NELHA and MTA Hydrogen Stations and Fuel Cell Electric Buses

OBJECTIVE AND SIGNIFICANCE: In 2022, HNEI commissioned a 65kg/day hydrogen production and dispensing station on the Island of Hawai'i at the Natural Energy Laboratory Hawai'i Authority (NELHA) (Figure 1) and demonstrated on-site fueling of an electric-fuel cell hybrid bus. The overall objective of the project is to evaluate the technical and financial performance and durability of the equipment, and support a fleet of three hydrogen Fuel Cell Electric Buses (FCEB) operated by the County of Hawai'i Mass Transit Agency (MTA). The knowledge gained in this project will inform the MTA on benefits and issues associated with transitioning from a diesel bus fleet to a zero emissions FCEB fleet in support of the County of Hawai'i's clean transportation goals. The knowledge will also help inform decisions on other islands.

Figure 1. HNEI's NELHA hydrogen station.

BACKGROUND: Development of hydrogen-based transportation systems requires infrastructure to produce, compress, store, and deliver the hydrogen; a means to dispense the fuel; and vehicles to use the hydrogen. The HNEI hydrogen station at NELHA has been designed to dispense hydrogen at 350 bar (5,000 psi). In place of ground-mounted tank storage, HNEI will demonstrate centralized hydrogen production and distributed dispensing with a fleet of three hydrogen transport trailers (HTT). High purity hydrogen produced at NELHA will be delivered to the MTA base yard in Hilo to support heavy-duty FCEBs operated by the MTA Hele-On public bus service (Figure 2).

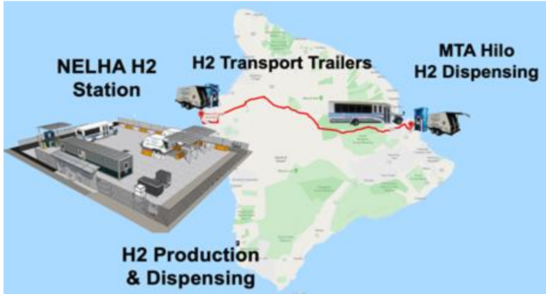

Figure 2. Concept of hydrogen transport.

PROJECT STATUS/RESULTS:

Hydrogen System: The NELHA hydrogen fueling station (Figure 3) was commissioned in 2021. The first fill of a hydrogen bus for public transportation took place on March 24, 2022.


Figure 3. HNEI's NELHA hydrogen station.

The station uses a Proton Onsite (now Nel) electrolyzer to produce 65 kg of hydrogen per day at an outlet pressure of 30 bar (440) psi. A HydroPak compressor (Figure 4) compresses the hydrogen to 450 bar (6,600 psi).


Figure 4. HydroPac compressor.

The system is powered by the Hawai'i Electric Light Company (HELCO) grid which includes a substantial fraction of renewable energy including solar, wind, and geothermal.

Three trailers (Figure 5) are available for transport between the production and fueling site and are certified by the Federal Transit Administration for use on U.S. public roads. The hydrogen cylinders must be recertified every five years.

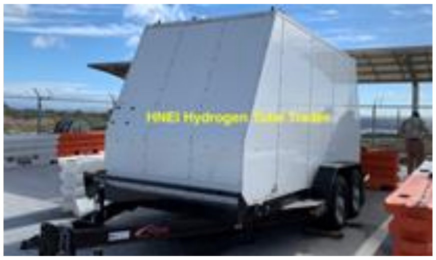

Figure 5. Hydrogen transport trailer.

The dispensing system (Figure 6) is connected to a fueling trailer via an underground hydrogen piping distribution system. The hydrogen dispenser is fully automated and programmed to "fail safe" for unattended operation.

Figure 6. Hydrogen station dispenser.

The fueling dispensers located at NELHA and at MTA are identical except for the addition of a boost compressor at the MTA site integrated into the MTA fueling post (Figure 7). The boost compressor system was developed to dispense up to 90% of the hydrogen stored in the HTT in order to reduce transportation costs by not having to return half-filled trailers to be refilled at NELHA.

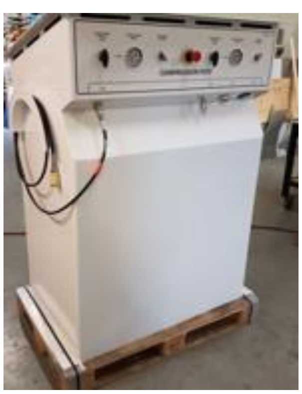

Figure 7. MTA boost compressor fueling post.

The Hele-On 21-passenger FCEB (Bus #111) (Figure 8) was purchased with funds from the Energy Systems Development Special Fund. This bus, manufactured by Eldorado National, and converted to a hydrogen-electric drive train by U.S. Hybrid, is ADA-compliant. Within the last year, the fuel cell power system was upgraded by replacing the original 30 kW Hydrogenics fuel cell with a new state-of-the-art 40 kW U.S. Hybrid fuel cell. Data on bus and fuel cell performance has been collected and is being analyzed.

Figure 8. Hele-On 21-passenger FCEB.

Onboard hydrogen is stored in composite carbon fiber cylinders located under the bus with a capacity of 19 kg. The fuel cell power system is integrated with two 11 kWh (total 22 kWh) LG Lithium-ion battery packs to provide motive power to a 200 kW electric drive system. At cruising speed, the fuel cell maintains the battery state of charge within a range that supports the long-term health of the battery.

During deceleration, the electric motor acts as a generator sending power back into the battery ("regenerative braking"). This contributes to overall system energy efficiency and improves bus mileage depending on the route topography and driver skills. A 10 kW export power system (Figure 9) was installed in the 21-passenger bus to enable the bus to provide 110/220VAC electric power at full power for up to 30 hours as emergency power for civil defense resilience operations when the grid power is down.

Figure 9. Bus export power unit.

In additon to the Hele-on 21 passenger bus, two 19-passenger FCEBs (Figure 10) were acquired by the MTA from Hawai‘i Volanoes National Park

(HAVO). These buses were converted by U.S. Hybrid and are of similar design to the 21-passenger FCEB. Onboard hydrogen capacity is 10 kg giving a projected range of 100 miles. These buses are being upgraded with 90 kW Hyundai fuel cells and one 33 kWh A123 Lithium-ion battery using funding provided by the County of Hawai‘i.

Figure 10. HAVO 19-passenger FCEB.

Figure 11 is a conceptual design of the hydrogen fueling dispensing system proposed to be located at the MTA base yard in Hilo which is comprised of repurposed, new equipment that was originally intended to support the two HAVO buses at Volcanoes National Park.

Figure 11. Concept design of MTA fueling dispensing station.

Hydrogen Station Energy Consumption: The total power consumption of the hydrogen system including the electrolyzer, compressor, and balance of plant is ~210 to 240 kW when operating at the maximum production rate of 65 kg/day (2.7 kg/hr). This corresponds to approximately 78 to 88 kwh/kg of compressed hydrogen. Table 1 provides the breakdown of the observed power usage.

Table 1. NELHA Hydrogen Station Observed Power Usage.

Electrolyzer in pre-start (no other equipment)	550	W
Electrolyzer in standby	740	W
Electrolyzer air cooler	260	W
Electrolyzer/Compressor room fans	800	W
Compressor Chiller	800	W
Electrolyzer filling/verifying A500 tank (air cooler)	850	W
Electrolyzer stack circulation state w/ air cooler	1.05	kW
A500 filling with electrolyzer room fan/air cooler	1.35	kW
Small compressor (only operates in short bursts)	1.5	kW
Full production with fans, compressor, chillers	210-240	kW

MTA FCEB Performance: The MTA buses are fitted with sensors and a data acquisition system that monitors bus system performance. Data is transmitted by cell phone telemetry to a remote computer. Outputs include powertrain energy consumption in kWh per mile and miles per kg of hydrogen. This data supports management of the bus fleet including identifying developing maintenance problems. The first bus (#111) travelled a total of 6,471 miles under fuel cell power.

This project has produced the following papers:

- 2020, A. Headley, et al., **Valuation and cost reduction of behind-the-meter hydrogen production in Hawai‘i**, MRS Energy & Sustainability, Vol. 7, Paper E26.
- 2020, M. Virji, et al., **Analyses of hydrogen energy system as a grid management tool for the Hawaiian Isles**, International Journal of Hydrogen Energy, Vol. 45, Issue 15, pp. 8052-8066.

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