Technology Issues in Renewable Energy and Energy Efficiency



Presented to Hawaii State Legislature
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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

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

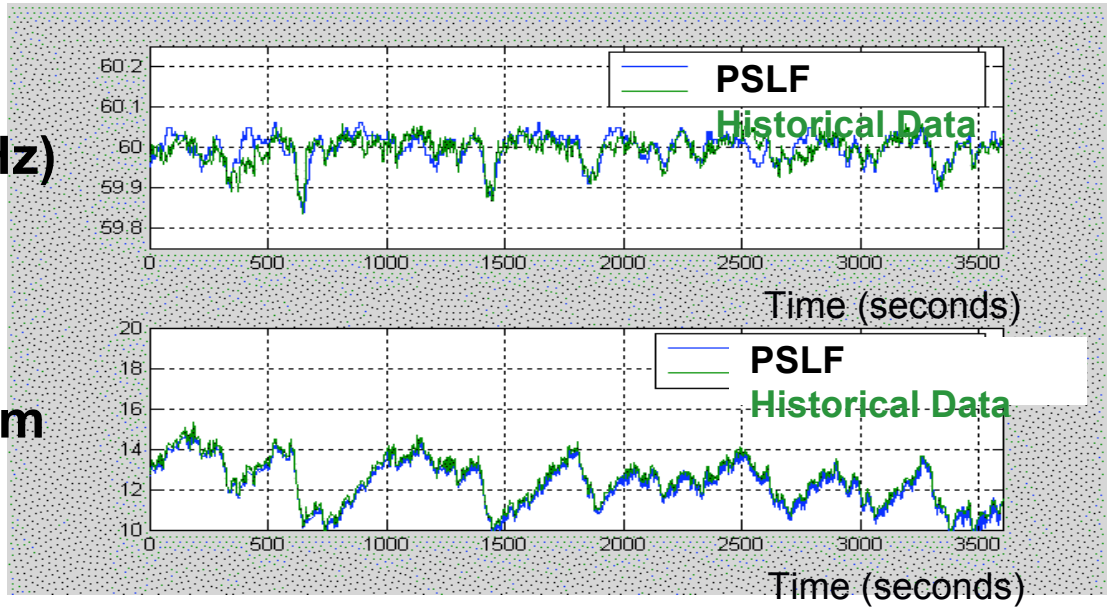
Wind

- **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

Frequency (Hz)

Apollo Windfarm (MW)



- 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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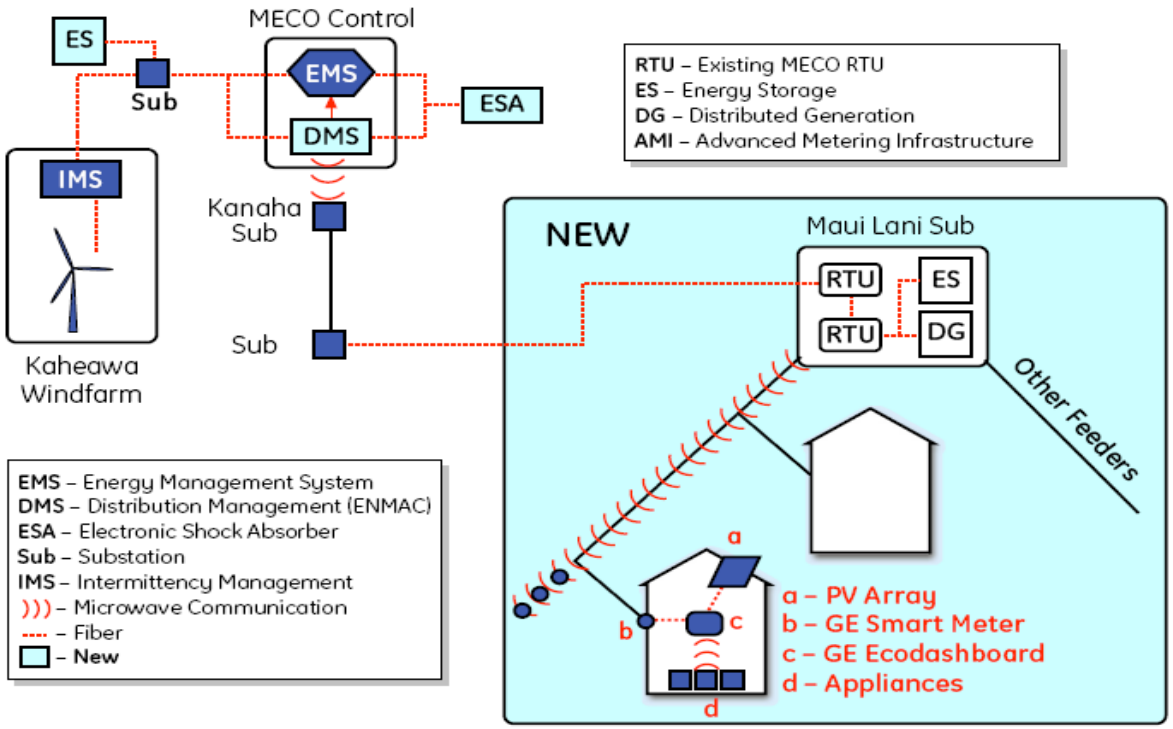
Maui Smart Grid Project

- **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**

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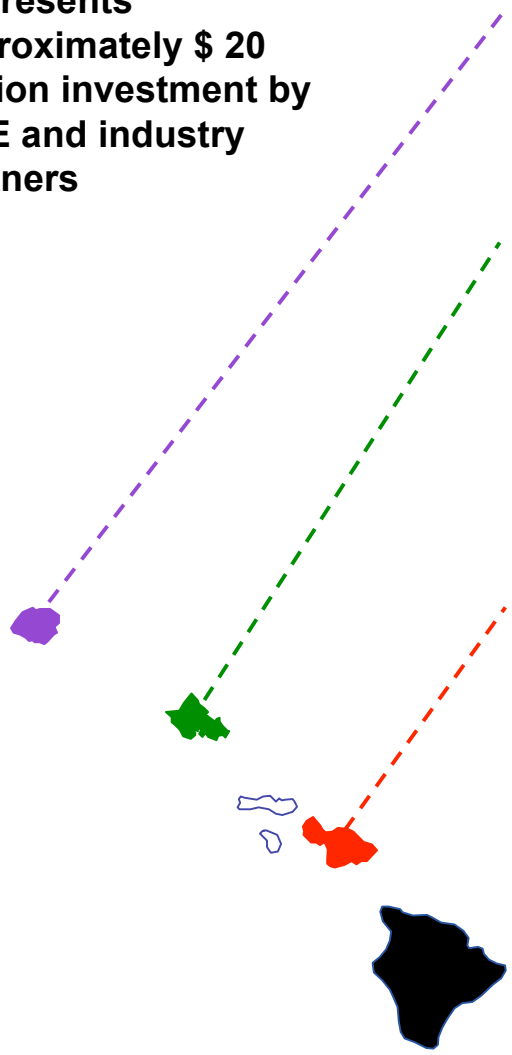
Current Efforts Being Used to Define Technology Needs for Increasing Renewable Energy Use

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

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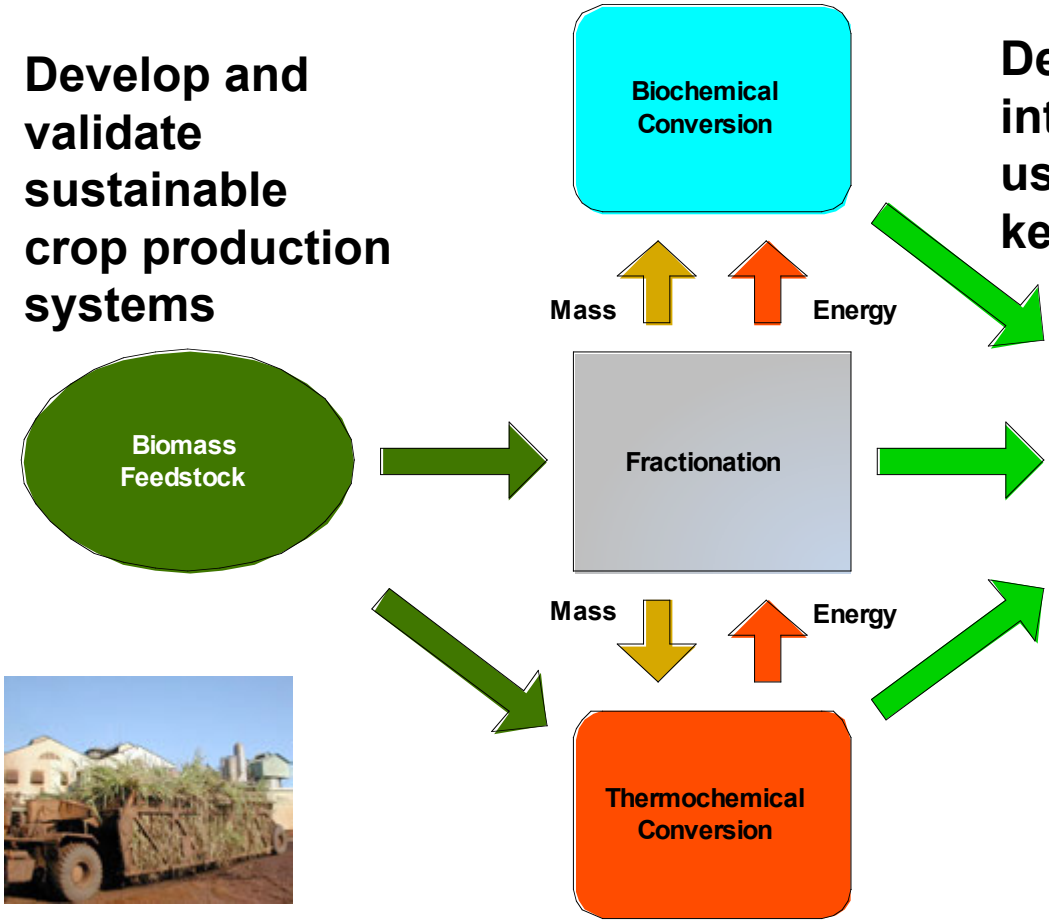
Needs for Development of Sustainable, Integrated Bioenergy Systems for Hawaii

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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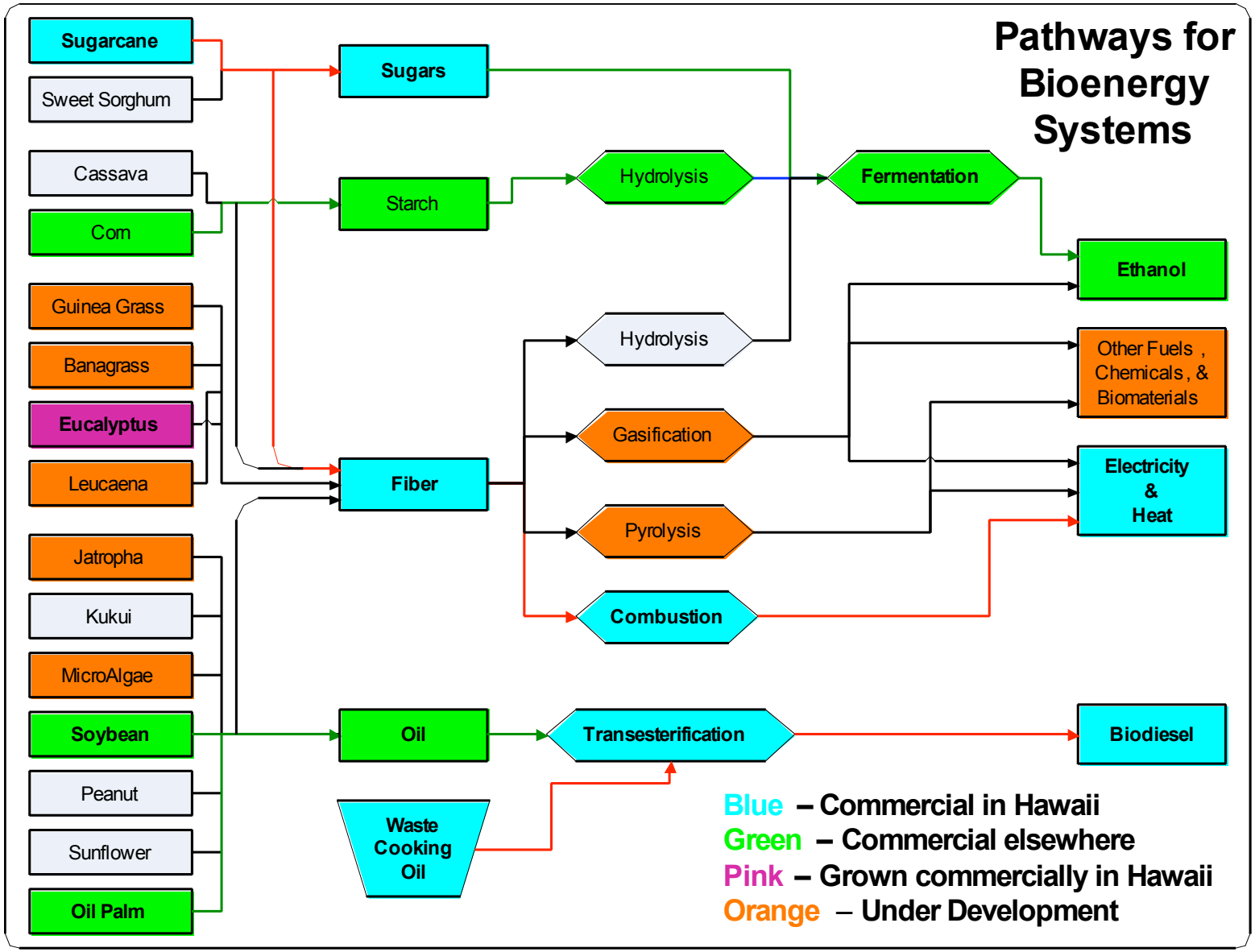

Pathways for Bioenergy Systems
Sugarcane
Sweet Sorghum
Cassava
Corn
Guinea Grass
Banagrass
Eucalyptus
Leucaena
Jatropha
Kukui
MicroAlgae
Soybean
Peanut
Sunflower
Oil Palm
Sugars
Starch
Fiber
Oil
Waste Cooking Oil
Hydrolysis
Fermentation
Hydrolysis
Gasification
Pyrolysis
Combustion
Transesterification
Ethanol
Other Fuels , Chemicals , & Biomaterials
Electricity & Heat
Biodiesel
Blue – Commercial in Hawaii
Green – Commercial elsewhere
Pink – Grown commercially in Hawaii
Orange – Under Development
Crops
Intermediate Products
Conversion Technologies
Bioenergy Products

Hawaii Bioenergy Master Plan

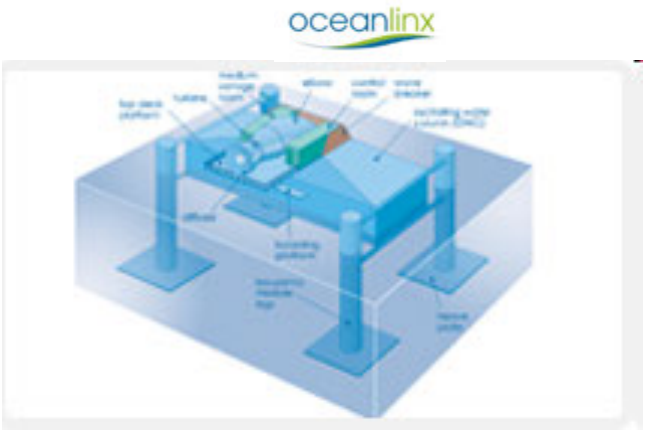
- **Legislatively mandated in 2007**
- **“ *The primary objective of the bioenergy master plan shall be to develop a Hawaii renewable biofuels program to manage the State’s transition to energy self-sufficiency based in part on biofuels for power generation and transportation.*”**
- **Supported by State 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



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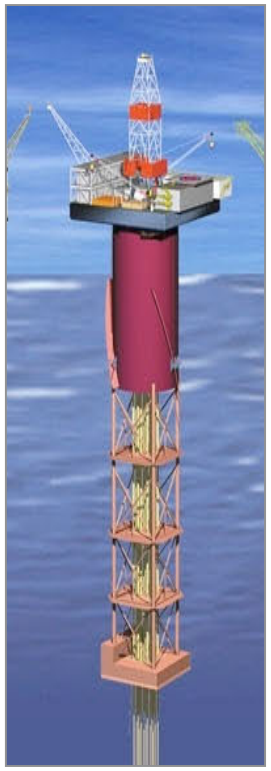
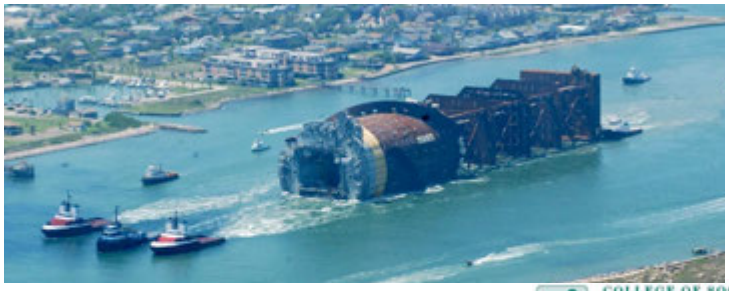
Ocean Thermal Energy Conversion



- 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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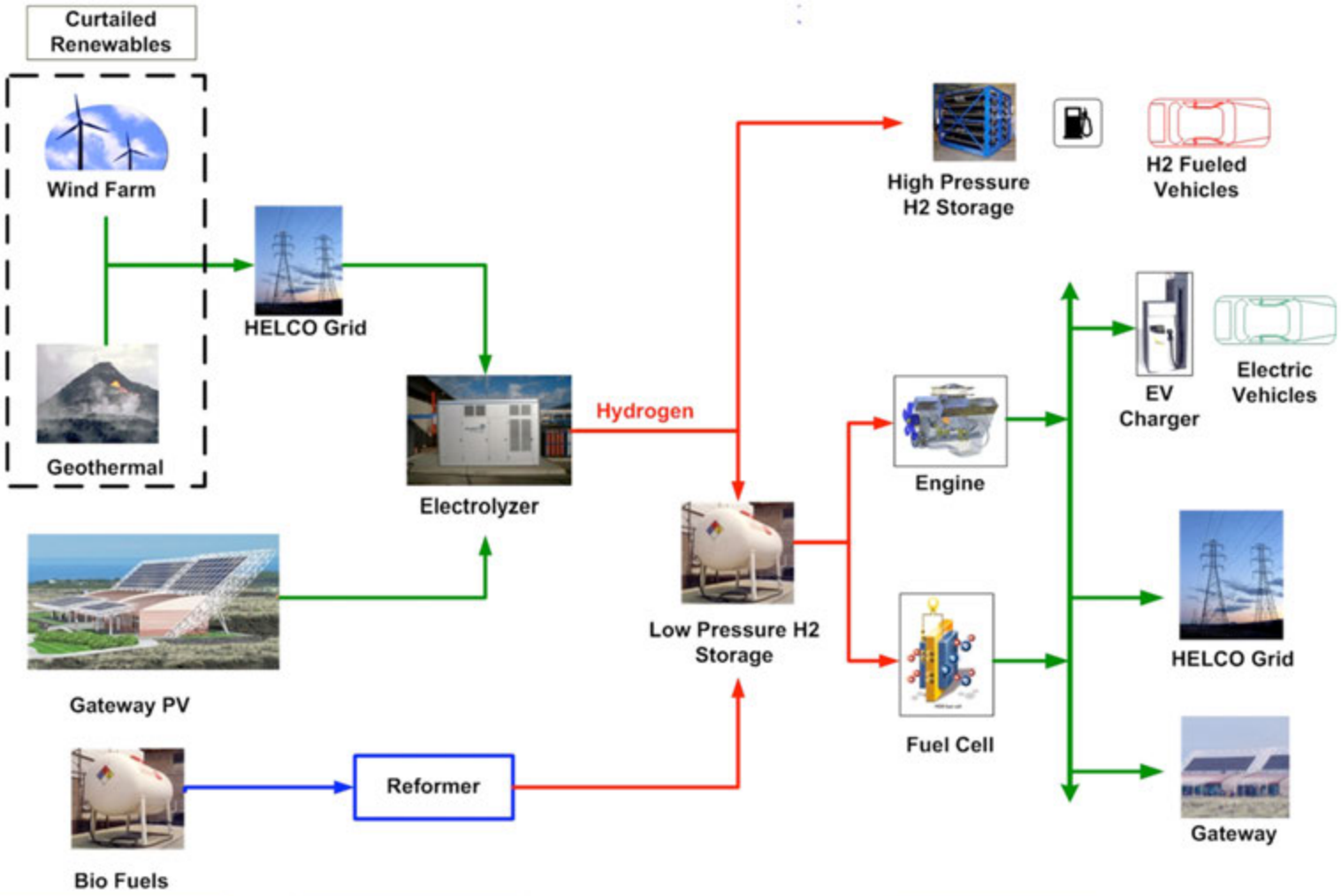
Hydrogen Power Park Concept



RENEWABLE ENERGY SOURCE → HYDROGEN PRODUCTION → HYDROGEN STORAGE → HYDROGEN DELIVERY → HYDROGEN USE

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**

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A Sustainable and Secure Future:
Hawaii Can be a Leader

- Environment
- Energy
- Economics
- Equity
- Education

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