Hawaii Hydrogen Center for Development and Deployment of Distributed Energy Systems

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This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Project comprised of 4 stand-alone tasks coordinated under one project.

Timeline
- Start - October 2004
- Finish - December 2008
- 95% Complete

Budget
- Total project funding
  - DOE $4.1 million
  - Cost share $1.2 million
- Funding received in FY04
  - $3.1 million
- Funding received in FY05
  - $1 million

Cost Share Partners
- ClearFuels Technology
- GE Global Research Center
- Hawaii Department of Business, Economic Development, and Tourism
- HELCO/HECO
- The Gas Company
- AirGas
- New Mexico Tech
- Hawaiian Commercial & Sugar Co.
- Center for a Sustainable Future
- PICHTR
- Sandia National Laboratory
- Sentech

Future Partners
- Puna Geothermal Venture
- Volcanoes National Park
- HCATT
- E-Nova Power Systems
Barriers

Task 1: Hawaii Hydrogen Power Park - Completed
• B, C, E, H, I: Technology Validation
• G, H: Hydrogen safety

• A, C: Fuel Cells – Durability and Performance

Task 3: Renewable Hydrogen Production: Biomass – 90% Completed
• S: Biomass Gasification – Feedstock Cost
• T: Biomass Gasification – Cost and Efficiency

Task 4: Big Island Energy Road Mapping - Completed
• B, C, D, H, I: Technology Validation
Objectives

Task 1: Hawaii Hydrogen Power Park: (Ewan)
• Develop integrated renewable hydrogen system (electrolyzer, hydrogen storage, and fuel cell) to characterize component & system performance
• Develop & validate control protocols
• Collect performance and cost data
• Conduct outreach to local authorities and the general public

Task 3: Renewable Hydrogen Production: Biomass: (Turn)
• Evaluate H₂ yield potential of Pearson Technologies’ gasification process
• Characterize technologies for tar reforming and H₂ purification

Task 4: Big Island Energy Road Mapping: (Rocheleau, Surles)
• Develop strategic energy roadmap to identify economically viable technologies to transform the Big Island energy infrastructure.
• Develop and validate baseline models for electricity and transportation.
• Identify scenarios to facilitate acceptance of emerging new energy systems including hydrogen.
Approach

Task 1: Hawaii Hydrogen Power Park
- Leverage existing renewable infrastructure at Kahua Ranch to establish integrated PV-wind-electrolysis and fuel cell test bed.
- Collaborate with SNL modeling group for economic and engineering analysis
- Use internet to leverage Power Park infrastructure for education & outreach

Task 3: Renewable Hydrogen Production: Biomass
- Leverage investment by ClearFuels LLC in biomass gasification to assess direct hydrogen production feasibility using Pearson Technologies pilot plant in Aberdeen, Mississippi
- Develop skid-mounted, producer-gas clean-up test bed to include tar reforming and hydrogen purification

Task 4: Big Island Energy Road Mapping
- Collaborate with GE Global GRC and island utilities to develop integrated energy model for Big Island
- Work with stakeholder groups to identify scenarios for evaluation, demonstration and deployment of DER technologies
Technical Accomplishments/Progress/Results
Task 1: Hawaii Hydrogen Power Park

HFCTF Component Evaluation
- Load-following, pressurized PEM electrolyzer (175 psi) from EH Inc. tested.
- Worked with EH to upgrade electrolyzer stack and refine system design by providing test data and equipment failure reports.
- Electrolyzer efficiency increased from 36% to 50.2% (HHV)

- All equipment installed and commissioned.
- Safety review completed. Ranch personnel safety brief.
- Extensive testing to ensure “fail-safe” operation.
- Over 60 days of operational data collected and analyzed.
- System operated remotely over the internet.

Public Outreach
- Daily slide presentation presented to public at the Hawaii Gateway Energy Center by the Friends of NELHA.
Kahua Ranch Power Park System

- Eliminated diesel generator
- Component & system testing
- Education and outreach
Hydrogen System Components

Excess RE
Hydrogen Production

\[ 2 \text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]

Electrolyzer Eh!
2 kW, 48 VDC, 0.2 Nm\(^3\)/h, 12 bar

Deionized Water Tank

Deficit of RE
Electricity Production

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

Fuel Cell Plug Power
5 kW, 48 VDC, 4 Nm\(^3\)/h, 2 bar

Hydrogen Storage
9 bottles, 50 liters, 12 bar (175psi)
452 g of hydrogen or 5.4 Nm\(^3\) or 17.8 kWh (HHV)
Interface/Control System

- Designed for fail-safe operation
- Optimizes the energy management in the system.
- Visible and controllable over internet.
Kahua Ranch Layout

- Wind Turbine
- PV
- Office
- Electric Room
- Battery Room
- Hydrogen Storage
- WT for pumping (out of order)
Installation at Kahua Ranch

- Breaker Box
- HNEI Interface
- Gas Supply
- Water Tank
- Gas Panel #2
- N2 Supply

- Emergency Buttons (3)
- Battery Room Door
- Fire Sensor
- Firewall

- Signs and Labels
- Gas Storage anchored and grounded
- Fence
Data Visualization and Remote Control

Visible on the project web site (Available on Request)
First conclusions

Eh! electrolyzer (adapted design)
- Short warm up period (5 min)
- Delivers hydrogen in only 3 min
- 50.2% efficient (HHV)

Plug Power FC unit
- Adapted FC low bus mode to Kahua Ranch DACS
- 34.3% efficient (HHV)

Hydrogen Storage System Efficiency
- Over 68 days of operation overall average system efficiency of between 12% and 17%* (HHV)
- Areas for efficiency improvement:
  - Lower losses
  - Decrease FC power (oversized)
  - Co-Generation: Heat + Electricity

* With new EH stack
Technical Accomplishments/Progress/Results
Task 3: Renewable Hydrogen Production: Biomass

• Parametric tests conducted at Pearson Technologies’ 5 ton/day pilot plant at Aberdeen, MS
• Hydrogen yields up to ~180 lb/ton biomass (90 kg/tonne) without gas upgrading demonstrated
• Clearfuels building 50 ton/day plant at G&R on Kauai (F)
• HNEI to have access to slipstream for testing of gas clean up and conditioning and hydrogen technologies (F)
• Kauai facility to serve as anchor site for biomass/biofuels RD&D

Product gas yield as function of residence time showing hydrogen concentration up to 55%
H₂ from Biomass Gasification: Sulfur contaminant speciation and removal

Dry Producer Gas Composition
H₂ – 60.6%  CH₄ – 5.8%
CO – 10.4%  CO₂ – 22.6%

ZnO Bed Operating Temperature
- 350°C
- 400°C
- 450°C

ZnO Bed Exit, ppm volume

H₂S Inlet = 50 ppmv

C₄H₄S Inlet = 1.5 ppmv

COS Inlet = 1 ppmv

Dry Producer Gas Composition

H₂ – 60.6%  CH₄ – 5.8%
CO – 10.4%  CO₂ – 22.6%
Technical Accomplishments/Progress/Results
Task 4: Big Island Energy Road Map

- Developed and validated baseline models for electricity (dispatch & stability) and transportation
- Identified & evaluated scenarios for deployment of new energy systems
Electricity Model Validation

Transient Performance (GE PSLF™)
- Full network model, incorporating generator governors and AGC
- Transient stability simulation
- Long-term dynamic simulation
- Major dynamic fluctuations accurately characterized by model

Production Cost (GE MAPS™)
- Representation of dispatch and unit commitment rules
- Hour-by-hour simulation of grid operations for a full year
- Annual unit dispatch from model within 1% of actual grid operations
Transportation and Electricity Systems
Models Developed

INPUT

TRANSPORTATION
- Fleet breakdown
- Fuel types
- Vehicle types
- Driving patterns

ELECTRICITY
- Unit Dispatch / Commitment
- Heat rate / Emissions
- Start-up / O&M costs
- Power purchase agreements
- Transmission system model
- Load forecast
- Fuel price

OUTPUT

Fuel demand forecasts
Fuel price projections
Emissions
Land use for biofuel

GE Power Systems Tools

Economy: cost of service ($/mile)
Environment: CO₂ (net & tailpipe)
Energy Security: % land use
Sustainability: % renewable

Economy: cost of electricity ($/kWh)
Environment: CO₂, SOₓ, NOₓ (tons)
Societal: Reliability & Power Quality
Sustainability: % renewable

Future scenarios may include H₂ use, high wind penetration, economic dispatch etc.
Future Work

• **Task #1: Hydrogen Power Park**
  • Use Kahua Ranch for education & outreach. HNEI teamed with Bishop Museum for DOE education proposal (pending).
  • Expand internet bandwidth to allow public viewing of system operation.
  • Install hydrogen fueling infrastructure at Hawaii Volcanoes National Park (HAVO) to support up to 5 hydrogen hybrid shuttle buses as continuation of SEP Power Park project.

• **Task #2: Hydrogen Fuel Quality Assessment**
  • Work continuing under separate agreement with NREL.

• **Task #3: Renewable Hydrogen Production: Biomass**
  • Work continuing under separate agreement with DOE.

• **Task #4: Big Island Road Mapping**
  • Work continuing under separate agreement with DOE.
  • Roadmapping/analysis underway for other major islands.
HAVO Renewable H2 Fueling Station

- Power Park to provide hydrogen infrastructure to support hydrogen shuttle bus program at Volcanoes National Park (HAVO)
- Over 2 million park visitors annually. Hawaii’s biggest tourist attraction.
- Supports NPS “Climate Friendly Parks” program to reduce carbon footprint.
- HAVO has facilities & team of tour guides for public outreach:
  - Visitor Center theater and interpretation center
  - Park Ranger interpreters on shuttle buses will incorporate hydrogen outreach into presentations.

![Map of Volcanoes National Park](image)

- Crater Rim Drive 11 miles
- Chain of Craters Road 38 miles round trip
- Eruption Site
HAVO Program Details

- Hydrogen Fueling Infrastructure funded by USDOE with cost share from State of Hawaii via H2 Capital Investment Fund
- Total funding for infrastructure approx $2.4 million
- Up to five (5) battery-dominant Hydrogen Plug-in Hybrid Electric Vehicles. First 2 vehicles approved.
- Geothermal power from Puna Geothermal Ventures over HELCO grid to HAVO.
- Hydrogen production up to 15 kg/day depending on final vehicle design
- DOD Kilauea Military Camp proposed as site for fueling infrastructure
- Hawaii Center for Advanced Transportation Technologies—proposed partner for vehicle conversions. Leverages Hickam Air Force hydrogen programs
Leveraging the HAVO Project

- Positions HAVO and HNEI as NPS system-wide resource to demo zero emission transportation solutions.
- First step towards Hawaii Hydrogen Highway on Big Island
- Kolohala/HNEI team selected to manage $8.7 million H2 capital investment fund