Supporting a Hawaii Hydrogen Economy

Mitch Ewan

Hydrogen Systems Program Manager

Hawaii Natural Energy Institute

School of Ocean Earth Science and Technology

University of Hawaii at Manoa

13 August 2018

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hawaii Natural Energy Institute (HNEI)

- ✓ **Organized Research Unit in School of Ocean and Earth Science & Technology Founded in 1974.**
- ✓ **Conduct R&D&D to accelerate and facilitate the use of resilient alternative energy technologies and reduce Hawaii's dependence on fossil fuels.**
- ✓ **Partnerships with local, national and international organizations.**
- ✓ **Diverse staff (70): engineers, scientists, lawyers, students & postdoctoral fellows, visiting scholars.**

Core Functions

- Research & Development
- Technology Validation & Implementation
- Analysis & Modeling
- State Energy Policy Support
- Education & Training

Areas of Interest

- Alternative Fuels
- Electrochemical Power Systems
- Renewable Power Generation
- Building Efficiency
- Transportation
- Grid Integration
- Policy & Innovation

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

HNEI Fuel Cell/Hydrogen Research

- ✓ ***HI Sustainable Energy Research Facility***
  - **Testing fuel cell and battery systems for manned and unmanned vehicles;**
  - **Development of advanced air filtration for FC operations in high contaminant environments.**

- ✓ ***Marine Corps Base Hawaii* Dual *Pressure "Fast-Fill" H2 Fueling Station***
  - **Basis for design of public stations;**
  - **Unattended operation, 400 fills since Nov 2014.**

- ✓ ***Hydrogen Energy Systems for Grid Management***
  - **Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy;**
  - **Evaluate effect of multiple revenue streams on overall hydrogen costs.**

- ✓ ***Grid Analysis – Integration of renewables into Hawaii grid systems***

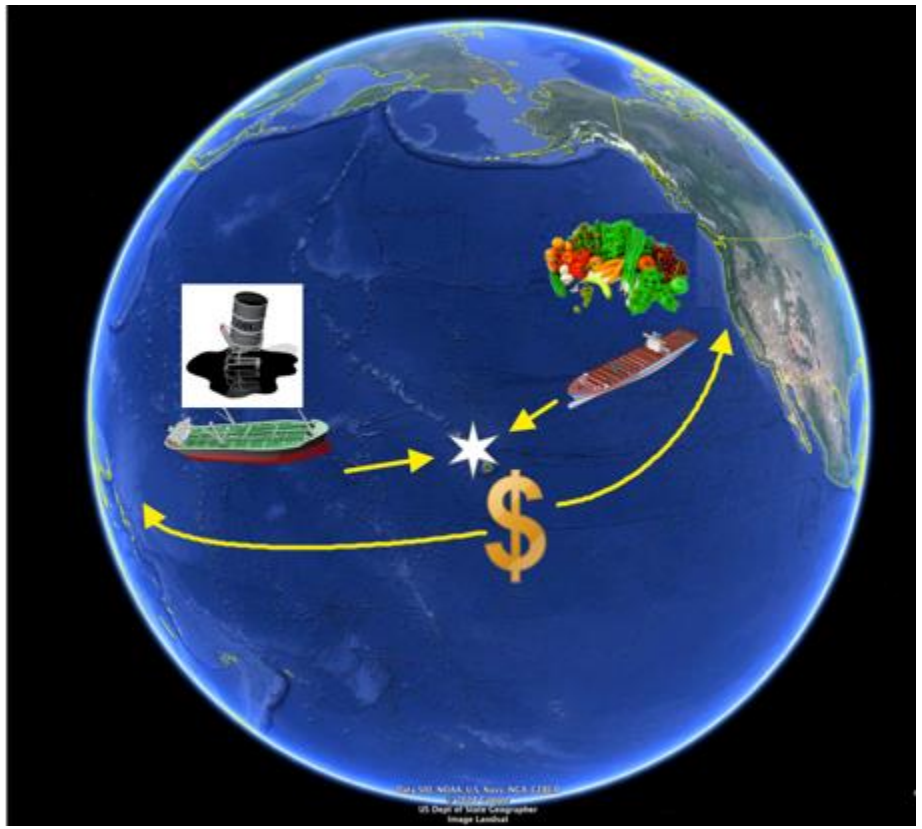
Why Hydrogen in Hawaii?

- ✓ **Potential to displace imported fossil fuels for transportation;**
- ✓ **Can be manufactured using any of Hawaii indigenous renewable energy resources;**
- ✓ **Energy security for Hawaii;**
- ✓ **Retains money in Hawaii which is good for the economy and jobs.**

CHALLENGES

Hawaii is Most Petroleum-Dependent State in US

68% of Grid Electricity Production
$11Billion leaves Hawaii economy*



Highest/Most Volatile Electricity Rates in US

* Based on $4B x 2.75 economic multiplier

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Fundamental Challenges

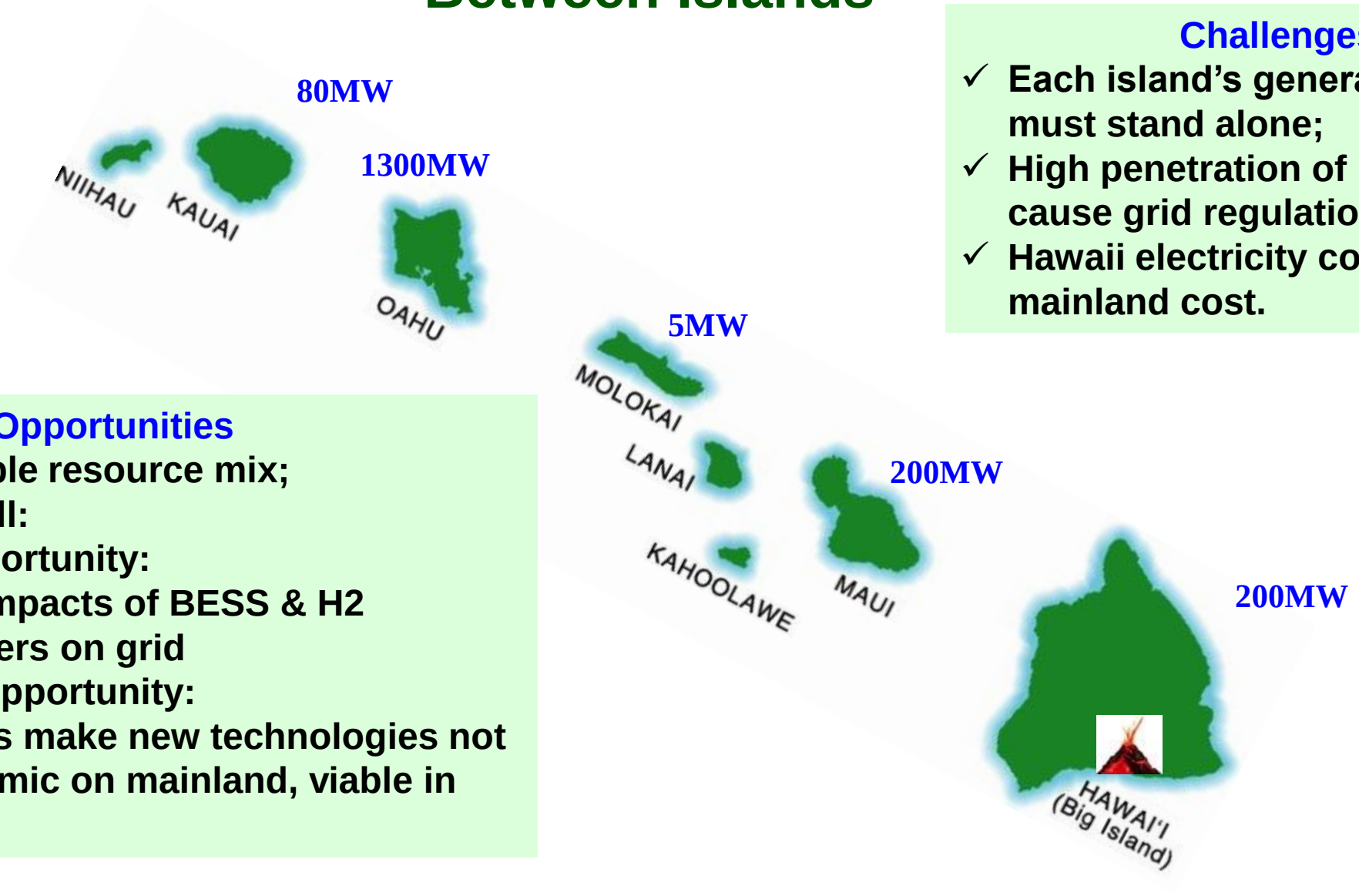
Over dependence on imported oil threatens:

- **Economy:**
  - **Electricity $0.30-$0.36/kWh, Gasoline $3.70+/gallon;**
  - **Syngas Residential $3.88/therm.**
- **Environment;**
- **Security; and**
- **Quality of Life of its residents.**

Solutions

- ✓ **Reduce Hawaii's dependence on imported oil for electricity and ground transportation @ prices that provide more stable and lower energy costs;**
  - ➢ **Aggressively reduce our energy use;**
  - ➢ **Add as much renewable energy as possible, as soon as possible.**

Challenge: No Transmission Interconnection Between Islands



Challenges

- ✓ Each island's generating system must stand alone;
- ✓ High penetration of renewables cause grid regulation issues;
- ✓ Hawaii electricity costs 3X to 4X mainland cost.

Opportunities

- ✓ Good renewable resource mix;
- ✓ Grids are small:
- ✓ Research Opportunity:
  - ➢ Validate impacts of BESS & H2 electrolyzers on grid
- ✓ Commercial Opportunity:
  - ➢ High costs make new technologies not yet economic on mainland, viable in Hawaii.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Fuel Cell Electric Vehicles have Arrived

Challenge: Hydrogen Infrastructure

Building Blocks for a Hydrogen Economy

1. **Political Will**
2. **Policies & Plans**
3. **Resources**
4. **Strategic Projects**
5. **Community Support**
6. **Strategic Partners**

We are addressing all 6 of these!

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

H2wai'i

Political Will

This is a key for early infrastructure projects

Hydrogen Policies & Plans

It is Hawaii State Policy
Enshrined in Law
to Establish a Hawaii Hydrogen Economy

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hawaii Renewable Portfolio Standards

GOAL: 100% Renewable Energy for Electricity by 2045
Achieved: 27.6% in 2017

- **30% 2020**
- **40% 2030**
- **70% 2040**




Hawaii's sun, wind, land, & sea resources can provide limitless amounts of hydrogen – forever!

Hydrogen for transportation and grid support could make an important contribution to meeting RPS goals.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hawaii Renewable Hydrogen Program

Objective: Transition state to a renewable hydrogen economy:

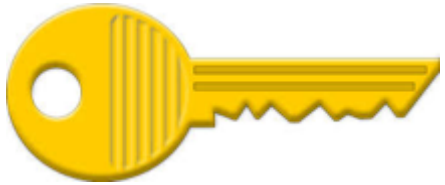
- ✓ **Strategic R&D, testing & deployment of renewable hydrogen technologies;**
- ✓ **Engineering & economic evaluations;**
- ✓ **Electric grid reliability & security projects to increase penetration of renewable energy;**
- ✓ **Hydrogen demonstration projects including infrastructure, storage, refueling hydrogen vehicles;**
- ✓ **Promoting Hawaii renewable hydrogen resources to potential partners & investors.**

Hawaii Hydrogen Implementation Working Group

- ✓ **Established by legislature**
- ✓ **Coordinates Hawaii hydrogen program.**
- ✓ **Major stakeholders represented:**
  - ➢ **Government, Industry, Academia**
- ✓ **Reports to legislature**
- ✓ **Meetings open to public**
- ✓ **Needs rep from Governor's Office.**

H2wai'i

Resources



HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hydrogen Investment Capital Special Fund

- ✓**Objectives:**
  - ➢**Provide seed capital and venture capital for private and federal projects for research, development, & testing;**
  - ➢**Implement the Hawaii Renewable Hydrogen Program;**
  - ➢**Any other purpose deemed necessary to carry out the purposes of the Hawaii Renewable Hydrogen Program.**
- ✓**Sources of Funds**
  - ➢**Appropriations made by the legislature;**
  - ➢**Contributions from public or private partners.**

Fund Status

- ✓ **Originally funded at $10 million;**
- ✓ **Originally managed by a VC:**
  - ➢ **Seed Funding – good ideas;**
  - ➢ **Cost Share for Federal Projects;**
  - ➢ **VC Investments up to $1 million.**

- ✓ **All initial funds dispersed;**
- ✓ **The special fund vehicle remains in place;**
- ✓ **Vehicle to accept additional funds;**
- ✓ **Now managed by State agency.**

Barrel Tax

- ✓ **Enacted in 2010**
- ✓ **$1.05 per barrel of oil excluding air transportation;**
- ✓ **Generates ~$30 million per year;**
- ✓ **60% goes to General Fund;**
- ✓ **40% goes to:**
  - ➢ **Oil Spill emergency clean-up fund**
  - ➢ **State energy office**
  - ➢ **State Department of Agriculture**
  - ➢ **Energy Systems Development Special Fund (HNEI)**
- ✓ **Hydrogen projects have received funding from HNEI allocation.**

Potential source for Hydrogen Fund Replenishment

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hydrogen Program Needs to be Cost Effective

- ✓ **Program needs to be seen as providing cost effective solutions/benefits:**
  - ➢ **What problems can hydrogen fix?**
  - ➢ **Is it affordable?**
- ✓ **Competing for scarce resources:**
  - ➢ **Long term vs. short term;**
  - ➢ **Do we fund hydrogen or air conditioners for schools? The kids are suffering today!**
- ✓ **Need success stories;**
  - ➢ **Technology validated;**
  - ➢ **Affordable.**

Need champions.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Must Keep Community Informed

- ✓ Need to justify investment of taxpayer dollars to the taxpayer;
- ✓ Public needs to see an immediate benefit to them:
  - ➢ Public transportation vs. perception of supporting “rich man’s toys”;
  - ➢ Leverage public infrastructure for private transportation for early adopters.
- ✓ Workforce development for the new jobs created;
- ✓ First Responder training helps address safety concerns;
- ✓ Legal and insurance industries need to be educated;
- ✓ Active public outreach campaign

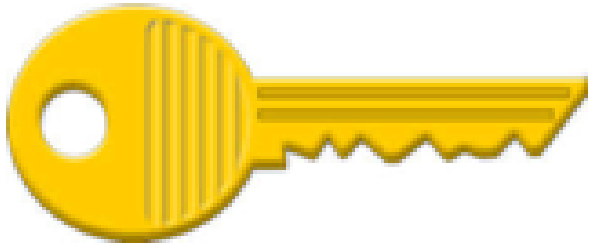
Community: First Responder Training

- Trained 300 first responders from Oahu and Big Island;
- Classroom & field work covering hydrogen and electrical;
- Live fire with “Burn Prop”;
- Enthusiastic reception by fire departments and civil defense.

Effective public outreach & promotes community acceptance.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

PROJECTS



Projects Need to be Strategic

- Need to demonstrate the economic viability and benefits of the technology.
- Will not get private investment until the numbers work out relative to other options.

Strategic Focus for Hawaii

- ✓ **Demonstrate cost effective infrastructure to produce, distribute, and dispense hydrogen;**
- ✓ **Focus on fleet vehicles starting with public transportation & county trucks;**
  - ➢ **Central fueling - 30 kg per day per bus;**
  - ➢ **Public benefit - tax dollars support public transportation needs;**
- ✓ **Industry will take care of the vehicles;**
- ✓ **Support early heavy users of hydrogen to develop a hydrogen market.**

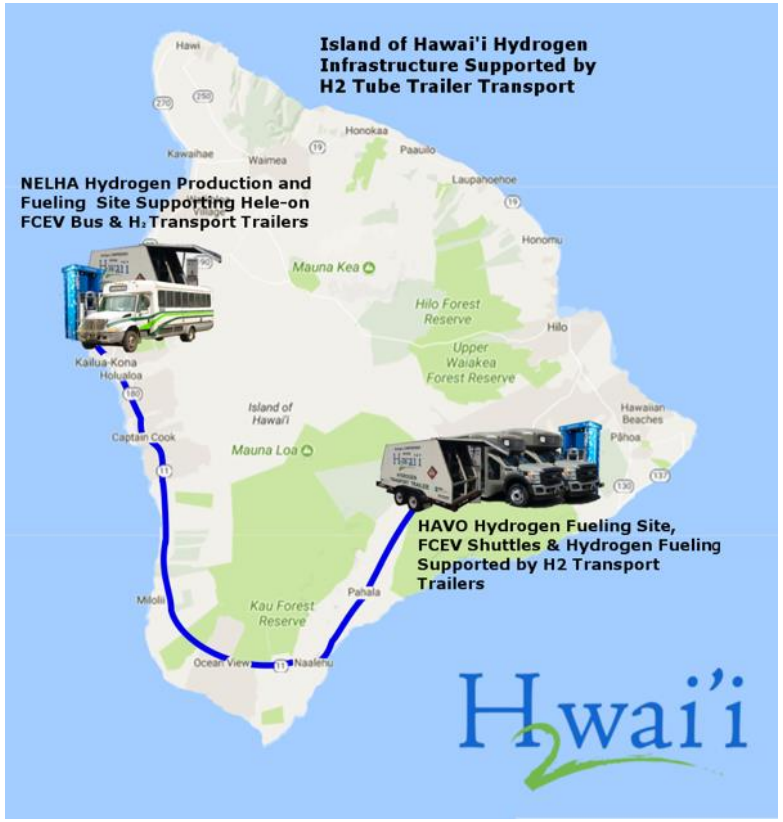
Private industry will take over infrastructure when it sees it can make money.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Hydrogen Energy Systems for Grid Management

- ✓ **Use electrolyzers to mitigate the impacts of intermittent renewable energy by regulating grid frequency;**
- ✓ **Characterize performance/durability of commercially available electrolyzers under dynamic load conditions;**
- ✓ **Supply hydrogen to shuttle buses operated by County of Hawaii Mass Transit Agency, and Hawaii Volcanoes National Park;**
- ✓ **Conduct performance/cost analysis to identify benefits of integrated system including grid Ancillary Services & off-grid revenue streams; and**
- ✓ **Evaluate effect on reducing overall hydrogen costs offset by value-added revenue streams.**
- ✓ **First step in developing hydrogen infrastructure.**

Big Island Hydrogen Project



- ✓ **Central site production for highest capital utilization;**
- ✓ **Distributed dispensing sites with minimum complexity to reduce fuel distribution costs;**
- ✓ **Optimize additional revenue streams from:**
  - ➢ **Monetizing ancillary services;**
  - ➢ **Sale of hydrogen for transportation.**

Economically viable electrolytic hydrogen will require low cost electricity + high capital utilization.

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

Project Objectives

- ✓ **Evaluate dynamic response of electrolyzer-based hydrogen production system for potential use as demand response tool;**
- ✓ **Develop dynamic models of system to identify hardware and control limitation to cycling;**
- ✓ **Evaluate durability of electrolyzers used as a variable load;**
- ✓ **Provide hydrogen fuel to bus demonstration projects island-wide;**
- ✓ **3 hydrogen buses currently available.**

NELHA Hydrogen Plant

- ✓ **65 kg/day, 275 kW PEM electrolyzer/compressor production system housed in 40 foot ISO container;**
- ✓ **3 hydrogen transport trailers;**
- ✓ **350 bar dispenser fuels 29-passenger shuttle bus;**
- ✓ **Powered from grid ~ 50 to 83% renewable energy;**
- ✓ **Automated system for unattended operation;**
- ✓ **Remote monitoring.**

Site Preparation

Excavation

Concrete Pad

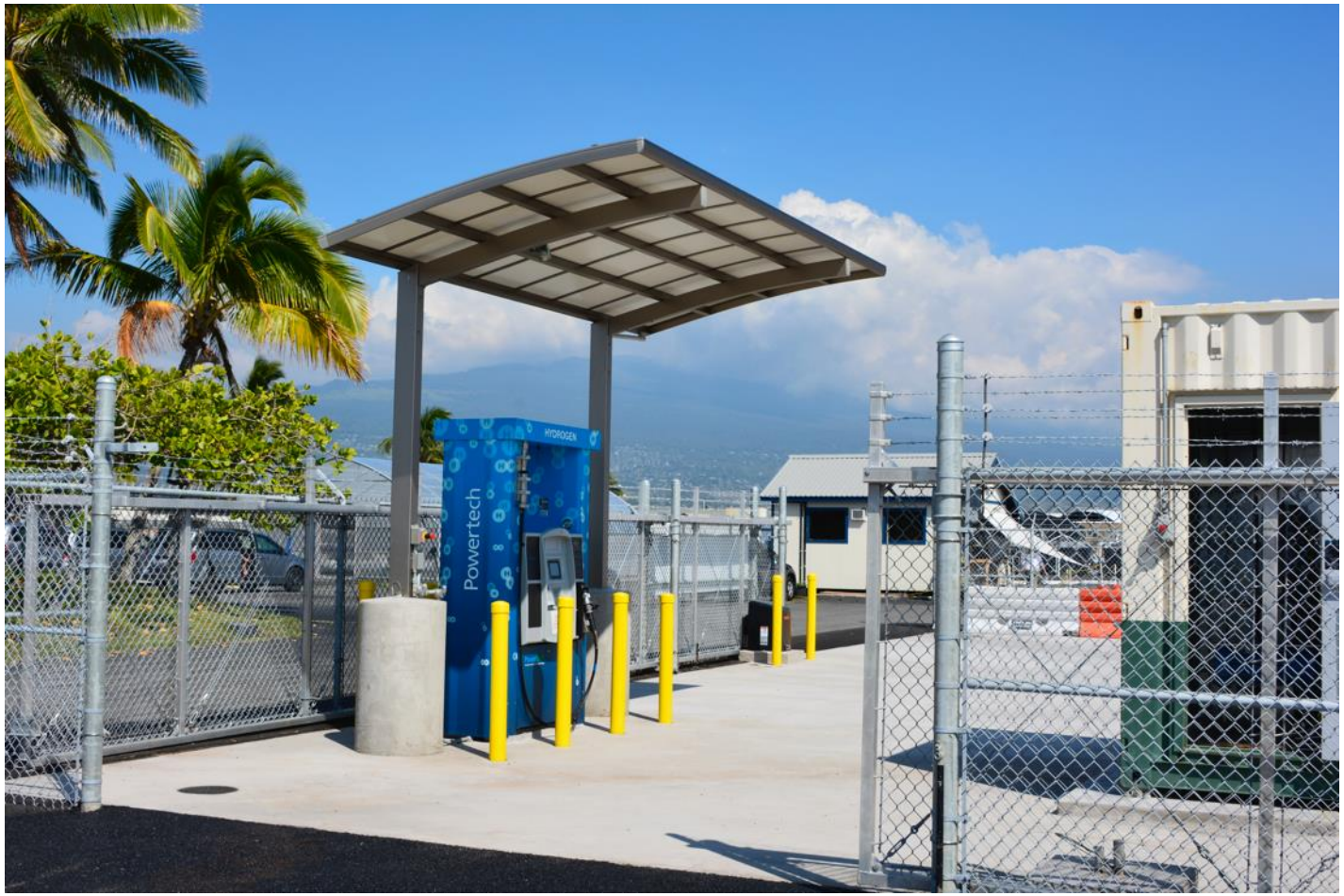
Equipment Installation

Setting Equipment
20-ton Lift

Site Work Completed

Tube Trailer Filling Bays

Hydrogen Dispenser



Hydrogen Transport Trailers

- ✓ **Hydrogen Transport Trailer carries 105 kg @ 450 bar;**
- ✓ **Demonstrate distributed dispensing using cascade fill to 350 bar using a "Smart" dispenser;**
- ✓ **Trailer O&M costs will be evaluated including US DOT hydrostatic testing requirement every 5 years;**
  - ➢ **Currently no facility in Hawaii can hydro test cylinders of this size:**
  - ➢ **Must be shipped to mainland (very costly and time consuming);**

Converted 3 Hydrogen Buses

County of Hawaii Bus (1) 29 Pass

HAVO Bus (2) 19 Pass

- ✓ **Hawaii MTA Fuel Cell Electric Hybrid Shuttle Buses demonstrate to the general public the advantages of fuel cell buses and electric drive.**
  - ➢ **Quiet ride;**
  - ➢ **No diesel fumes;**
  - ➢ **Potential for lower O&M costs (need low cost hydrogen).**
- ✓ **HAVO Buses will demonstrate HNEI's "Smart" air filtration sensor systems in a high air contaminant environment.**

DoD/GM Equinox FCEV Deployment

MCBH Hydrogen Fueling Station
Fueling GM Equinox FCEV

Marine Corps Base Hawaii Dual Pressure "Fast-Fill" H2 Fueling Station

- ✓ Basis of design for public stations;
- ✓ 700/350 bar dual pressure "Fast Fill";
- ✓ Supports GM Equinox deployment project;
- ✓ Containerized system by Powertech;
- ✓ 700 bar fast fill required significant electrical upgrades;
- ✓ Several codes & standards issues identified for containerized systems;
- ✓ HNEI developed data acquisition system.

Fuel Cell Electric Buses for the Big Island

County of Hawaii Bus (1)
29 Pass, 200 miles

HAVO Bus (2)
19 Pass. 100 miles

- ✓ **Fuel Cell Electric Shuttle Buses demonstrate to the general public the advantages of fuel cell buses and electric drive.**
  - ➢ **Quiet ride;**
  - ➢ **No diesel fumes;**
  - ➢ **Potential for lower O&M costs;**
  - ➢ **An experience for thousands of people.**

Option: 10kW Export Power Unit

- ✓ **Allows bus to power a critical load in a civil defense emergency.**
- ✓ **Can deliver 10kW for 32 hours**
- ✓ **AC Output: 110/220 VAC 60 Hz**
- ✓ **Stand alone operation**
- ✓ **Efficiency: 94%**
- ✓ **Can refill hydrogen tank in 15 minutes and get another 30 hours.**

Program Safety

- ✓ **Supplier (Powertech) has extensive experience in designing and building similar hydrogen systems.**
- ✓ **Subsidiary of BC Hydro (multi $billion government owned utility);**
- ✓ **Design meets national and international codes and standards;**
- ✓ **Rigorous hazards and operability (HAZOP) analysis part of design process;**
- ✓ **Independent third party inspection and certification;**
- ✓ **Systems will be operated and maintained by experienced professionals;**
- ✓ **Safety training for all personnel including hydrogen delivery drivers and bus operators.**

Education & Social Acceptance

- ✓ **Passing from limited use by trained workforces to public use will require a balancing of existing regulations;**
- ✓ **The use of hydrogen as an energy carrier is a relatively new concept and may be vulnerable to erroneous public perceptions;**
- ✓ **Education is essential and must provide information on safety as well as emphasizing the environmental advantages of hydrogen as a fuel.**

Contact Information

ewan@hawaii.edu

Land Line: 808-956-2337

Cell: 832-212-6129

Website: www.hnei.hawaii.edu

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa