2012 Hydrogen and Fuel Cells Program Annual Merit Review Meeting

Hydrogen Energy Systems as a Grid Management Tool

Dr. Richard Rocheleau - Principal Investigator

Mitch Ewan – Program Manager

Hawaii Natural Energy Institute

May 16, 2012

Project: MT008

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

Overview

Timeline

- ✓ **Project start date: 30 Sep 10**
- ✓ **Project end date: 29 Sep 12**
- ✓ **Percent complete: 50%**

Barriers

✓**Hydrogen Production**

- ➢ **J: Renewable electricity generation integration**
- ➢ **Non-technical issues preventing full commercialization of hydrogen**

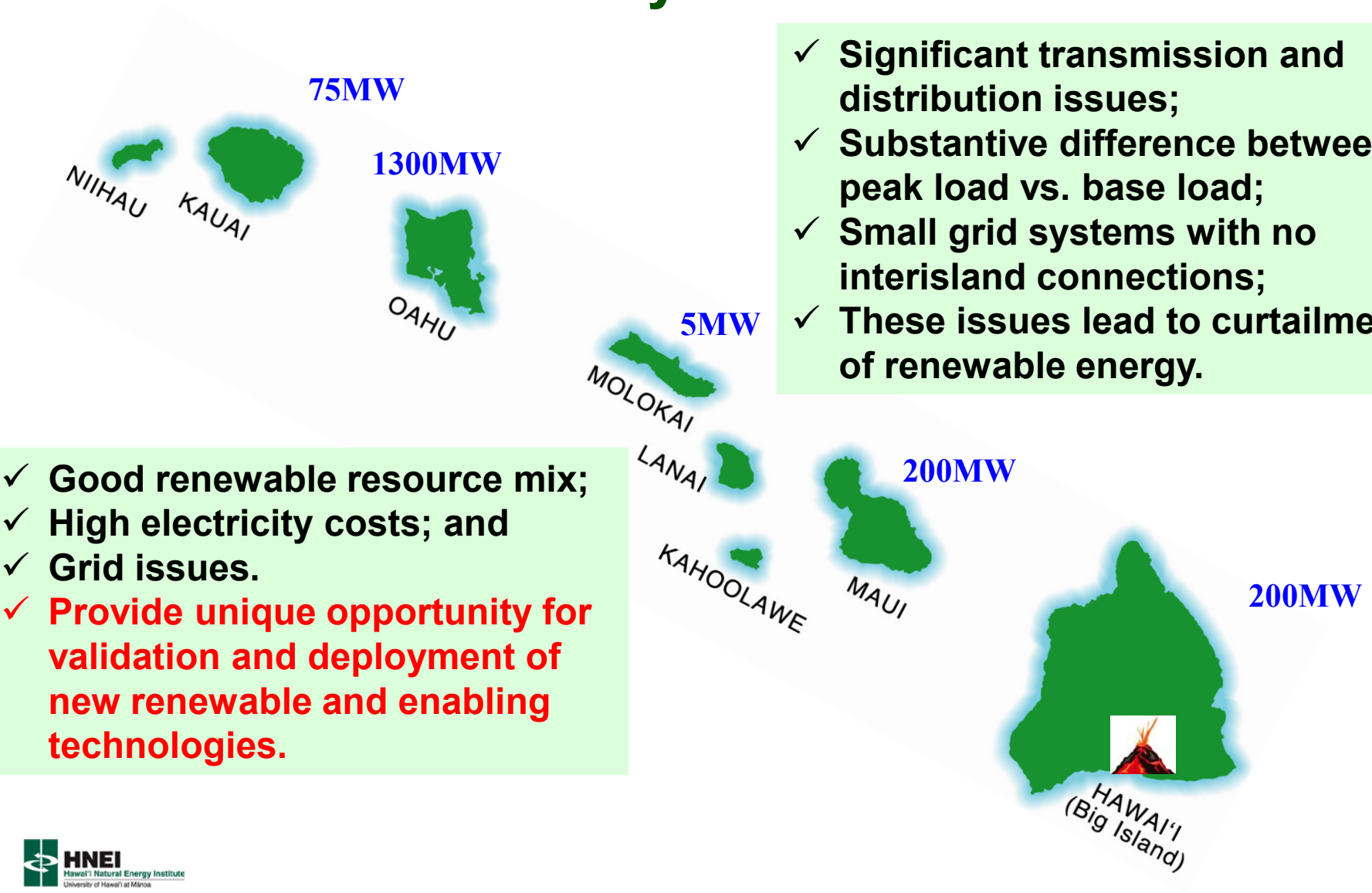
Budget

- ✓ **Total project funding:**
  - ➢ **$1,796,515**
- ✓ **Funding received in FY11:**
  - ➢ **$1,500,000 State of Hawaii**
  - ➢ **$600,000 ONR**
  - ➢ **$500,000 US DOE**

Partners

- ✓ **US DOE:** Project Sponsor & Funding
- ✓ **Office of Naval Research:** Supplemental funding
- ✓ **Naval Research Laboratory:**
  - ➢ Federal Technical Program Manager
- ✓ **HNEI:** Implementing Partner, Technical Lead
- ✓ **Puna Geothermal Ventures:**
  - ➢ Host site, Power & Water Provider.
- ✓ **County of Hawaii Mass Transit Agency:**
  - ➢ Host Site, Bus Operator
- ✓ **HELCO: Potential partner for expanded program**

Relevance: High Percentages of As-Available Renewable Resources Creates Problems for Grid Systems



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

- ✓ 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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Approach: Energy Roadmapping/Technology Validation

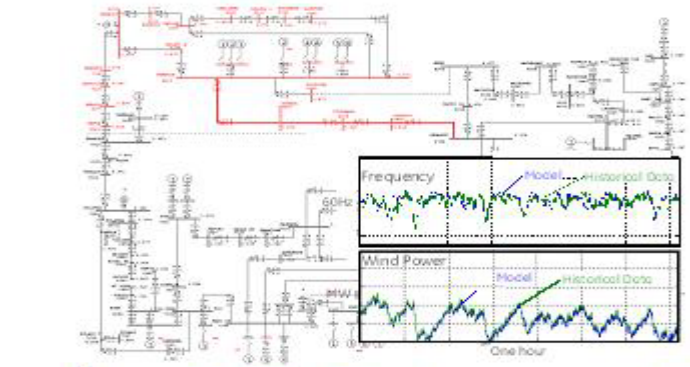
FOUR-STEP PROCESS TO EVOLVE ENERGY SYSTEMS:

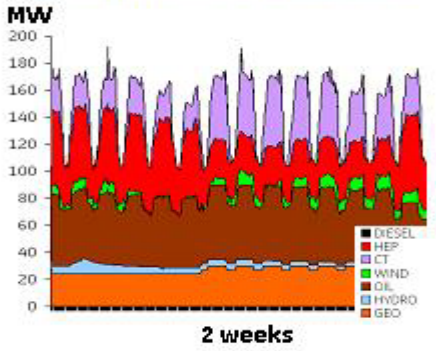
Step 1:	**Develop and validate rigorous analytic models for electricity and transportation**
Step 2:	**Develop and model scenarios for deployment of new energy systems including additional renewables**
Step 3:	**Identify and analyze mitigating technologies (DSM, storage, Smart Grid, advanced controls, forecasting, future gen) to address systems integration (grid stability) and institutional issues.**
Step 4:	**Conduct testing and evaluation to validate potential solutions to facilitate utility acceptance**

Approach: HNEI & GE Modeled Electrical Infrastructure

- ✓ **Transient Performance (PSLF™)**
  - ➢ Full network model, incorporating generator governors and AGC;
  - ➢ Transient Stability Simulation;
  - ➢ Long-Term Dynamic Simulation.

- ✓ **Production Cost (MAPS™)**
  - ➢ Representation of dispatch and unit commitment rules;
  - ➢ Hour-by-hour simulation of grid operations for a full year;
  - ➢ Yields cumulative fuel usage, emissions, variable cost.





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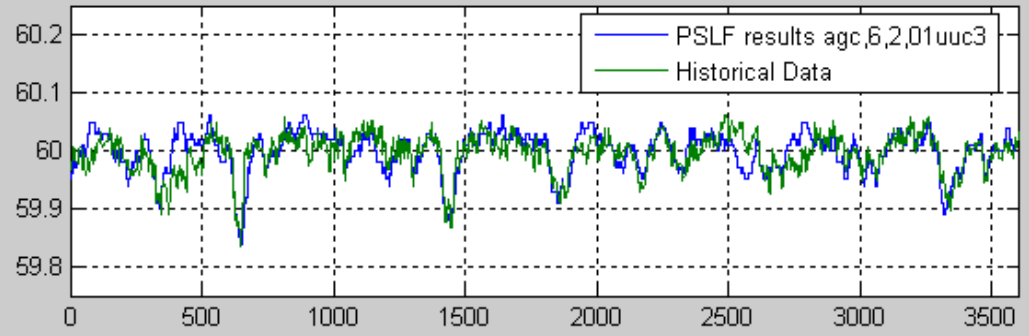
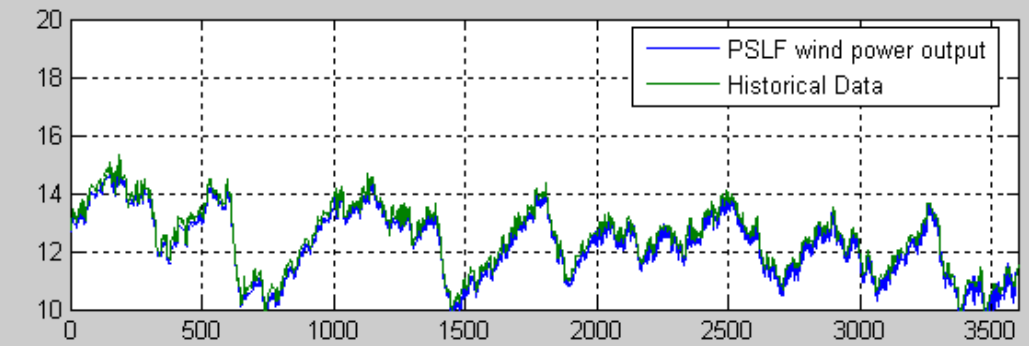
Approach: Frequency Variability due to Wind Fluctuation used as Initial Test of Model

- ✓ 100 to 200 MW w early evening peak
- ✓ 30 MW wind
- ✓ 30 MW unregulated geothermal
- ✓ Significant and growing photovoltaics

Frequency (Hz)



Apollo Wind Farm (MW)



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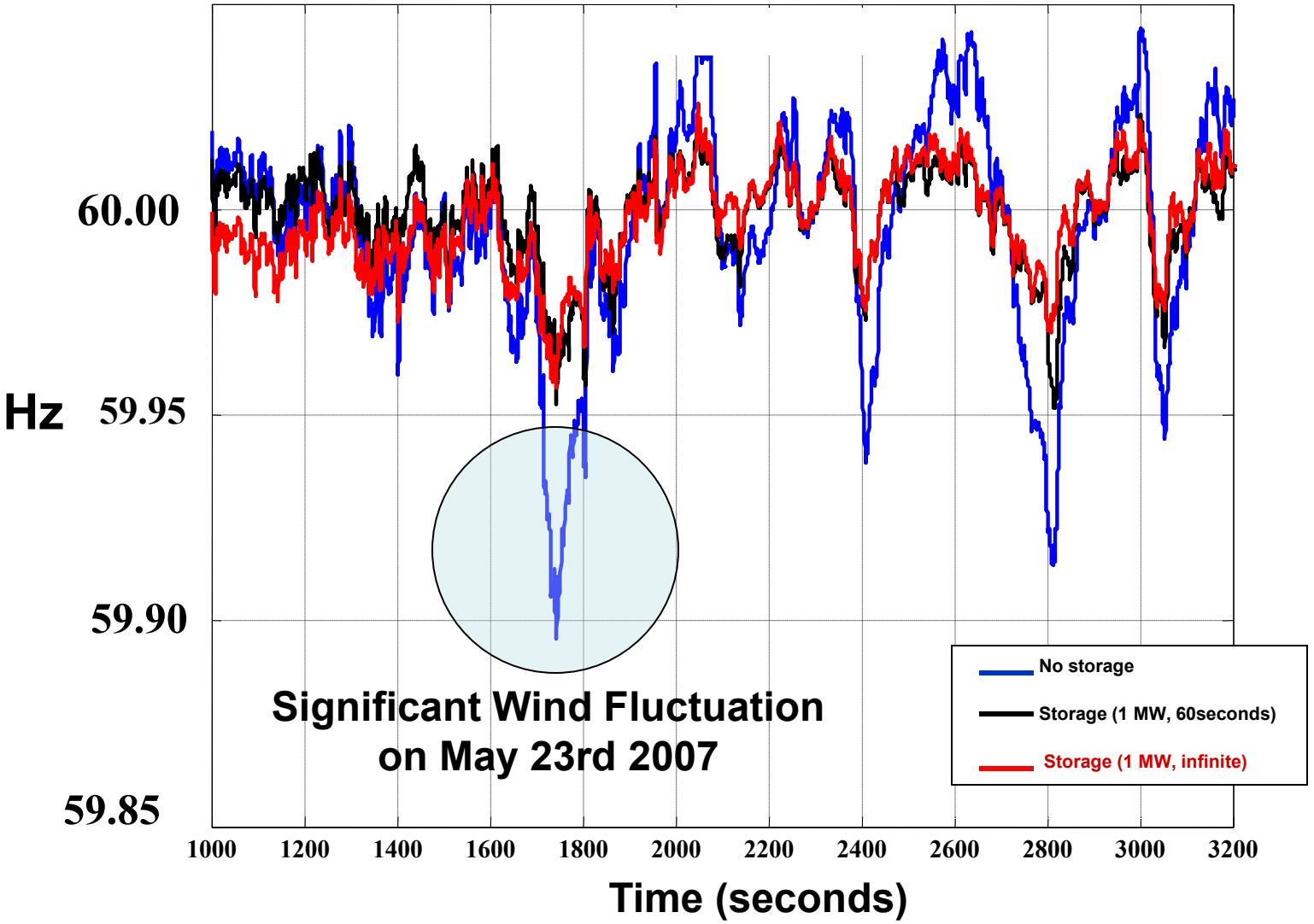
Approach: Models indicate that modest energy storage can mitigate negative effects of high wind penetration



Frequency Comparison

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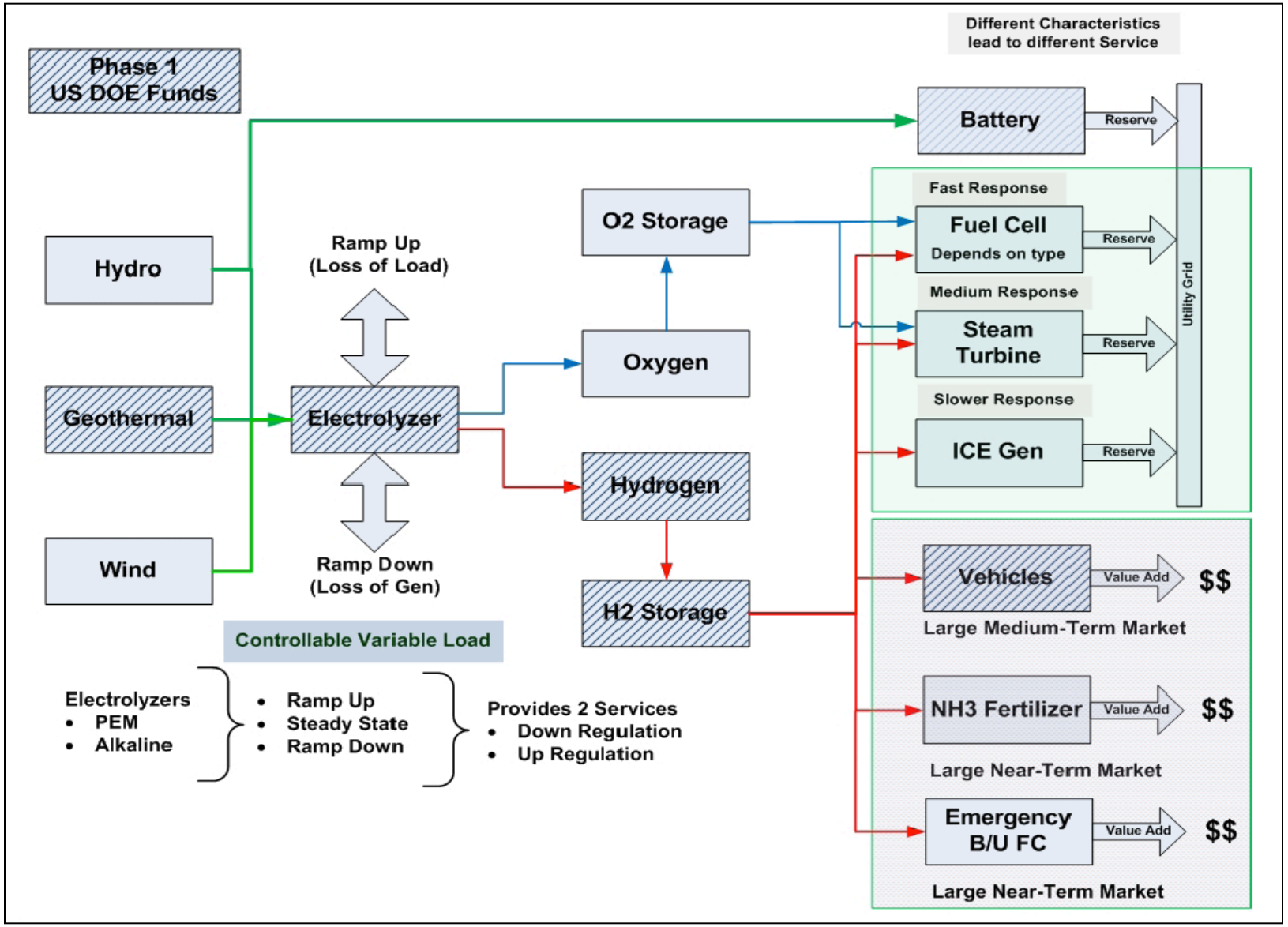
Approach: Utilize Hydrogen Energy Systems as a Grid Management Tool

- ✓ Demonstrate the use of electrolyzers as a grid management tool to mitigate the impacts of intermittent renewable energy;
- ✓ Characterize performance/durability of commercially available electrolyzers under dynamic load conditions;
- ✓ Provide hydrogen to fuel hydrogen shuttle buses for local community bus service operated by County of Hawaii Mass Transit Agency; and
- ✓ Conduct performance/cost analysis to identify benefits of integrated system including grid services & off-grid revenue streams.

Approach

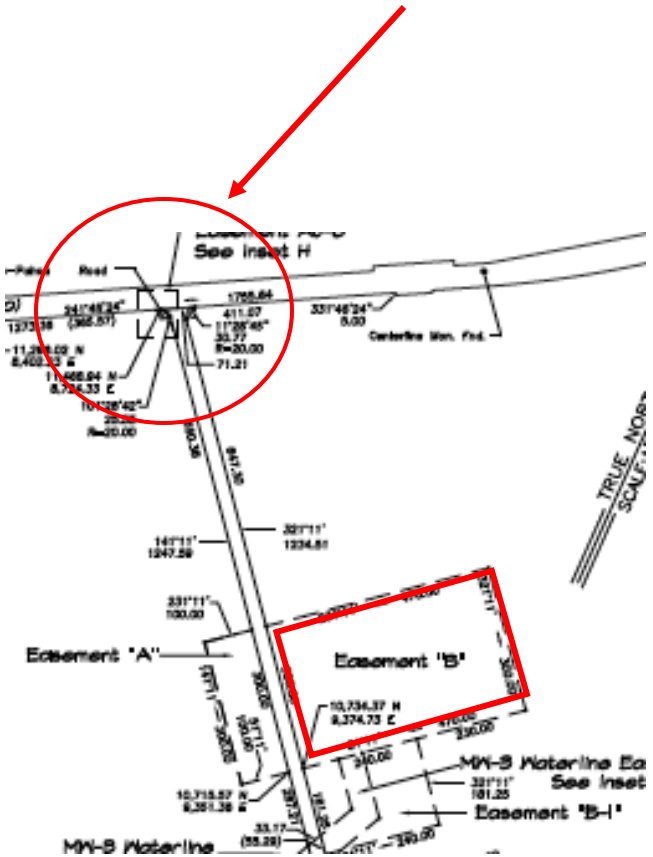

Different Characteristics lead to different Service
Phase 1
US DOE Funds
Battery
Reserve
Hydro
Ramp Up
(Loss of Load)
O2 Storage
Fast Response
Fuel Cell
Depends on type
Reserve
Medium Response
Steam Turbine
Reserve
Slower Response
ICE Gen
Reserve
Utility Grid
Geothermal
Electrolyzer
Oxygen
Hydrogen
Wind
Ramp Down
(Loss of Gen)
H2 Storage
Vehicles
Value Add
$$
Large Medium-Term Market
NH3 Fertilizer
Value Add
$$
Large Near-Term Market
Emergency B/U FC
Value Add
$$
Large Near-Term Market
Controllable Variable Load
Electrolyzers
PEM
Alkaline
Ramp Up
Steady State
Ramp Down
Provides 2 Services
Down Regulation
Up Regulation

Project Site

PGV Site

- ✓ **Greenfield with access to critical utilities;**
- ✓ **1 acre site**

Locations of PGV & MTA



Updated Project Schedule

Task #1: Develop Memorandum of Agreement & Contracts with Key partners (PGV, MTA): April 2012.
Took longer than planned. Has delayed other tasks.

Task #2: Define System Requirements: Dec 2010. **Completed**

Task #3: Select Supplier for Hydrogen System for delivery August 2012: **Contract Issued February 2012. Took longer than planned.**

Task #4: Complete PGV and MTA Site Infrastructure, Sep 2012

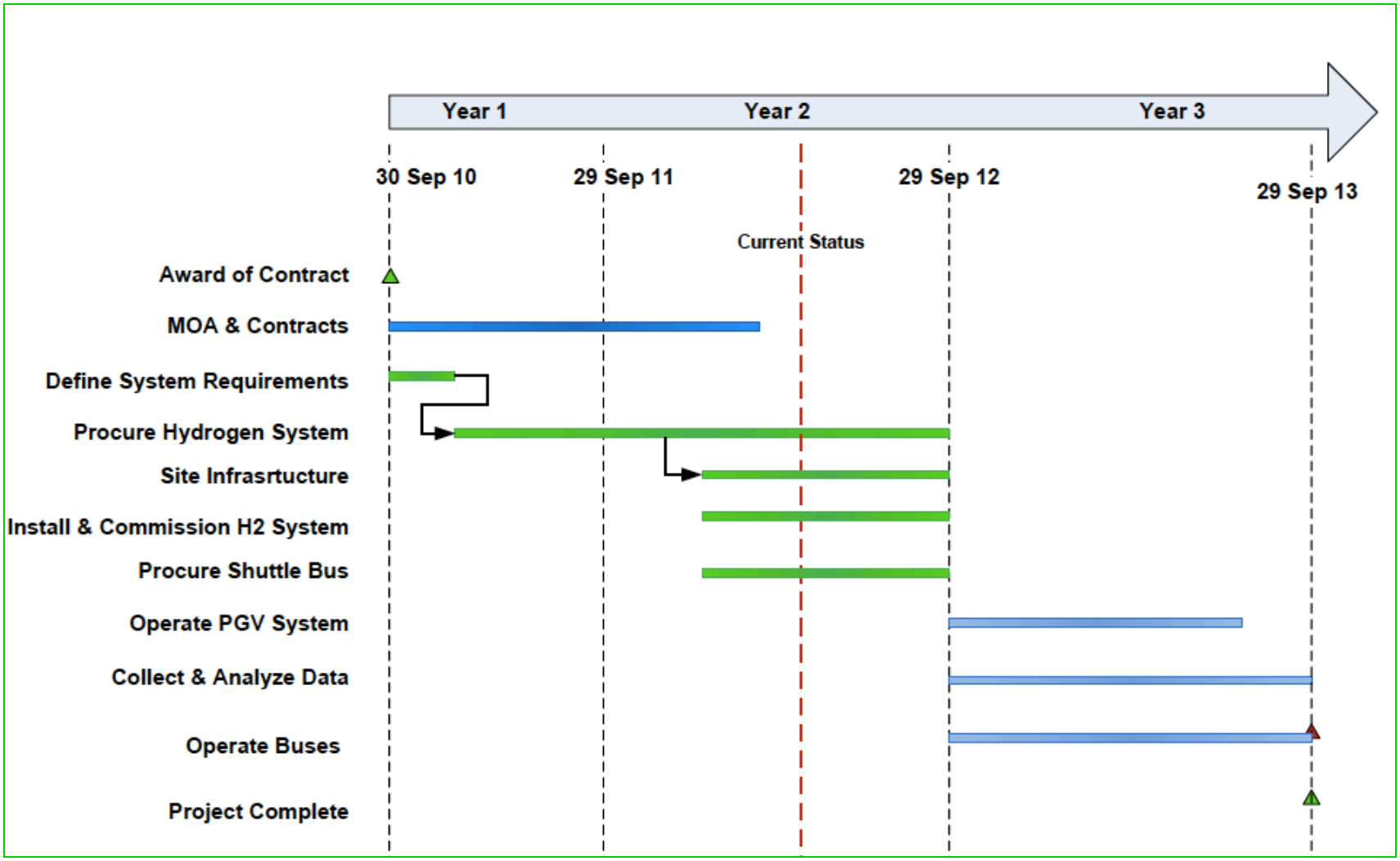
Task #5: Install & Commission Hydrogen System, Sep 2012

Task #6: Procure Shuttle Bus, Sep 2012

Task #7: Operate Hydrogen System, start October 2012

Task #8: Outreach &Education: **Ongoing**

Milestones


Year 1
Year 2
Year 3
30 Sep 10
29 Sep 11
29 Sep 12
29 Sep 13
Current Status
Award of Contract
MOA & Contracts
Define System Requirements
Procure Hydrogen System
Site Infrasrtucture
Install & Commission H2 System
Procure Shuttle Bus
Operate PGV System
Collect & Analyze Data
Operate Buses
Project Complete

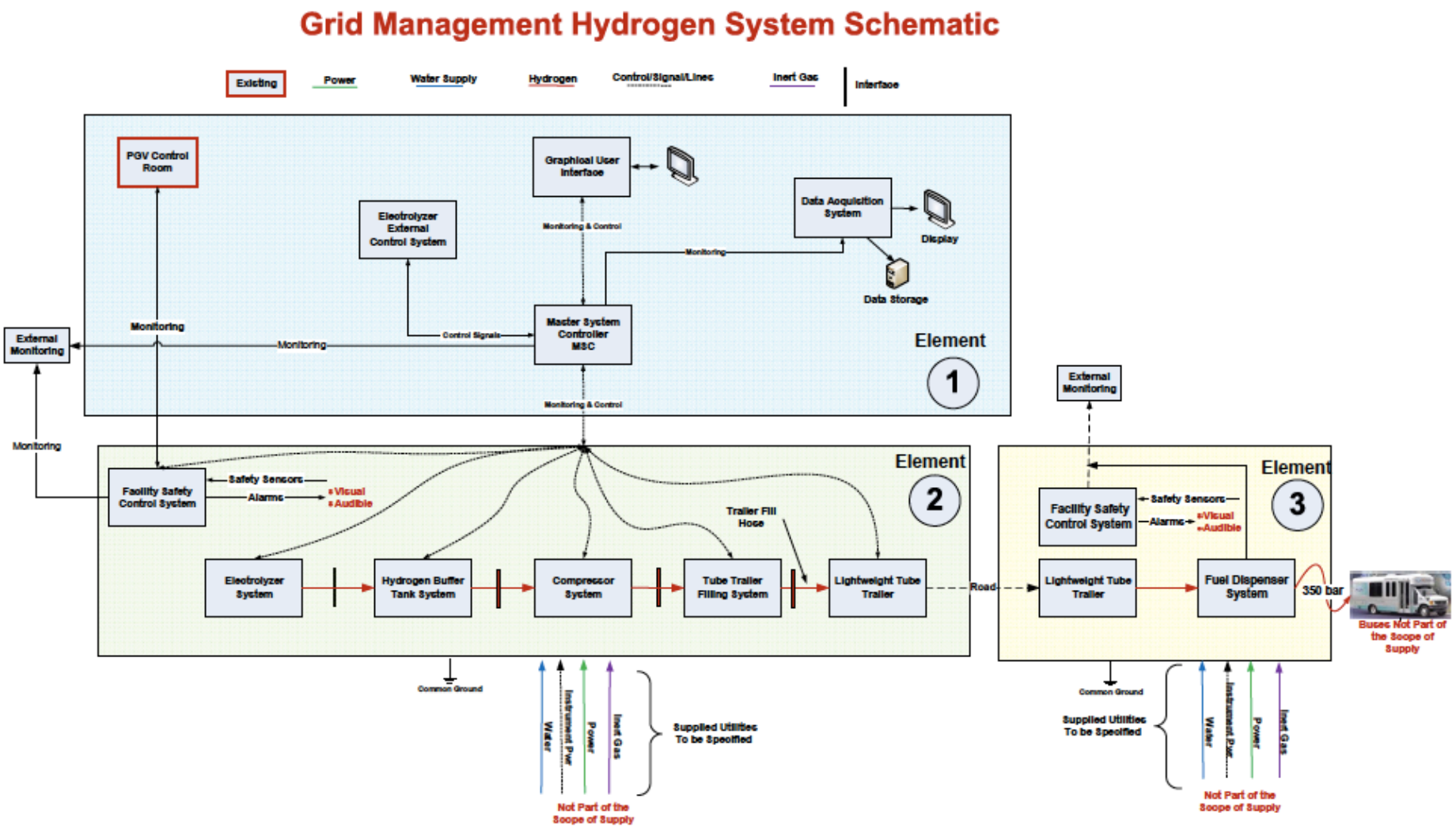
Task #1 Develop MOAs and Contracts 80% complete

- ✓ **Develop legally binding agreements from all parties before making major financial commitments;**
- ✓ **Puna Geothermal Venture:**
  - ➢ **Confirm power free: Confirmed**
  - ➢ **Confirm host site availability: Confirmed**
  - ➢ **Develop MOA – 95% complete. Took longer than planned.**
- ✓ **County of Hawaii Mass Transit Agency:**
  - ➢ **Confirm MTA host site availability, agree upon bus operations, develop maintenance commitments: Confirmed**
- ✓ **Hydrogen Production System Operator – final negotiations underway for third party operation of hydrogen/fueling plant. 80% complete.**
- ✓ **Complete Environmental Assessment. This is a State of Hawaii requirement if utilizing state $$. Underway.**

Task #2: Hydrogen System Requirements Completed

- ✓ Fully automated for remote monitoring, data acquisition, and control;
- ✓ Redundant fail-safe safety systems;
- ✓ Category 4 earthquake resistance;
- ✓ Highly corrosive salt air coastal environment;
- ✓ Hydrogen Production:
  - ➢ PEM or alkaline electrolysis with minimum 60 kg/day operated continuously at full capacity;
  - ➢ High purity hydrogen (SAE J2719) for engine and fuel cell use;
  - ➢ Dynamic Operation (frequent cycles up to 30% capacity, intermittent (2 per day) up to 80% capacity, one minute ramp rate;
  - ➢ Ability to control cycling directly or via grid frequency;
  - ➢ Lightweight hydrogen tube trailers for easy transport on narrow roads. Permanent on-site storage utilizing "spoolable" plastic pipe (subject to funding);
  - ➢ Compression consistent with maximum pressure of selected light-weight tube trailers (i.e. 350 bar or less).
- ✓ Mobile fueling station incorporating fueling dispenser & compressor.

Task #2: Hydrogen System Concept Design Completed



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Approach: Hydrogen Supply

H2-fueled shuttle buses

Hydrogen Dispensing under Grid Management Program

Hydrogen Delivery Trailer uses unique cascade fill process that required no onsite compressor

Hydrogen Dispensing under Hawaii Power Park Program

Geothermal Powered Hydrogen Production

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Tasks 3 and 4

- **Task 3: Procure H2 Production/Delivery/Dispensing**
  - ✓**RFP for turn-key integrated system including dispenser to insure system compatibility: Completed**
  - ✓**Select vendor for August delivery: Contract Awarded**
  - ✓**Supplier to offer complete product liability and indemnification insurance coverage. Completed**
  - ✓**Additional Hydrogen Delivery Trailers: Contract Awarded**
- **Task 4: Install Site Infrastructure**
  - ✓**HNEI to issue contract for site infrastructure upon award of hydrogen system; Started**
  - ✓**Permitting not expected to be issue at site.**

Task #5: Install & Commission Hydrogen System

- ✓ **HNEI will provide coordination between infrastructure contractor and hydrogen system supplier;**
- ✓ **Hydrogen systems modular & containerized for ease of installation; and**
- ✓ **Acceptance testing included in hydrogen system award.**

Task #6: Procure Shuttle Bus

- ✓ **Ford buses not available within project timeline.**
  - ➢ **Leveraging HAVO FCEV hybrid buses based on El Dorado 19 passenger bus**
  - ➢ **Bus conversion by HCATT. NRE by Air Force Research Laboratory ~ $750k savings to project.**
  - ➢ **State of Hawaii Barrel Tax funds ($500k) used to pay for conversion.**
  - ➢ **Reduced to 1 bus.**
- ✓ **Develop a "wrap" (graphics package) in accordance with DOE guidance.**
  - ➢ **MTA, NRL & ONR need to be included to ensure recognition.**
- ✓ **First bus being converted by HCATT.**
- ✓ **This represents a significant project improvement by replacing H2 ICE bus with FCEV bus**

Task #7: Operate PGV System

- ✓ **Prepare test protocols:**
  - ➢ **Dynamic response;**
  - ➢ **Liaise with project partners, DOE, and NRL;**
  - ➢ **Invite HELCO to participate.**
- ✓ **Operate PGV system in accordance with protocols for 12 months.**
  - ➢ **Operation beyond 12 months depends on availability of funding and buses.**
- ✓ **Operate FCEV buses**
  - ➢ **Meet bus requirements;**
  - ➢ **Conduct hydrogen delivery and fueling operations.**
- ✓ **Collect & analyze data;**
- ✓ **Develop alternate uses for hydrogen;**
- ✓ **Prepare reports.**

Technical Accomplishments & Progress

- ✓ Awarded contract to Powertech to supply Hydrogen Equipment;
- ✓ Started Environmental Assessment;
- ✓ Developed MOA with PGV;
- ✓ Awarded contract to Powertech for additional hydrogen delivery trailers
- ✓ Developing site design with infrastructure contractor;
- ✓ Replaced Ford H2 ICE buses with El Dorado FCEV bus. Additional funding from State.
- ✓ Procured additional $1 million from State H2 Fund for site infrastructure;
- ✓ Procured additional $600k from ONR for overall project support including additional hydrogen delivery trailers.

Collaborations

- ✓ **US Department of Energy:** Project Sponsor & Funding;
- ✓ **Office of Naval Research:** Supplemental Funding;
- ✓ **State of Hawaii:** Cost Share;
- ✓ **Naval Research Laboratory:** Federal Technical Program Manager;
- ✓ **Hawaii Natural Energy Institute:** Implementing Partner, Technical Lead;
- ✓ **Puna Geothermal Venture:** Host Site, Provide Power and Water (Cost Shared);
- ✓ **County of Hawaii Mass Transit Agency:** Host Site, Bus Operator (Cost Shared);
- ✓ **HELCO:** Interested Observer, Potential Partner for Grid Analysis;
- ✓ **HCATT:** Conversion of shuttle bus.

Proposed Future Work

- ✓ Install hydrogen production infrastructure at PGV site;
- ✓ Install fueling infrastructure at MTA site;
- ✓ Install & commission hydrogen systems at PGV & MTA sites;
- ✓ Procure 1 El Dorado shuttle bus;
- ✓ Operate systems;
- ✓ Collect & analyze data;
- ✓ Prepare performance reports;
- ✓ If results show promise, apply for a phase 2 follow-on project that increases the size of electrolyzers.

Summary

- ✓ 5MW of electrolysis would produce approximately 600,000 kg hydrogen per year, ~1% total Hawaii gasoline usage, ~ 10% Big Island gasoline usage;
- ✓ Electrolysis of water to produce hydrogen could contribute significantly to Hawaii fuel usage while providing significant support for renewable intermittency;
- ✓ Performance & durability of electrolyzer under sustained cyclic operation needs to be validated;
- ✓ Detailed grid behavior with significant electrolysis needs to be validated via models; and
- ✓ Costs required to justify large scale electrolysis for fuel need to be determined.