Hawai‘i Natural Energy Institute Research Highlights

Energy Policy & Analysis

Hawai‘i Hydrogen Integration Study

OBJECTIVE AND SIGNIFICANCE: Act 140 “Relating to the Hawai‘i Hydrogen Strategic Plan” of the 2022 Hawai‘i State Legislature tasked HNEI to “examine the potential for the production and use of renewable hydrogen in the State and the potential role of renewable hydrogen in achieving a local, affordable, reliable, and decarbonized energy system and economy.” Results of this study are being finalized and will be submitted to the legislature ahead of the 2024 session.

In conducting this study, HNEI sought to identify and quantify the potential uses for hydrogen (H_2) in Hawai‘i and to quantify the potential to produce hydrogen locally to meet those potential uses. Based on a conservative estimate for hydrogen use in Hawai‘i, the required materials, energy, water, land, and infrastructure needed to serve that demand are quantified. These analysis are intended to determine the feasibility of large-scale hydrogen production and use across the state and whether Hawai‘i can play the role of a hydrogen exporter.

KEY RESULTS: Results of this analysis show that while there is a potential for hydrogen to reduce the carbon intensity of some end uses, it is not likely to make a significant contribution to Hawai‘i’s decarbonization efforts. With limited production potential on O‘ahu relative to potential demand, the cost and difficulty of interisland transport of hydrogen further limits its decarbonization potential.

Producing hydrogen using electrolysis is extremely energy intensive. Given the ongoing challenges of siting new renewable resources to meet existing electric power needs, the ability to develop sufficient renewable energy sources solely for hydrogen production to offset meaningful quantities of oil imports is likely infeasible with land use constraints and community acceptance being significant factors. Stated another way, while there is an opportunity for some business development around the production and use of hydrogen, it is unlikely to contribute to a meaningful reduction in our GHG emissions, outside niche sectors.

BACKGROUND: During the 2022 legislative session, multiple bills were proposed to encourage the development of an H_2 industry in Hawai‘i. HB 1611 proposed a State Energy Plan that specifically addressed firm renewable options, including H_2, across Hawai‘i. HB 1937 requested that HNEI develop a H_2 strategic plan for Hawai‘i, which examined the State's ability to advance hydrogen production from local renewable energy resources. The study shall consider hydrogen availability and feasibility locally, water usage, costs/benefits, identify end-use markets, permitting requirements, hydrogen for transportation and grid, techno-economic feasibility, and environmental benefits for resiliency, and include a comparison to imported hydrogen.

The interest in Hawai‘i for large-scale hydrogen production and use was further elevated by passage of the Inflation Reduction Act and the expectation of significant federal funding for a national network of hydrogen hubs intended to decarbonize “hard to abate” sectors including chemical (ammonia, steel, cement), transportation (long-haul trucking), and power (long-duration storage) sectors.

Beginning in 2022 and continuing through much of 2023, multiple stakeholders in Hawai‘i were actively pursuing DOE funding for a local “hydrogen hub” in the state. While Hawai‘i’s Hub proposal identified sufficient production potential to meet DOE proposal requirements, to our knowledge, there has not been a study to quantify and identify the means to produce the quantities of hydrogen needed to decarbonize the Hawai‘i energy economy. Additionally, we are not aware of any assessment of integrating hydrogen production in a high variable renewable energy grid. This study will serve as an initial basis for future hydrogen analysis in Hawai‘i as decarbonization goals progress.

While many stakeholders have identified and discussed potential uses for green hydrogen, little has been done to analyze: 1) the electricity required for its production, 2) the storage that may be necessary for implementation of a practical system, or 3) the full life-cycle cost associated with producing and using hydrogen in Hawai‘i. As part of this assessment under Act 140, the HNEI-Telos team conducted a detailed analysis to identify high-priority use cases, quantify the scale of potential hydrogen and electrolysis needs, and to simulate the production and storage requirements.

PROJECT STATUS/RESULTS: A review of the potential hydrogen demand by end use has been completed and informs the basis of assessing how Hawai‘i can meet the expected demand via local resources. The transportation and electric power sectors make up the bulk of petroleum usage in Hawai‘i, offering potential markets for hydrogen, but competition from direct electrification must be considered. Disaggregating the end-use sectors into more granular energy uses, such as shown in Figure 1, is required to assess electrification versus H_2 potential.

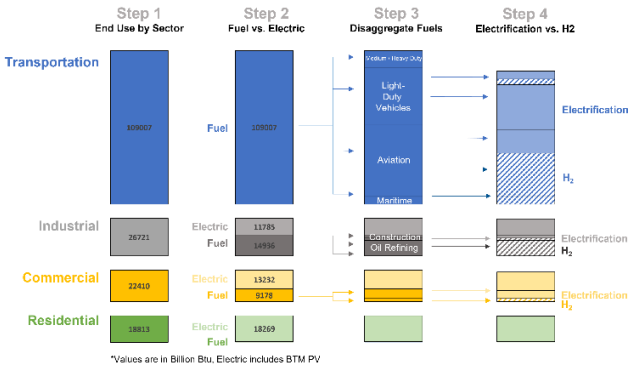

Figure 1. Example of the disaggregation of end use sector energy input into electrification versus H_2.

Based on an evaluation of potential end uses, the HNEI-Telos team identified four uses as being the most technologically mature with the potential for near-term deployment if clean hydrogen is available. These are:

- ***Aviation***: Production of sustainable aviation fuel (SAF) using hydrogen;
- ***Medium/heavy duty vehicles***: Buses and trucks, primarily those that need longer range are potential markets for hydrogen powered vehicles, although this application could be challenged by continued advancements in battery technology;
- ***Electric power***: Hawai‘i’s grids will need firm dispatchable power and seasonal storage to ensure grid reliability with high penetration of variable renewable generation; hydrogen for this application may be challenged by developments in long duration battery storage, biofuels, and advanced geothermal; and
- ***Oil refining/chemical processes***: Residual petroleum processing and industrial producers, such as Hawai‘i Gas, may have increased future hydrogen demand.

Based on this assessment, the end uses most likely to incorporate hydrogen were quantified using existing plans or by assuming a meaningful penetration of hydrogen use. Electric power needs were based on meeting the firm fuel needs for 2045 shown in HECO’s IGP plan, which is approximately 5% of electric energy. This assessment provides a meaningful scale of hydrogen use to inform the feasibility of producing quantities sufficiently large enough to benefit our energy systems.

Based on the penetration levels shown in column 2 of Table 1, the demand for H_2 was calculated.

Table 1. Act 140 study hydrogen end use estimate assumptions.

H_2 End Uses	H_2 Need Assumption	H_2 Mass Required (kg)
Ground Transportation	20% Trucks & 10% Buses	262,727,245
Aviation (SAF)	10% of annual jet fuel	15,067,000
Electric Power	5% of annual energy	37,894,099
Industrial (Hawai‘i Gas)	15% hydrogen in pipeline	839,500

Under the Act 140 study, the feedstock and energy requirements for producing hydrogen were assessed for each island by assuming production via biomass gasification or water electrolysis using renewable energy. Both of these methods require significant quantities of materials, energy, and land. Generally accepted values for conversion of organic feedstock or water into hydrogen (Table 2) were used to quantify the total input requirements.

Table 2. Conversion values for biomass gasification and water electrolysis to produce hydrogen.

H_2 Production Method	Conversion Factor
Gasification of Waste	13-20 kg waste/kg H_2
Gasification of Crops	10.5 kg biomass/kg H_2
Water Electrolysis	55 kWh/kg H_2

These conversion efficiencies with potential island by island demand were used to determine the capability of each island (O‘ahu, Hawai‘i, Maui, and Kaua‘i) to produce hydrogen to meet its own needs.

As the most populous island, O‘ahu would have potential markets for the largest amount of hydrogen

(64% of demand), which poses unique challenges since O‘ahu also has the lowest hydrogen production potential due to land constraints.

For H_2 production using renewable energy for water electrolysis, results indicate that in order to meet the estimated demand for hydrogen the statewide 2045 projected energy required (18,137 GWh) would need to more than double. Put another way, Hawai‘i would need to double its projected future electricity production to produce the equivalent of 326 million gallons of gasoline to meet demand (Tables 1 and 3). This scale issue is the most significant barrier to hydrogen playing more than a marginal role in decarbonizing Hawai‘i.

Table 3. Water electrolysis energy requirement to serve estimated hydrogen demand by island.

Island	Estimated H_2 Demand (kg/yr)	Energy Required (GWh/yr)
O‘ahu	207,153,703	11,507
Hawai‘i	57,006,330	3,166
Maui	44,665,492	2,481
Kaua‘i	17,702,323	983
Total	326,527,848	18,137

While hydrogen has limited potential for decarbonizing the Hawai‘i economy, the uses that have been identified represent significant opportunity for local business development. To inform this potential, the HNEI-Telos team then assessed production costs, storage, on-island transportation/storage needs, and inter-island shipping from Hawai‘i Island to O‘ahu. To support this work, we also conducted detailed grid modeling using the 2045 IGP portfolio integrated with electrolyzers to provide hydrogen for 5% of each island’s annual electricity demand.

Several electrolysis integration pathways were modeled to investigate different grid integration and production challenges for H_2 to serve electric power needs. These included:

- **No H_2 Resources**: the electrolyzer is added to the 2045 IGP grid with no additional resources, providing hydrogen only when there is surplus energy on the grid and battery storage is full;
- **Self-supply**: electrolyzers are powered by a separate portfolio of renewable energy resources and does not operate with the grid; and
- **Grid-supply**: the electrolyzers are powered by a separate portfolio of renewable energy resources, but those resources are integrated with the grid to also absorb curtailed energy.

Initial results of the grid analysis for the 2045 portfolio shows that water electrolysis can utilize a significant amount of the curtailed energy, but it is not sufficient to meet the 5% of electricity target. Additional renewable energy resources dedicated to hydrogen production are required to provide enough hydrogen to meet the 5% firm power need.

Results also indicate that using H_2 for electric power needs will require large-scale storage that would shift hydrogen seasonally. This poses a potential challenge due to large-scale infrastructure requirements where utilization will occur only during a few months of the year. The inclusion of additional end use demand in the next steps may alleviate this issue since storage would be used for multiple purposes.

The H_2 integration study will determine the operational requirements for future H_2 load to serve multiple purposes in the Hawai‘i energy economy and will inform the community on the feasibility of integrating large-scale hydrogen production using electrolysis and renewables. The study is expected to answer a number of important questions, such as:

- How much H_2 storage is required to meet H_2 end-use demands? How much storage would be required for long duration energy storage?
- What impact does H_2 load have on statewide electricity curtailments?
- How much additional renewable energy is required to serve H_2 production?
- What amount of load flexibility is useful from H_2 electrolyzers?
- What are the system losses and roundtrip efficiency of the H_2 system, inclusive of production, transportation, and storage of H_2 within the island?
- What impact will these potential hydrogen markets have on Hawai‘i’s GHG emissions?

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