.” LA 100 Study, Chapter 12.



³ Cochran, Jaquelin, Paul Denholm, Devonie McCamey, Garvin Heath, Daniel Steinberg, Elaine Hale, Bryan Palmintier, Matteo Muratori, and Ben Sigrin. 2021. “Chapter 12: Synthesis.” In The Los Angeles 100% Renewable Energy Study, edited by Jaquelin Cochran and Paul Denholm. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79444-12. <https://www.nrel.gov/docs/fy21osti/79444-12.pdf>.

In 2028, Los Angeles will host the world's most exciting sporting event, the Summer Olympics, at which point global attention will be on the city. LA can demonstrate its global leadership in hydrogen at this international convening.

3e. Economic Opportunities for Minority Communities

There are multiple economic opportunities for minority communities to be advantaged by HyDeal LA. For example, significant renewable energy capacity will be required to produce green hydrogen. Part of the HyDeal plan and vision is to seek opportunities within the Southwestern U.S. to collaborate with tribal Native American communities, through contracting renewable energy capacity – and possibly siting green hydrogen production centers – on tribal lands.

Lands that have been permanently set aside for the use of Native Americans, known variously as tribal lands and “Indian Country”, also turn out to be a vital energy resource. There are four types of such lands:

1. Those under the supervision of the United States government, held under the auspices and guardianship of the Bureau of Indian Affairs
2. Allotted lands that are subject to state and local taxation
3. Restricted status lands, where title to the land is held by an individual Indian person or tribe
4. State Indian reservations, lands held in trust by a state for an Indian tribe

A growing number of tribal communities who live on tribal lands are pursuing ambitious energy development goals to tap into existing significant resource potential. According to a 2018 study conducted by the National Renewable Energy Laboratory, while these tribal lands make up approximately 5.8% of the land area in the conterminous United States, the estimated utility-scale renewable energy technical potential on these lands is 6.5% of the total national renewable energy technical potential.

Producing clean hydrogen on tribal lands can also help replace traditional coal-generating and other existing energy sources with a clean, low emission resource. With additional federal support, dedicated renewables built to support HyDeal Los Angeles on tribal land could incorporate enough capacity to support a clean, hydrogen generating power stations for local Native American communities.

3f. Financing Mechanisms

The HyDeal LA initiative is seeking a multi-faceted approach to funding and fund development for the proposed program, recognizing that implementation costs cannot be borne by grant funding alone. As a result, the team is investigating and working to develop a funding portfolio that includes the following:

- Federal grants and low-interest loans
- State grants and low-interest loans
- Municipal bond-based funding
- Cash reserves

- Equity funding

Importantly, federal incentive funding for initial project development will be critical to the success of HyDeal LA. While experts around the globe agree that electrolytic pathways are poised for rapid cost reduction, the first projects, especially the first project of its kind in the US at scale, will be higher cost. Federal incentive funding to help offset the higher costs of early at scale projects including electrolysis equipment as well as hydrogen transport and storage will be incredibly helpful to jumpstart ecosystem and project development. The electrolytic ecosystem pathways identified in HyDeal LA point to a significant capital investment need to develop and install 20GW of electrolyzer capacity. The green hydrogen ecosystem and related infrastructure proposed for LA and the Ports will serve as a beachhead for additional green hydrogen hubs to connect to.

4. Hydrogen's Role in Enabling Grid Resiliency

Hydrogen can support a diversified and resilient, reliable grid for Los Angeles.

Although Los Angeles is the second largest city in the United States with transmission and generation resources throughout the western states, the NREL's LA100 study concluded that all paths to 100% renewable energy requires firm and dispatchable in-basin capacity. When energy demand spikes, it is crucial to have reliable, in-basin power generation from existing power plants. HyDeal Los Angeles initial phases focuses on converting existing natural gas-fueled power plants to green hydrogen-fueled power turbines, enabling the LA Basin to affordably maintain reliability with in-basin generation and reach zero-carbon goals.

5. Greenhouse Gas and Pollutant Emissions Reduction Potential

5a. Carbon Dioxide Emissions Reduction Potential

When fully implemented, the proposed vision will support the region's plan for a 100% renewable energy future, resulting in significant and substantial cradle-to-grave GHG emissions reduction, while effectively de-coupling GHGs from economic development and from Angelenos' daily lives. In total, our team estimates that full implementation of the vision will result in the offset of 30 million metric tons of carbon dioxide equivalents per year.

Emissions reduction potential was estimated on a life-cycle basis, considering offset of existing fossil fuel consumption in all affected sectors, including utility, residential, transportation, commercial, and industrial segments of the regional economy.

5b. Pollutant Emissions Reduction Potential

In concert with the vast anticipated reductions in carbon dioxide emissions reduction, the proposed vision will also support significant reductions in key criteria pollutants. Electrolytic hydrogen used in lieu of gray hydrogen and traditional fossil fuels will result in pollutant emissions savings across the board.

6. Diversity, Equity, Inclusion (DEI), Jobs, and Environmental Justice

6a. Stakeholder Engagement Opportunities

By the end of summer 2021, HyDeal LA aims to hold an educational briefing with relevant EJ organizations and targeted communities to build trust, foster collaboration, ensure EJ concerns are integrated into this effort, and get feedback from local community stakeholders.

HyDeal LA plans to establish an official Environmental Justice Steering Committee, recruiting representatives from these organizations (and possibly others), who will serve as advisors on all EJ aspects of HyDeal LA project scoping and development throughout all phases of the HyDeal LA project.

6b. Historically Underserved Communities

HyDeal LA will strongly support benefits to communities in the Los Angeles Metro region that have long suffered from environmental justice related concerns. Inner city areas of the region are characterized by excessively high pollutant loads—particularly associated with vehicle emissions from the transportation sector. HyDeal Los Angeles can help greatly reduce emissions, with the most significant benefits being realized specifically in those environmental justice and disadvantaged areas of the region. Thus the proposed vision will help to charter in a new era of reduced disparities in pollution burden for the most vulnerable communities.

6c. It is possible that renewable production and local hydrogen production could take place in distressed communities or on tribal land. There are multiple economic opportunities for minority communities to be advantaged by HyDeal LA. For example, significant renewable energy capacity will be required to produce green hydrogen. Part of the HyDeal plan and vision is to seek opportunities within the Southwestern U.S. to collaborate with tribal Native American communities, through contracting renewable energy capacity – and possibly siting green hydrogen production centers where feasible and acceptable – on tribal lands.

7. Job Opportunities

HyDeal LA will not only transition our energy future, it will also provide and develop a new cadre of advanced, skilled and well-paying jobs and opportunities for the LA region. The Green New Deal plan is designed to ensure every Angeleno has the ability to join the green economy by creating avenues to well-paying, green jobs. Green hydrogen is an economic engine that is well-positioned to employ California's skilled and trained workforce.



Goldman Sachs has identified green hydrogen as ‘the next transformational driver of the utilities industry’ and estimates that the globally addressable market will achieve nearly \$12 trillion by 2050 for the utilities industry alone.

One important piece of HyDeal is thermal plant conversions. Based on two-real world thermal conversion projects, the Coalition has identified the average job potential of converting one of California’s large thermal power plants to hydrogen turbines that uses electrolytic hydrogen from wind and solar. Scaling these numbers to even 10% of California’s approximately 200 gas fired power plants would translate to more than 41,000 peak construction and more than 2,500 ongoing operations skilled clean energy jobs. Combined with at-scale green hydrogen use in other sectors, the economic opportunity is significant and geographically dispersed throughout the state.

Figure 10: Jobs Associated with Thermal Plant Repowering

Job Type	Number of Jobs Created During Peak Construction	Number of Jobs Created for Ongoing Operations
Production	225	45
Storage	32	6
Pipeline	338	0
CCGT	1125	50
Associated Renewables	338	25
Total	2,058	126

**Job numbers assumes electrolytic production of the hydrogen with renewable wind/solar and above ground storage of the resulting hydrogen*

8. Environmental Justice (EJ) Communities

8a. GHC recognizes that there are historical inequities in energy and will seek to engage diverse communities with legitimate and substantive engagement on the development and progress of HyDeal LA.

8b. Overview of Efforts to Create Opportunity in EJ Communities

The HyDeal LA initiative involves a stakeholder engagement workstream, and one of the goals of this workstream is to support diversity and environmental justice (EJ) through the following efforts:

- Education and outreach efforts to key EJ and community stakeholders to educate about green hydrogen environmental benefits, inform EJ stakeholders of the HyDeal LA project plans, understand their areas of interest and concern, and solicit their feedback and possible formal collaboration on HyDeal LA efforts
- Target power plant conversions in historically disadvantaged communities as a pathway to reduce pollution and emissions and enhance community health
- Emphasize job creation and workforce training in historically disadvantaged and marginalized communities as part of the HyDeal LA infrastructure development process
- Fair treatment and meaningful involvement of all people in the LA metro area regardless of race, color, national origin, or income with respect to the development and implementation of key milestones in the HyDeal LA initiative

Summary of EJ Community Outreach to Date:



HyDeal LA has identified and prioritized outreach and engagement with the following Environmental Justice organizations, as we identified their work as being most aligned with the HyDeal LA goals of job creation and air pollution reduction:

- California Environmental Justice Alliance (SCG)
- Communities for a Better Environment (CBE)
- East Yard Communities for Environmental Justice (EYCEJ)
- Environmental Defense Fund
- GRID Alternatives
- Los Angeles Business Council
- Natural Resources Defense Council
- Pacoima Beautiful
- Physicians for Social Responsibility Los Angeles
- Sierra Club
- The Coalition for Environmental Health & Justice (CEHAJ)

HyDeal Los Angeles' EJ Education, Engagement & Partnership Goals:

1. By the end of summer 2021, HyDeal LA aims to hold an educational briefing with relevant EJ organizations and targeted communities to build trust, foster collaboration, ensure EJ concerns are integrated into this effort, and get feedback from local community stakeholders.
2. HyDeal LA plans to establish an official Environmental Justice Steering Committee, recruiting representatives from these organizations (and possibly others), who will serve as advisors on all EJ aspects of HyDeal LA project scoping and development throughout all phases of the HyDeal LA project.

Science and Innovation Needs and Challenges

9. Fundamental Science, Basic and Applied Research, and Information Needs and Challenges

The HyDeal team recognizes that additional scientific advancements will be beneficial in supporting the advancement and implementation of a real-world, full scale hydrogen transition for our region. To this end, we have identified the following fundamental and applied research and innovation needs:

- **Pipelines:** Technical potential and cost-effectiveness of repurposing use existing methane pipelines to carry hydrogen; materials compatibility; long term transition/use; hydrogen leakage rates and potential associated climate implications, together with implications on materials requirements and preferred hydrogen transport patterns to mitigate any identified climate impacts.
- **Electrolysis:** Large scale electrolysis that can be responsive to multiple users and applications, and ideally capture excess mid-day renewable production capacity.
- **Hydrogen Gas Turbines:**
 - Research is required to determine whether hydrogen turbines may increase NO_x emissions due to higher flame temperature and local hotspots if imperfectly mixed

- Need research on NO_x prevention in the turbine fuel combustor
 - Need advancements in DeNO_x technologies to mitigate NO_x post turbine
- Higher reactivity pushes flame towards burner and increases risk of explosion or flashback
 - Needed further research on 100% hydrogen ready turbines over 100MW (DLN combustor technology)
 - Needed further research on 100% hydrogen retrofit combustors for existing turbines that are 100MW+
- **Geologic Storage:** The GHC supports further research of geologic storage of hydrogen gas in California, which will be crucial to reducing the cost of delivered hydrogen to a \$1.50 in Los Angeles for HyDeal.
 - The large-scale storage of hydrogen gas is an enabling technology for a commercial hydrogen ecosystem. The most secure and economic approach is underground storage in natural or engineered salt caverns, as used by major companies around Houston, TX. However, salt deposits are rare geologic formations. The lack of availability of salt formations seriously restricts the establishment of hydrogen storage in California and elsewhere in the US. The GHC supports urgent and necessary research to understand the efficacy and feasibility of using depleted natural gas reservoirs for hydrogen storage in California. The injection of hydrogen into porous geologic formations raises new considerations. In particular, hydrogen gas is more diffusive, more chemically reactive and more biologically available than methane, suggesting there could be pathways for hydrogen losses that diminish roundtrip storage efficiency. The laboratory and field studies necessary to quantify and mitigate such potential losses are clearly defined, but only in recent years, however, principally in Europe, have has relevant work commenced. Working in the context of the UK's North Sea Transition Deal, for example, the EU-funded HyStorPore project has to date found only small evidence of hydrogen reactivity affecting storage in porous geologic media ⁴. The natural gas reservoirs in California's Central Valley are geologically distinct to the North Sea formations, requiring site-specific studies. As the CA formations are characterized by tight porosity reservoirs and low-permeability seals, however, they are expected to be effective for hydrogen storage.

10. Available Facilities

The Los Angeles region encompasses multiple global leading research institutions including the University of California at Los Angeles (UCLA), the University of California at Irvine (UCI), and the California Institute of Technology (Caltech), and many others. SoCalGas also oversees an extensive research and development program that includes coordination with other regional universities, national laboratories, and industry research groups and organizations.

⁴ Prof. Katriona Edwards, Director of HyStorPor, personal communication.

Additional Information

11. Near Term Funding Opportunities

Our team recognizes that fully funding the proposed HyDeal LA initiative will require multiple sources of funding. The identification of discrete, readily-fundable sub projects supports the funding development process, and will help to more rapidly advance the deployment process. Moreover, initial investments should be used to address and mitigate the most pressing and challenging issues and concerns, and de-risk the program. To this end, we recommend the following foundational, near term projects that will greatly support near term implementation of HyDeal LA:

- **Hydrogen Blending Investigation + Pilot facility (\$25-\$40M installed cost):** Use of repurposed methane pipelines will be a key cost-saving and time-saving component of the proposed infrastructure development process. Our team recommends prioritizing the demonstration of hydrogen transport through repurposed methane pipelines. Following a study to investigate and mitigate associated risks and constraints, including those associated infrastructure management, blending, and end use, the team will develop a pilot blending facility to demonstrate blending, hydrogen transmission, and distribution / use. Once feasibility is verified, a pilot blending facility will enable the demonstration, and will also be needed to support the near-term integration of hydrogen for use in available infrastructure. The proposed facility will be located in the Los Angeles Region. The blending rate is to be confirmed.
- **Depleted Natural Gas Reservoirs Investigation and Pilot (\$10-\$25M):** As discussed above, there are multiple potential depleted reservoirs that could be used for large scale hydrogen storage in the target region. This comprehensive investigation + pilot will identify, investigate, and mitigate key challenges associated with the use of depleted reservoirs for hydrogen storage, including hydrogen loss / attenuation, biological processes, natural geochemical processes, fate, and extraction. The investigation will then complete a pilot scale demonstration of large scale hydrogen storage.
- **Detailed Regulatory and Policy Study (\$5-\$10M):** The proposed vision will require multiple levels of regulatory compliance, as well as policy development to support the large-scale vision proposed under the HyDeal LA initiative. The proposed policy study will support and address the regulatory compliance process, while also enabling our constituent agencies and utilities to develop and update their policies as needed to align with the HyDeal LA initiative. The study will serve as a basis for other regions that are also working to develop similar hydrogen clusters.