Technology Issues in Renewable Energy and Energy Efficiency



Presented to Hawaii State Legislature
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State Capitol
January 22, 2009

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University of Hawai'i at Mānoa

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Hawaii Natural Energy Institute

- Research unit in the School of Ocean and Earth Science and Technology (SOEST) at University of Hawaii at Manoa
- Act 253 (2007) established HNEI in statute and tasked HNEI to:
  - Develop renewable sources of energy for power generation and transportation fuels by working in coordination with state and federal agencies and private entities
  - Conduct research and development of renewable sources of energy
  - Demonstrate and deploy efficient energy end-use technologies including those that address peak electric demand issues
  - Aggressively seek matching funding from federal agencies and private entities for its research and development and demonstration issues
  - Administer the Energy Systems Development Special Fund

Energy Systems

- **Electricity**
  - Generation – transmission – distribution – end use
- **Transportation (ground, air, marine)**
  - Vehicle type - fueled, hybrid, plug-in hybrid, electric
  - Fuel type - fossil, biofuels, hydrogen
- **Energy Efficiency**
  - Applicable to all technologies and users
  - More efficient power generation can be as valuable as more efficient end use
  - Efficiency often the most cost-effective and near-term option
- **Commercial vs Demonstration/Research**
  - Proven reliability, cost, availability of technology
  - Tendency to consider technology commercial before it really is

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Electricity Generation
Some Definitions/Considerations

- **Centralized vs Distributed**
  - Centralized generation is large and grid connected
  - Distributed generation smaller may be grid connected or at end user site
  - Grid transmission (or not) a significant cost factor
- **Baseload vs Peaking Generation**
  - Baseload - higher capital cost, lower operating costs, typically high efficiency
  - Peaking - lower capital cost, higher operating costs, more responsive than baseload
- **Firm vs Intermittent**
  - Firm power available for dispatch when needed
  - Intermittency may include short term fluctuation

Renewable energy technologies may fit into any of the above categories

Renewable & Enabling Technologies

- **Commercial**
  - Wind
  - Solar - photovoltaics, concentrated solar power, and solar thermal
  - Biofuels - combustion, ethanol via fermentation, biodiesel
  - Geothermal
- **Developing/Research**
  - Biofuels - sustainable crops, advanced conversion technology
  - Ocean energy – wave, ocean thermal energy conversion
  - Advanced solar
- **Enabling Technologies**
  - Smart electricity grid and infrastructure
  - Energy storage – important for grid and transportation
  - Electric and hybrid electric vehicles
  - Hydrogen and fuel cells

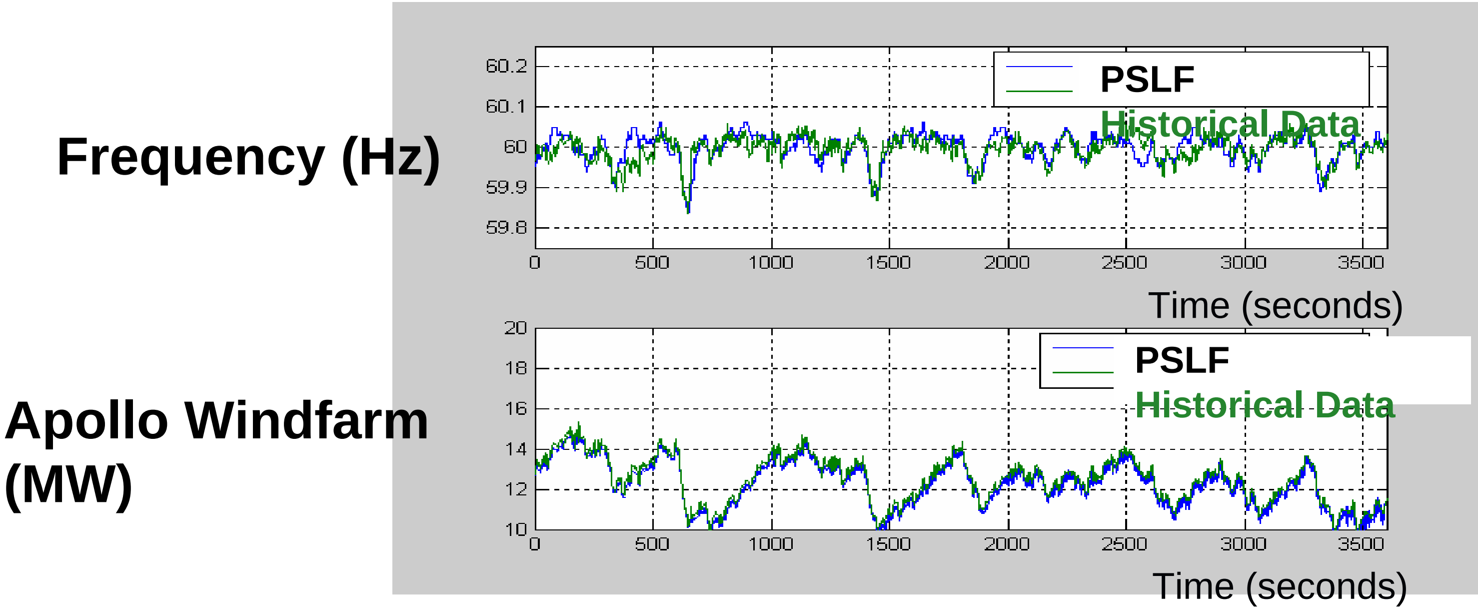
Solar

- **Current Status**
  - Photovoltaics and solar thermal electricity generation are commercial
  - PV ~ 30 - 40¢ /kWh without tax credits.
  - Solar thermal ~ 20 - 25¢ /kWh without tax credits.
  - PV usually distributed generation (end user site)
  - Solar thermal often centralized (fed into grid for T&D)
  - Effective job creation – generates 70% more than oil & gas sector
  - World market has been growing at ~ 40% per year
- **Issues**
  - Intermittent resource – not dispatchable, loss of power can be sudden with no warning to or control by utility, grid issues may be challenging at high penetrations.
  - Public policy and education. Policies need to be consistent and long-term

Wind

- **Current Status**
  - **Commercial - world capacity (Jan08) at ~ 90GW.**
  - **5 MW turbines entering market.**
  - **~ 6 - 10¢/kWh at 13 mph without Production Tax Credit (PTC)**
  - **Usually centralized generation at large scale**
  - **National interest in offshore wind farms. Difficult in Hawaii**
- **Issues**
  - **Intermittent resource – integration with the grid is challenging at high penetrations. We are already experiencing this in Hawaii.**
  - **Permitting, land use, view planes**
  - **Availability and long lead times**
  - **Public policy and education. Policies need to be consistent and long-term**

Effect of Intermittency



- **HNEI working with GE and electric utilities to develop models to address grid stability, and institutional issues for high penetration renewables.**
- **Validated models used to analyze site specific scenarios incorporating high penetrations of renewable energy (e.g. wind) and advanced technology solutions including forecasting, energy storage, and demand management**

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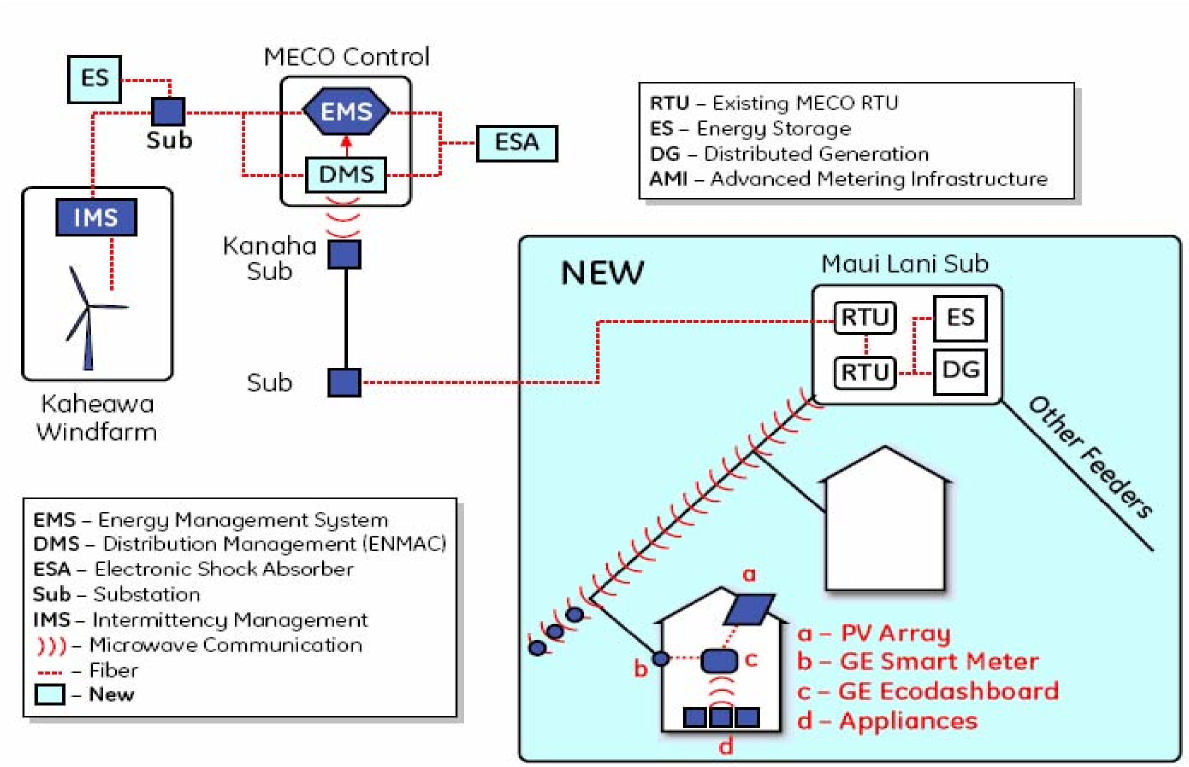
Maui Smart Grid Project

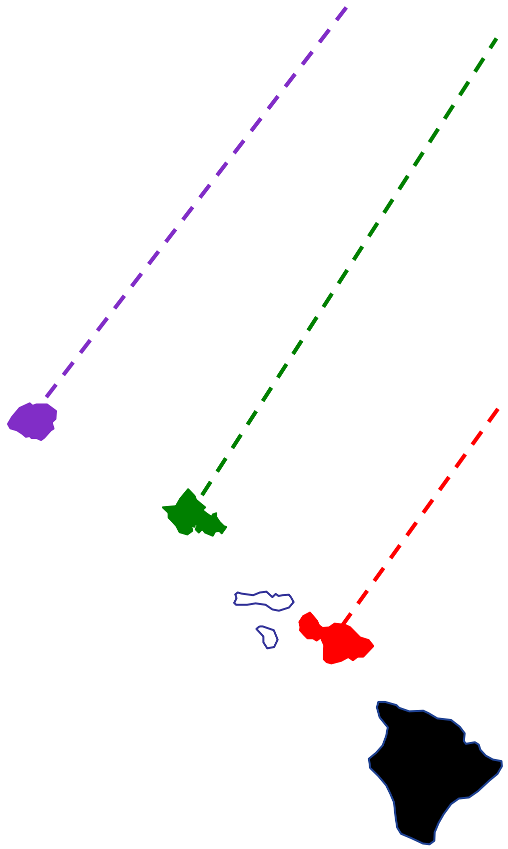
- **Objective is to develop and demonstrate a distributed automation system that aggregates distributed generation, energy storage, and demand response technologies in a distribution system to achieve both T&D level benefits.**
- **Specific goal is "reduction of peak demand by at least 15%"**



- **Additional effort to identify and validate solutions for mitigating the effects of as-available renewable energy**

Current Efforts Being Used to Define Technology Needs for Increasing Renewable Energy Use

Represents approximately $ 20 million investment by DOE and industry partners



- **Kauai Energy Roadmap**
- **Develop possible roadmap for increased penetration of renewable energy.**

- **Oahu Grid (BIG Wind) Study**
- **Oahu grid model being developed to address wind projects that could impact the Island**

- **Maui Grid Modernization**
- **Energy storage, generation and demand-side management technologies being deployed to reduce peak load and enable further expansion of renewable energy**

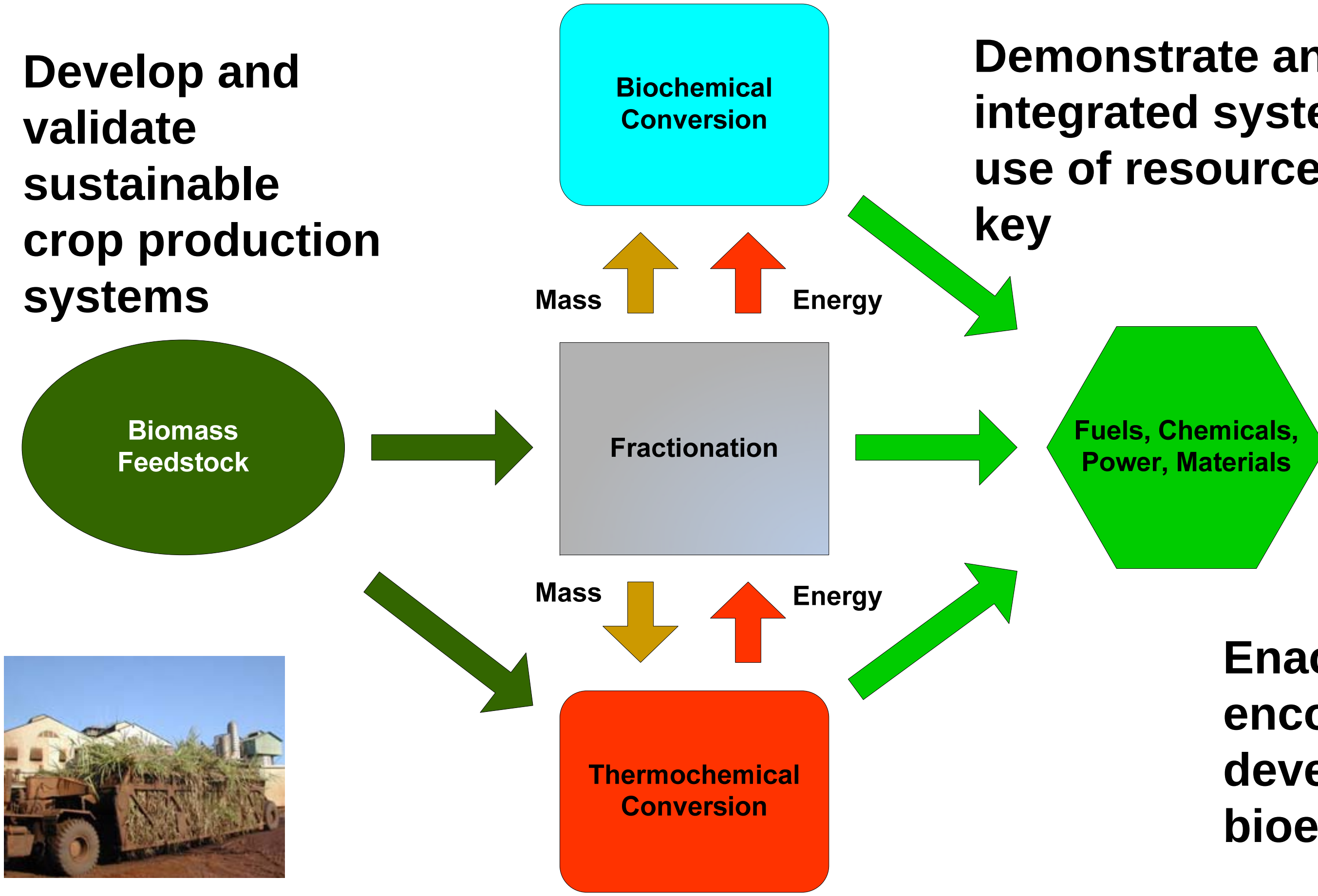
- **Maui Grid Study**
- **Validated power systems model used to address impacts of increased wind and the necessary mitigation technologies**

- **Big Island Energy Roadmap**
  - Technology approaches to increase energy security and the penetration of renewable energy being evaluated
  - Storage demonstration project being negotiated

Needs for Development of Sustainable, Integrated Bioenergy Systems for Hawaii

Develop and validate sustainable crop production systems

Demonstrate and scale-up integrated systems – optimized use of resource and technology is key



Validate conversion technologies and feedstock compatibility

Enact policy to encourage long range development of bioenergy industry

- **Biofuels Master Plan (ACT 253)**
- **Renewable Fuels Standards**

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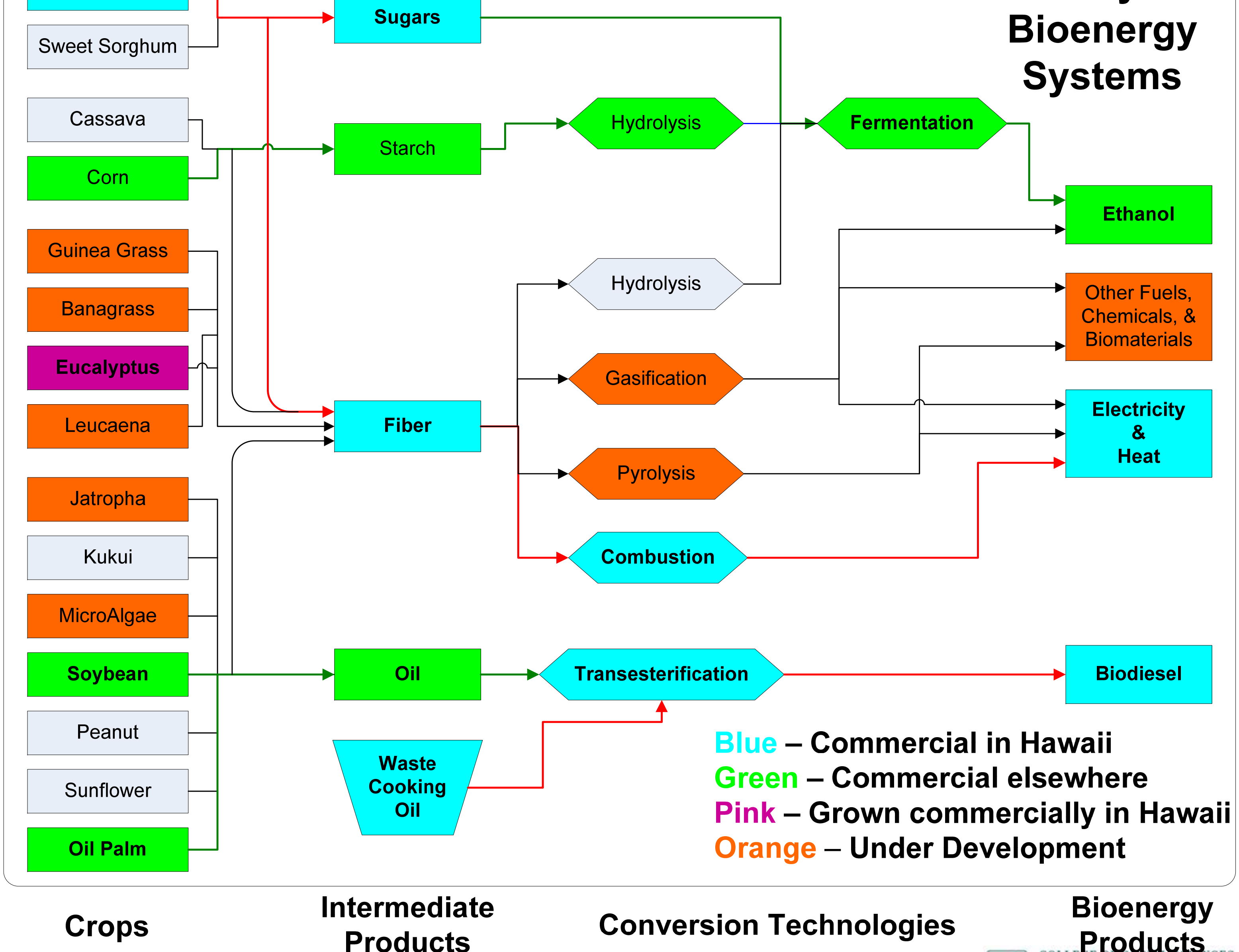
Pathways for Bioenergy Systems



Hawaii Bioenergy Master Plan

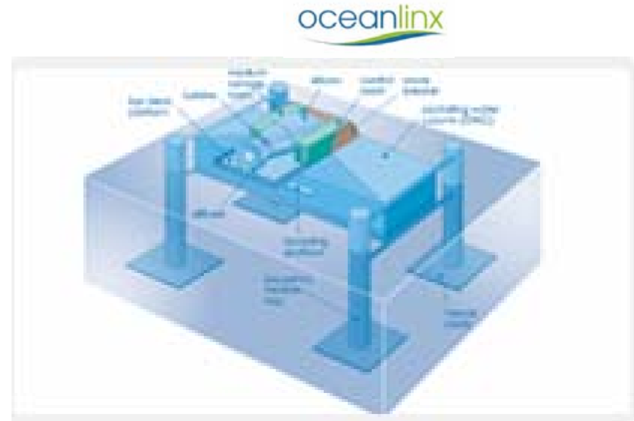
- **Legislatively mandated in 2007**
- **" *The primary objective of the bioenergy master plan shall be to develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.*"**
- **Supported by State of Hawaii and USDoE**
- **Stakeholder meetings held**
- **Negotiations underway to contract technical experts to conduct analysis in relevant areas**
- **Draft report to DBEDT June 2009**

Geothermal

- **Current Status**
  - Commercial. Baseload.
  - ~ 7-9¢/kWh
  - Puna Geothermal Venture (PGV) operates a 30 MW plant on the Big Island. Owned by Ormat Technologies.
  - Permitted for a total of 60MW. Currently installing bottom cycling equipment to capture waste heat ~ 8 MW .
  - Potential sources on Kona side of Big Island. Warm spots on Maui, Molokai and Oahu.
- **Developing**
  - Low temperature technologies will expand resource base
  - Engineered Geothermal Systems (EGS) using water injection under development for hot spots without steam resource
  - Geothermal to Hydrogen Roadmap prepared in September 2008.

Wave

- **Current Status**
  - Demonstration scale
  - Intermittent but hourly and daily forecasting likely
  - Cost estimate from 25 - 80¢ / kWh
- **Issues**
  - Robustness and efficiency of wave energy generators
  - Environmental impacts
  - Wave forecasting techniques – short and long term
  - Corrosion and survivability
  - Integration into the grid



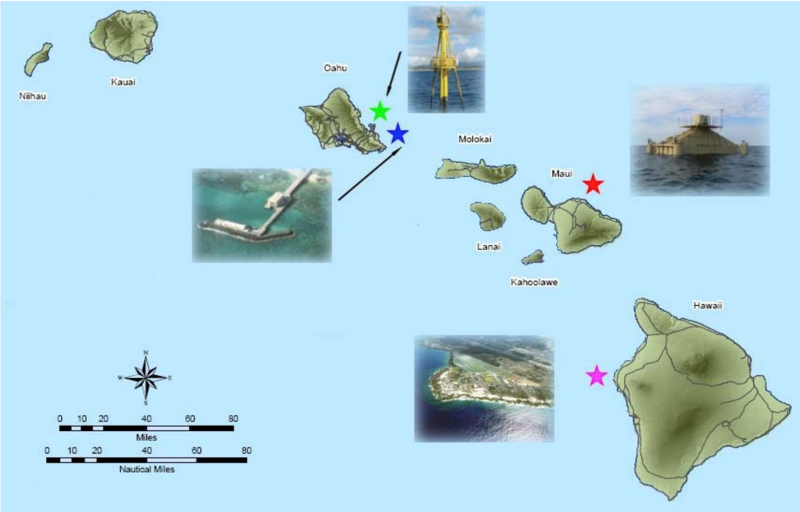
Ocean Thermal Energy Conversion

- Uses temperature difference between deep and shallow ocean waters to run a low temperature engine
- Technical challenges
  - Large diameter and long pipelines
  - Low cost, efficient heat exchangers
  - Large, stable platform and mooring design
  - Dynamic power cable to shore
- Environmental challenges –large intake and discharge of water
- Cost challenge:
  - Requires new materials, better engineering, and innovative designs, while taking advantage of economy of scale and current offshore technology

Courtesy Makai Ocean Engineering

Ocean Energy - Hawaii National Marine Renewable Energy Test Center

- **UH awarded one of two ocean energy test centers announced by USDOE fall 2008**
- **Objectives:**
  - **Wave: Facilitate development & implementation of commercial wave energy systems – with one or more of these systems to supply energy to grid at >50% availability within 5 years**
  - **Ocean Thermal Energy Conversion: Conduct long-term testing and help move OTEC to pre-commercialization**
- **Establish up to four field test facilities on Maui, Oahu, and Hawaii**
- **National and international partners**



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Electric & Hybrid Vehicles

- **Hybrid**
  - •liquid fueled with batteries used to allow engine to operate at near peak efficiency
  - •batteries maintained within narrow range of state-of-charge
  - •commercially available but cost – profitability for manufacturers remains an issue
- •**Plug-in hybrid:**
  - •electricity for short haul supplemented by engine for longer trips
  - •requires larger battery capacity than hybrid and deep-discharge capability
  - •Not commercialy available today. Toyota, GM, Nissan, and others have announced production of plug-in hybrids production in 2011 or beyond.
- **Electric:** battery only, larger capacity, deep-discharge required

- **Issues**
  - – Battery technology for long-life with deep-discharge still under development (3 to 5 years ??)
  - – Battery costs remain high
  - – Charging infrastructure may requires substantial investment for grid upgrade
  - – Need consistent policies, regulations, and incentives to accelerate technology and acceptance of technology

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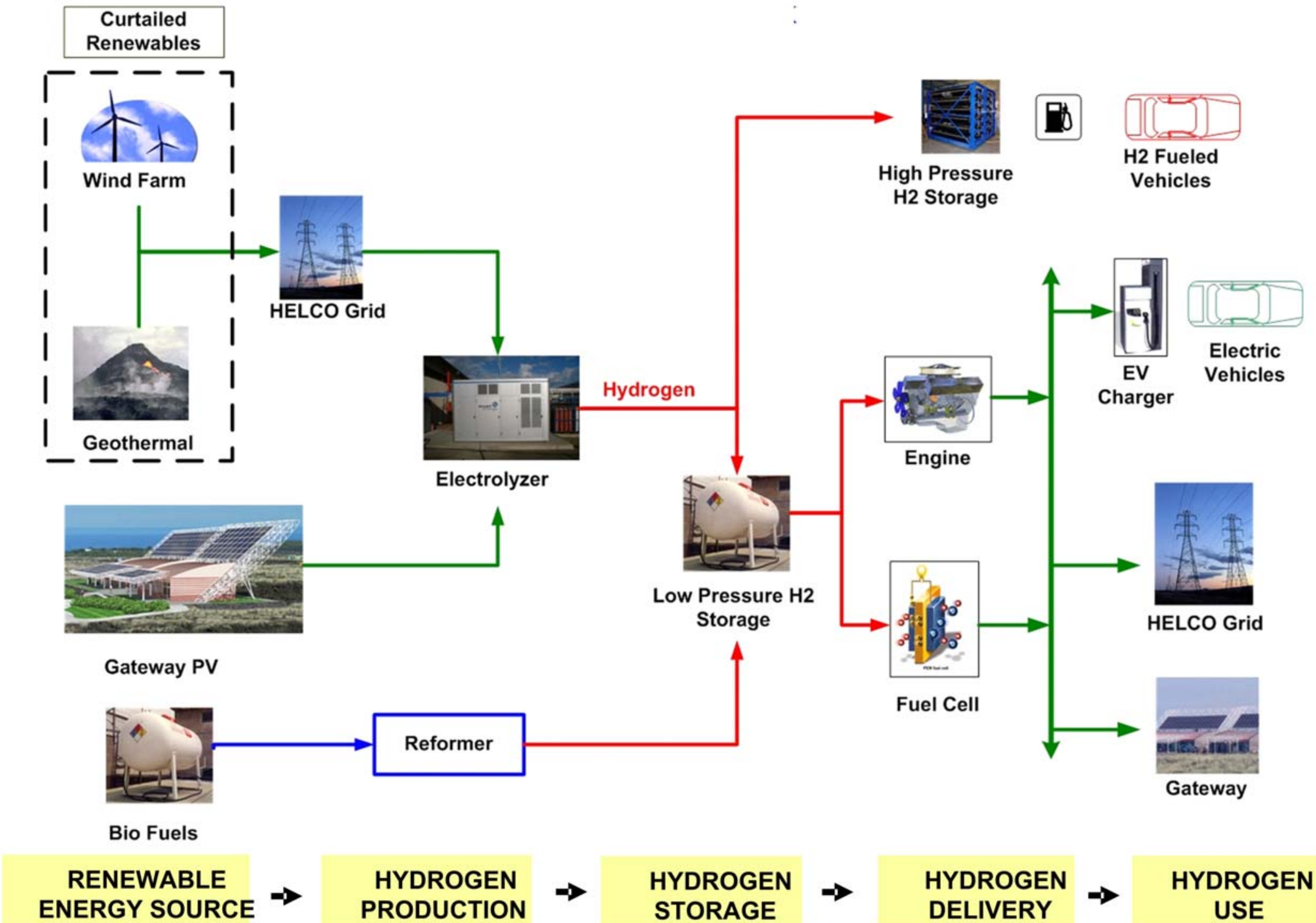
Hydrogen Power Park Concept



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Hawaii Volcanoes National Park Renewable Hydrogen Fueling Station

- **Hydrogen Fueling Infrastructure funded by USDOE with cost share from State of Hawaii via H2 Capital Investment Fund**
  - $ 2.4 million shared by USDOE and State of Hawaii
  - Hydrogen production using electrolysis of water
  - Electrolyzer powered by renewable electricity from HELCO at special research rate. (under negotiation)
  - Hydrogen production 12 -60 kg/day depending on vehicle needs
  - Fueling station to be located on Kilauea Military Camp (DOD)
- **Vehicles provided by DOT/DOI to Volcano National Park under Advanced Transportation for Parks and Public Lands program.**
  - Plug-in hybrid vehicles with H2 for fuel
  - Vehicle integration by Hawaii Center for Advanced Transportation Technology (HCATT)
  - Additional Ford E450 shuttle bus provided by USDOE

A Sustainable and Secure Future:
Hawaii Can be a Leader

- **Environment**
- **Energy**
- **Economics**
- **Equity**
- **Education**

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