Hawaii Hydrogen Projects Status & Lessons Learned

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

Hawaii Natural Energy Institute

Organized Research Unit in the School of Ocean and Earth Science and Technology, University of Hawaii at Manoa

Alternative Fuels: Biomass and biofuels

Electrochemical Power Systems

Fuels Cells, Batteries

Renewable Power Generation

Ocean Energy

Photovoltaics

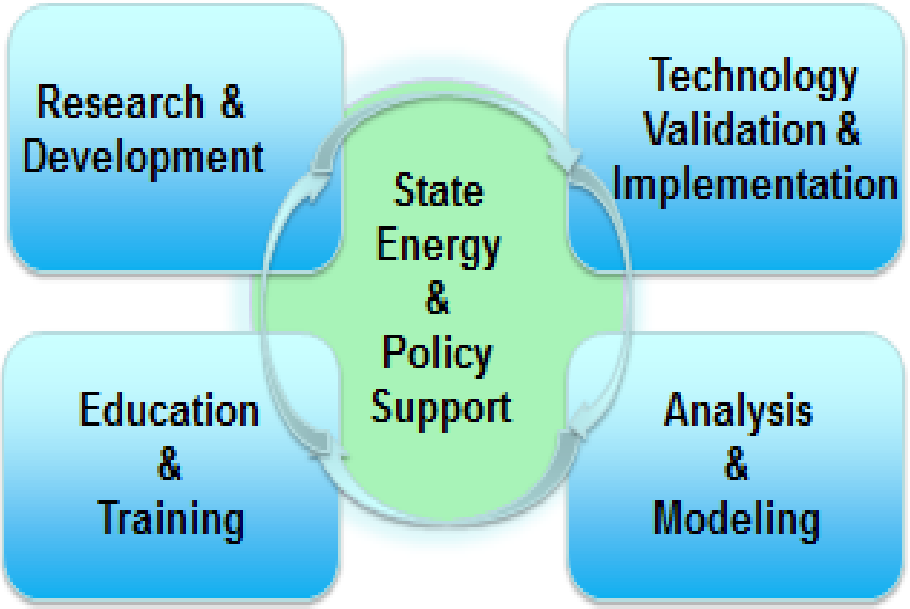
Energy Efficiency

Building technology

Sea Water Air Conditioning

Systems Integration

- Grid modeling and analysis
- Smart grid development
- Grid-scale storage



- **$20 million extramural funding**
- **70 staff**

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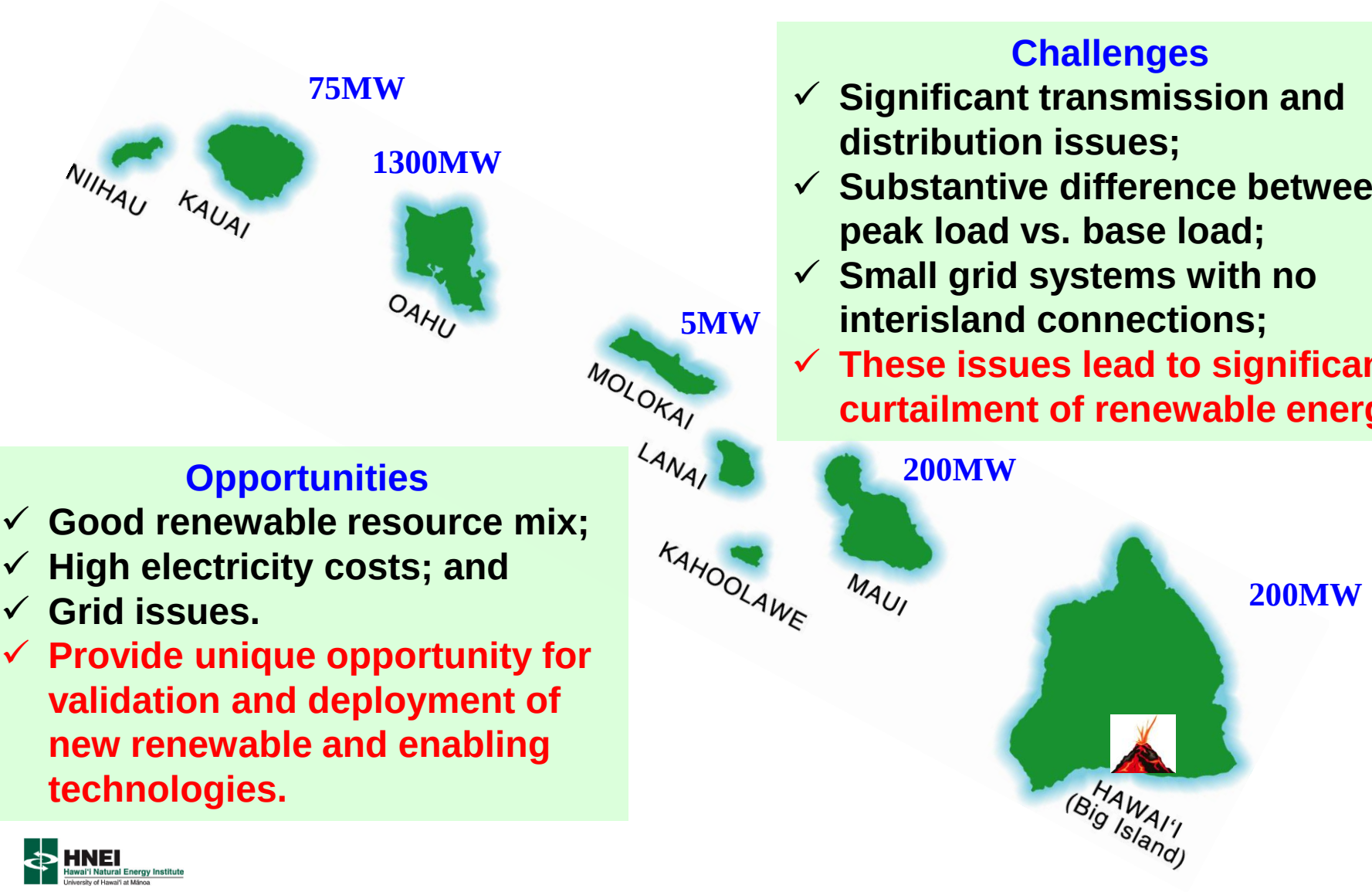
In Hawaii High Percentages of Intermittent Renewable Resources Creates Problems for Grid Systems



Challenges

- ✓ Significant transmission and distribution issues;
- ✓ Substantive difference between peak load vs. base load;
- ✓ Small grid systems with no interisland connections;
- ✓ These issues lead to significant curtailment of renewable energy.

Opportunities

- ✓ Good renewable resource mix;
- ✓ High electricity costs; and
- ✓ Grid issues.
- ✓ Provide unique opportunity for validation and deployment of new renewable and enabling technologies.

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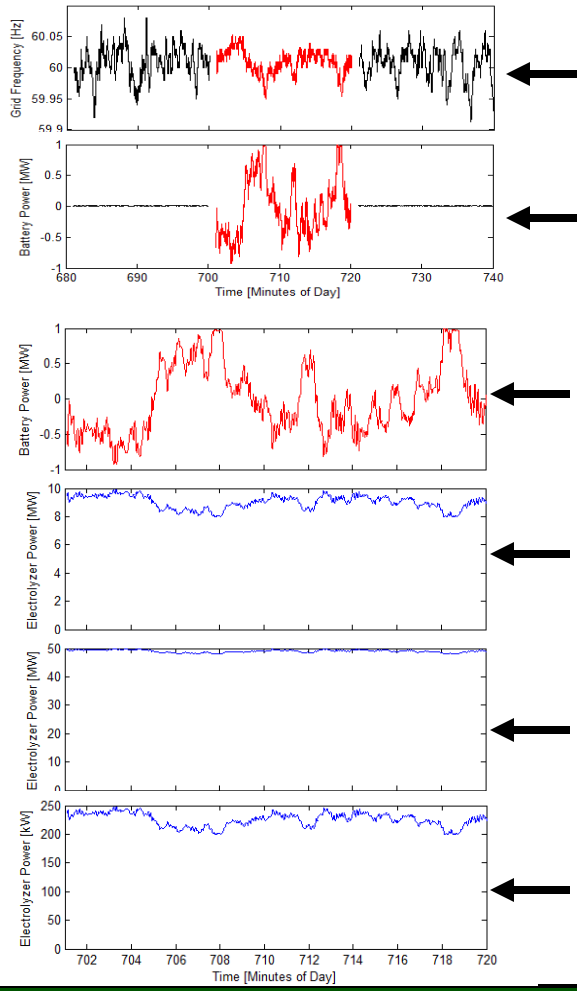
Electrolyzer vs. BESS Management of Grid Frequency



Grid Frequency (Hz): Measured with battery off (black) and on (red) at twenty(20) minute intervals

Battery Output (MW): Can alternate between charge and discharge up to 10 times per second

Battery Output (MW): Expanded scale

10MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

50MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

250kW Electrolyzer: power cycle proposed to test durability assuming part of a 10 MW system

Frequency variability on 150MW grid system reduced with a 1MW, 250kwh fast BESS. Same power range as 1MW BESS easily achieved with 'low' stress and good CAPEX utilization using MW-scale electrolyzers.

Big Island Program Objective:
Evaluate Hydrogen Energy Systems for Grid Management

- ✓ **Demonstrate the use of 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.**

Central Site Production/Distributed Dispensing

H2-fueled shuttle buses

1 Bus

Hydrogen Dispensing under Grid Management Program

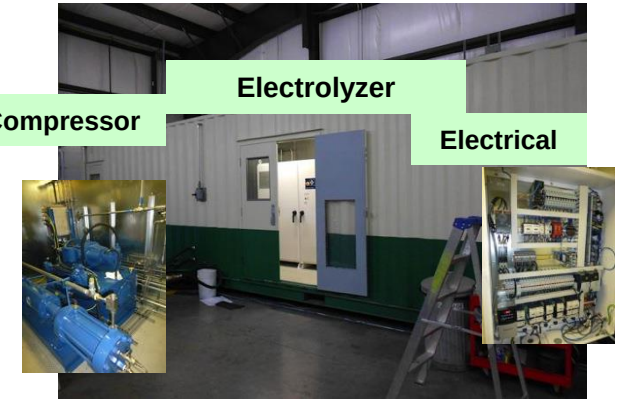
2 Buses

Geothermal Powered Hydrogen Production.
Electricity is PGV cost-share to project.

Hydrogen Dispensing under Hawaii Power Park Program

Containerized Hydrogen Equipment Reduces On-Site Installation Time/Costs

- ✓ **Autonomous Data Acquisition, Monitoring & Control System**
  - ➢ All systems capable of being remotely monitored and operated through a system of sensors, remotely operated valves, & circuit breakers;
  - ➢ Safety systems are independent and hardwired to active elements;
- ✓ **Hydrogen Production & Compression Module**
  - ➢ Integrated into 40’ ISO container
  - ➢ Proton 65 kg/day electrolyzer system
  - ➢ HydroPac Compressor
  - ➢ Control system



- ✓ **Hydrogen Dispensing System**
  - ➢ Hydrogen tube trailer – 105 kg H2 @ 450 bar
  - ➢ Hydrogen fueling post interfaces between tube trailer & dispenser;
  - ➢ Hydrogen “smart” dispenser

H2 Trailer

Fueling Post

Dispenser

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Hawaii Volcanoes National Park Shuttle Bus

Oahu H2 Projects

DoD/GM Equinox FCEV Deployment

- ✓ **GM selected Hawaii as a location to roll out its FCEV fleet (H2I)**
- ✓ **15 GM Equinox FC vehicles leased by DoD and deployed among the Air Force, Navy, and Army**
- ✓ **Hydrogen fueling infrastructure deployed at 3 bases**
  - ➢ **Hickam Air Force Base:**
    - **65 kg/d electrolysis system, 700 bar fueling**
    - **Powered by wind (50 kw) & PV (180 kw)**
  - ➢ **Schofield Army Base:**
    - **65 kg/d electrolysis system, 700 bar "Fast Fill"**
  - ➢ **Marine Corps Base Hawaii:**
    - **12 kg/d electrolysis system, 700 bar "Fast Fill" fueling**
    - **Grid powered**
    - **Hydrogen transport trailer to augment hydrogen supply**

“Tip of the Iceberg”




- **$700,000+ for site improvements;**
  - **Extensive below grade work & materials;**
    - **Grounding requirements;**
    - **Underground conduits reduce separation distances**
- **Can gas station owners support this level of investment?**
- **How many hydrogen fills to break even?**

Infrastructure Costs Too Much

$100,000 Transformer Upgrade

Lessons Learned: Technical

- ✓ **Equipment**
  - ➢ **Scale up electrolyzers to 2000 kg/day+++**
  - ➢ **Scale up compressors to handle large H2 production volumes**
  - ➢ **Develop better power supplies**
    - **More dependable**
    - **More efficient**
  - ➢ **Reduce costs**
- ✓ **Safety**
  - ➢ **Codes & Standards development process an "anchor" on innovation.**
    - **Not keeping up with pace of innovation;**
    - **Either expedite the process or develop an alternative.**

Lessons Learned: Non Technical

- ✓ **Choice of 700 bar for Light Duty Vehicles**
  - ➢ **Doubles cost of infrastructure;**
  - ➢ **Increases cost of dispensed hydrogen.**
- ✓ **Legal profession & insurers slowing the market transformation process:**
  - ➢ **Liability & indemnification issues take too long:**
    - **3rd parties control the pace;**
    - **Why do we need to reinvent the wheel for every project?**
    - **3.5 years to develop agreements;**
    - **Need "straw man" set of standard terms & conditions;**
    - **Make risk analyses available to insurers and lawyers.**
- ✓ **No Sense of Urgency!!!!**

Plans for Future Projects

- ✓ **Let's leverage H2 projects:**
  - ➢ **Eliminate "Fire & Forget" projects;**
  - ➢ **Selection Criteria: "Commitment"**
    - **Support host site strategic H2 infrastructure development plan.**
  - ➢ **Invest in outreach. More workshops.**
  - ➢ **Utilities**
  - ➢ **Legal profession.**