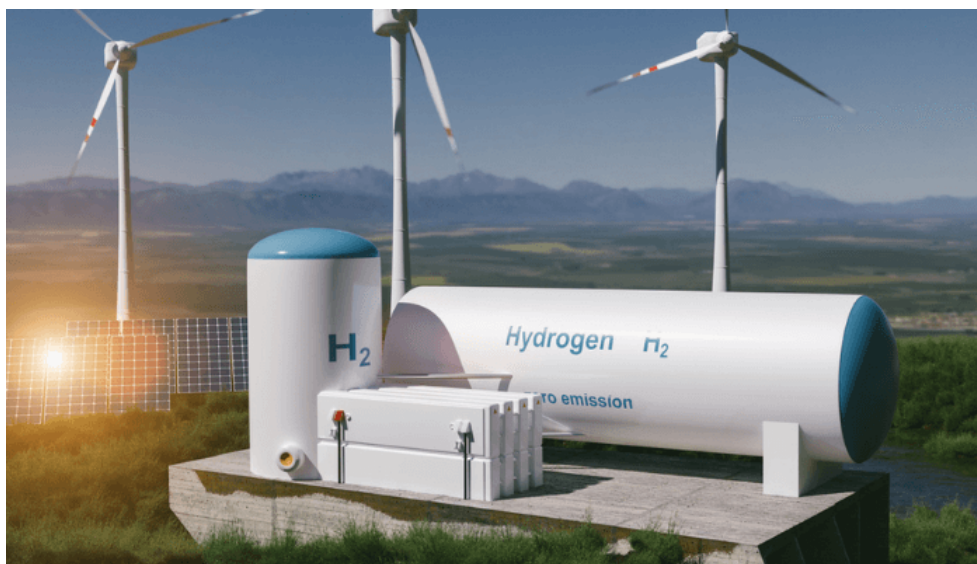




Identifying Geographic Feasibility for California's Hydrogen Hub

A Bren MESM Group Project Proposal | 2023 – 2024



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OBJECTIVES

This group project will identify key regions for siting hydrogen hub infrastructure in California for the California Governor's Office of Business and Economic Development (GO-Biz) to inform decisions of how to prioritize deployment. The primary objectives of this work are:

1. Determine key regions and locations for hydrogen production and distribution using data on existing infrastructure, industrial activity, land use policies, and socioeconomic trends.
2. Conduct geospatial multi-criteria optimization modeling based on the above criteria to discover locations with the most potential for rapid, environmentally-just implementation.
3. Recommend the geographic regions across California with characteristics most suitable for hydrogen hub components and provide estimates for hydrogen production capacity.

SIGNIFICANCE

In our national push to systemically transition to sustainable energy sources, hydrogen is positioned to serve a crucial role in the decarbonization of some of the most difficult to decarbonize energy systems. California's ambitious clean energy targets depend on the aggressive growth in supply and utilization of substitute energy sources. This requires an equally rapid build-out of production capacity and distribution. Hydrogen (H₂) possesses immense chemical energy potential making it an attractive substitute for fossil fuels used in certain heat generation processes. Electrification remains largely infeasible in the immediate future in the industrial and transportation sectors, where heat generators are used to produce steel, cement, and chemicals or power trucking and shipping.^{[1][2]} Hydrogen production is a resource intensive process with multiple methods of refinement that requires careful planning to ensure competitiveness with conventional fuels. The California government's strategy for H₂ prioritizes renewable hydrogen, which produces hydrogen from electrolysis using water and renewable electricity.^[3] Scaling renewable hydrogen in California will require a careful analysis of how to site and size hydrogen facilities to balance availability of both water and renewable electricity capacity with ease of distribution to users. This group project would assist the state of California in reaching its emissions reduction and zero-emission transportation targets, hastening the speed of the just energy transition.^[4]

BACKGROUND

California has been at the forefront of renewable energy and hydrogen adoption. A combination of electrification and hydrogen adoption is necessary to reach the state's decarbonization goals. Hydrogen has myriad potential uses in transportation, power, industry, residential and commercial buildings, and feedstock for chemicals. The California Energy Commission has spent over \$240 million on hydrogen projects between 2008 and 2021.^[5] However, hydrogen is still expensive to make and transport.^[6] Most of the hydrogen used in California now is imported from states like Arizona. The lack of infrastructure and low cost-effectiveness of hydrogen within California are bottlenecks to large-scale hydrogen adoption. In-state production of hydrogen fuel needs to expand to overcome these bottlenecks. According to the California Air Resources Board's 2022 Scoping Plan, "the scale of transition includes adding about 1,700 times the amount of current hydrogen supply."^[4] To scale this alternative fuel, California needs to create systems to manufacture and move renewable hydrogen to transportation, power, industrial, commercial and residential consumers across the state.

The federal Infrastructure Investment and Jobs Act, signed into law in 2021, gave the U.S. Department of Energy (DOE) responsibility for administering \$8 billion in funding for the H2Hubs program.^[7] Hydrogen hubs are defined as "a network of clean hydrogen producers, potential clean hydrogen consumers and connective infrastructure located in close proximity."^[7] To demonstrate the viability of clean hydrogen, H2Hubs will need to develop a full value chain for clean hydrogen. In 2022, GO-Biz created a statewide alliance, ARCHES, to partner with and submit a single state-wide application to the DOE for a federally co-funded hydrogen hub in California.^[8] Ramping up in-state production and distribution channels for

hydrogen will help lower costs and reduce multi-sector emissions.^[8] This will help California to meet its state-wide decarbonization target of net zero by 2045 by facilitating hydrogen adoption in power generation, heating buildings, and manufacturing processes.^[4] Additionally this will progress intermediate targets such as California’s goal of 100% zero-emission vehicles by 2035 for drayage trucks and off-road vehicles.^[9] Once deployment begins for the creation of the clean hydrogen hub, California will have the task of allocating resources in a way that produces a quick, environmentally-just rollout of hydrogen hub capacity.

EQUITY

Building hydrogen hub components in California contributes to an equitable and just energy transition by improves air quality and creating green jobs.^[8] Some of the communities which will reap the most air quality improvements from hydrogen adoption are those neighboring freight corridors and ports.^[8] The makeup of the communities most impacted by poor air quality are majority minority and low-income. By phasing out fossil fuel and substituting in hydrogen, there will be decreases in harmful air pollution exposure; thus reducing environmental health risks for asthma, cardiovascular disease, low birth rates, and more. The project team will analyze socioeconomic indicators and exposure to environmental pollutants like nitrogen oxide, sulfur dioxide, and particulate matter. By including these outcomes, the team will make hydrogen hub siting recommendations with the intent of reducing environmental impacts in disadvantaged and tribal communities.

AVAILABLE DATA

We expect publicly available data to be sufficient for the scope of the project. Most data will be used for the modeling which spans objectives 1 and 2. This modeling will balance the various layers of data to identify locations that intersect resource availability, favorable regulation, and energy equality. In addition to the sources listed here, GO-Biz will assist with additional infrastructure and economic data from their work with hydrogen projects, and from California state agencies and partners.

Hydrogen and water supply – Geospatial hydrogen production and demand forecasts alongside infrastructure cost estimates will be used to assess financial feasibility and future supply capacity at the county-level, which may be downscaled to a finer geographic resolution ([NREL HyDRA](#)). Water source locations, including wells and surface water, water quality ([USGS California Water Data](#), [California DWR Land Use Viewer](#)), and water transport infrastructure ([CNRA National Hydrography Dataset](#)) will be used to identify potential hydrogen production locations adjacent to water and renewable energy resources.

Renewables, power plants, and the electrical grid – Existing and planned solar and wind energy systems will be identified for powering electrolysis (California Energy Commission: [existing](#), [planned](#)), as well as grid transmission infrastructure to assess readiness for additional capacity ([California Energy Commission](#)). Solar and wind resource potential maps and levelized cost of electricity estimates ([NREL Renewable Energy Supply Curves](#)) will be used to identify sites for co-location adjacent to hydrogen. Facility-level fossil fuel generator data will be used to identify possible sites for equipment conversions from fossil fuel use to hydrogen fuel ([EPA flight](#)), while emissions data informs the air quality improvements from such conversions ([EPA National Emissions Inventory](#)).

Transportation – Roadway, rail, freight corridors ([Caltrans GIS Data](#)) and ports ([CA State Geoportal](#)) will be used to model proximity to major consumers and distributors. Locations of existing and planned fueling stations will avoid overlap with model recommendations ([H2FCP Fueling Station Map](#)).

Economics and equality – Industry clusters and regional business environments will inform potential centers of high demand ([Cluster Mapping](#)). Household energy and transportation burden ([NREL SLOPE](#)), disadvantaged communities ([CA ARB Priority Populations](#)), and pollution exposure maps

(OEHHA Calenviroscreen 4.0) will be used to identify locations where clean energy access particularly benefits low-income communities.

Regulation – Information on zoning (California Zoning Atlas), land use and land cover (USGS EarthExplorer) will be used to identify areas suitable for energy development. City and county permitting policies (Contractors State Licensing Board) will be used to assess deployment speed based on building requirements.

POSSIBLE APPROACHES

Wherever possible, the project will leverage existing hydrogen siting frameworks to reduce the amount of development required for the modeling and impact analysis.^{[9][10][11]} It will also prioritize completing all analysis steps for high demand end-uses, such as transportation and industry, before including additional dimensions. The proposed methodology is as follows:

1. Review literature and take stock of the feasibility of comparable methodologies:
 - Survey past studies using multi-criteria decision analysis for green hydrogen siting.
 - Explore potential technologies that could be used to produce or carry hydrogen, as well as existing fossil fuel infrastructure that is most suitable for conversion to hydrogen.
 - Evaluate the feasibility of using different kinds of water sources available for electrolysis.
2. Assess the regulatory landscape that could impact the deployment speed of hydrogen infrastructure, including CEQA, local zoning, and local permitting.
3. Use the identified data sources to estimate the amount of hydrogen production that is possible spatially across California based on proximity to water and renewable electricity.
4. Develop a geospatial model to optimize hydrogen production, distribution, and deployment speed based on the following: access to renewable electricity resources, availability of water sources, distribution coverage, demand for hydrogen, and infrastructure cost.
 - Utilize methods from previous research, which have examined and modeled hydrogen production and refueling placement independently, to consider the interconnection of infrastructure and build speed.^{[13][14][15]}
5. Estimate the amount of hydrogen that the recommended hydrogen hub sites can produce, and contextualize this with the quantity needed to meet California’s decarbonization targets.
6. Analyze the impacts of the proposed sites on reducing energy inequality.

DELIVERABLES

1. Data visualization using GIS mapping with layers for each metric and location model outputs, with modeling and code made publicly available for use.
2. Ranked list and map of recommended regions for hydrogen hub siting.
3. Report of methodology, findings, and recommendations to help GO-Biz facilitate and incentivize the development of hydrogen hub components.

INTERNSHIP

GO-Biz is committed to hosting one intern, either remotely or in Sacramento, during the summer of 2023. The intern will be mentored by Gia Vacin (MESM ‘09) and Tyson Eckerle (MESM ‘09) while furthering group project research and understanding of California’s hydrogen market. The intern will do this through working with GO-Biz in its capacities with the Hydrogen Fuel Cell Partnership, ARCHES, and its interagency hydrogen working group, as well as direct interaction with state agency leaders, staff and market stakeholders. The intern will gain exposure and contribute to the cross agency, multi-stakeholder work of GO-Biz to accelerate clean energy and zero-emission vehicle markets. Additionally, they will develop and deliver a short research project to inform next steps on key hydrogen policy or implementation.

APPENDIX

BUDGET

It is not anticipated for the proposed project to need funding beyond the \$1,000 contribution by the Bren School. GO-Biz is unable to provide additional funding.

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