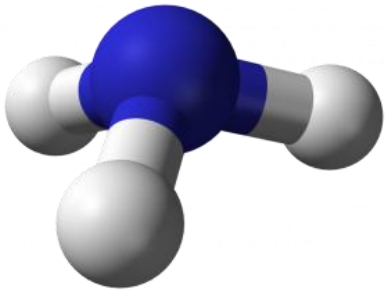


Feasibility of Ammonia Production in Hawaii from Curtailed Renewables for Food and Fuel Securiy

h2technologies

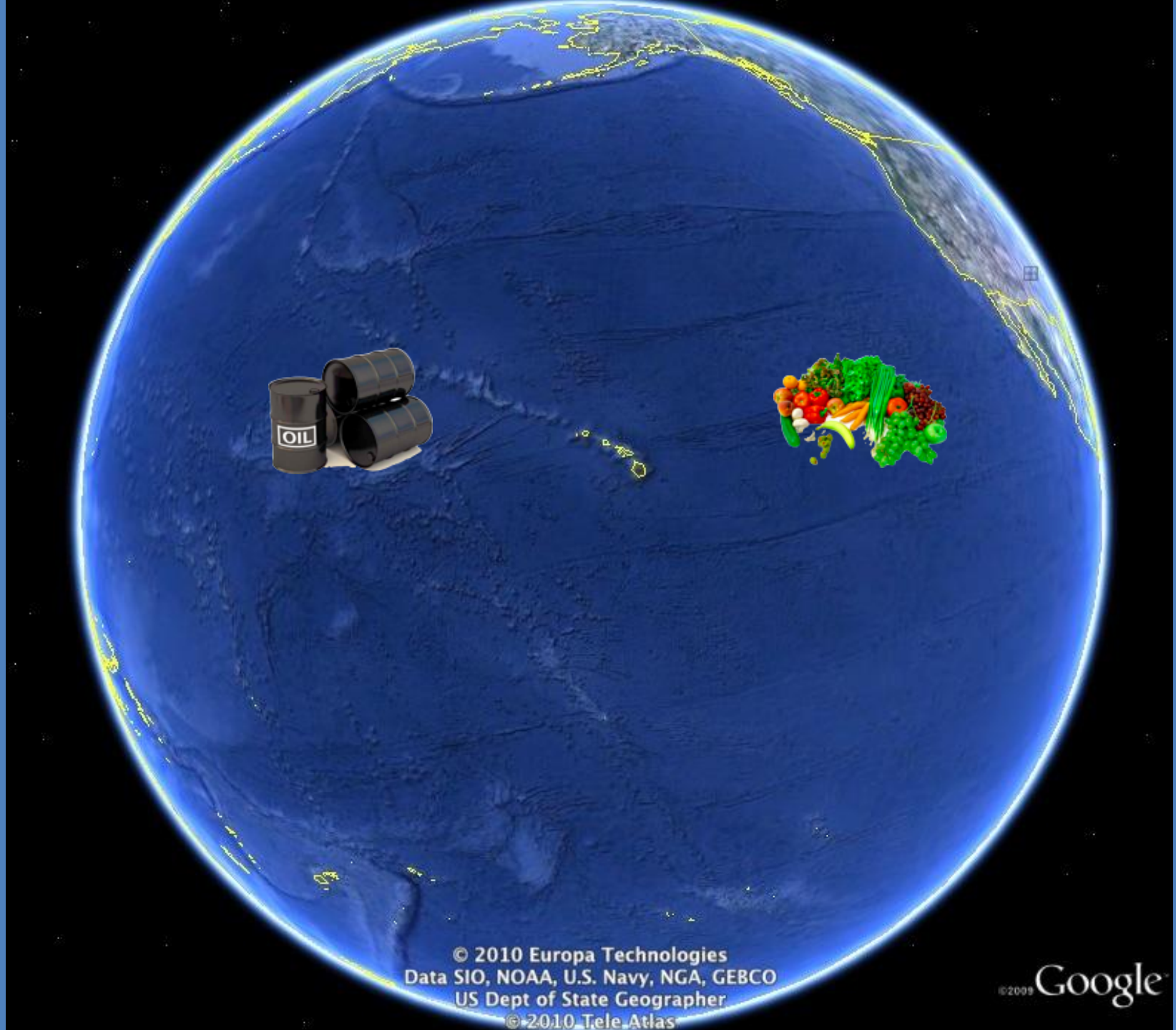
NH3 Fuel Conference
Portland, Oregon
September 20, 2011

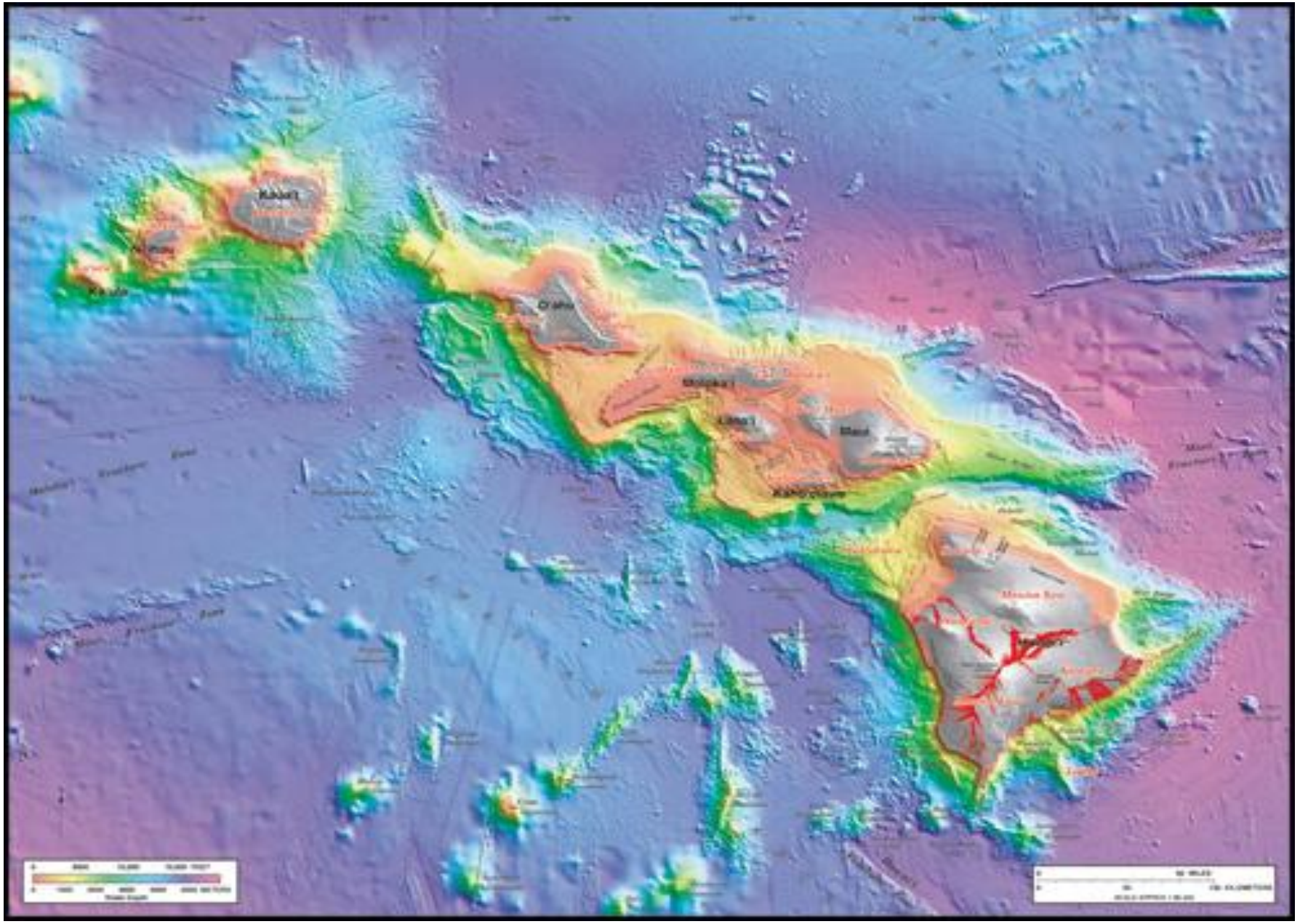
Hawai'i has no indigenous sources of Fossil Fuels: Coal, Oil or Natural Gas

Coal

Natural Gas

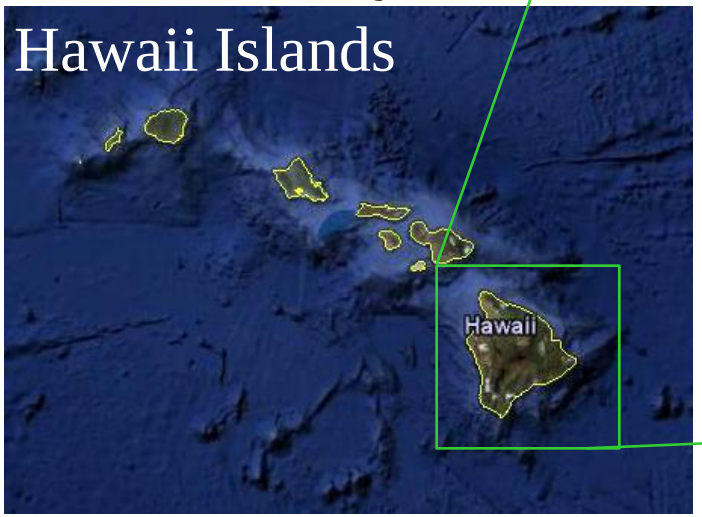
Oil

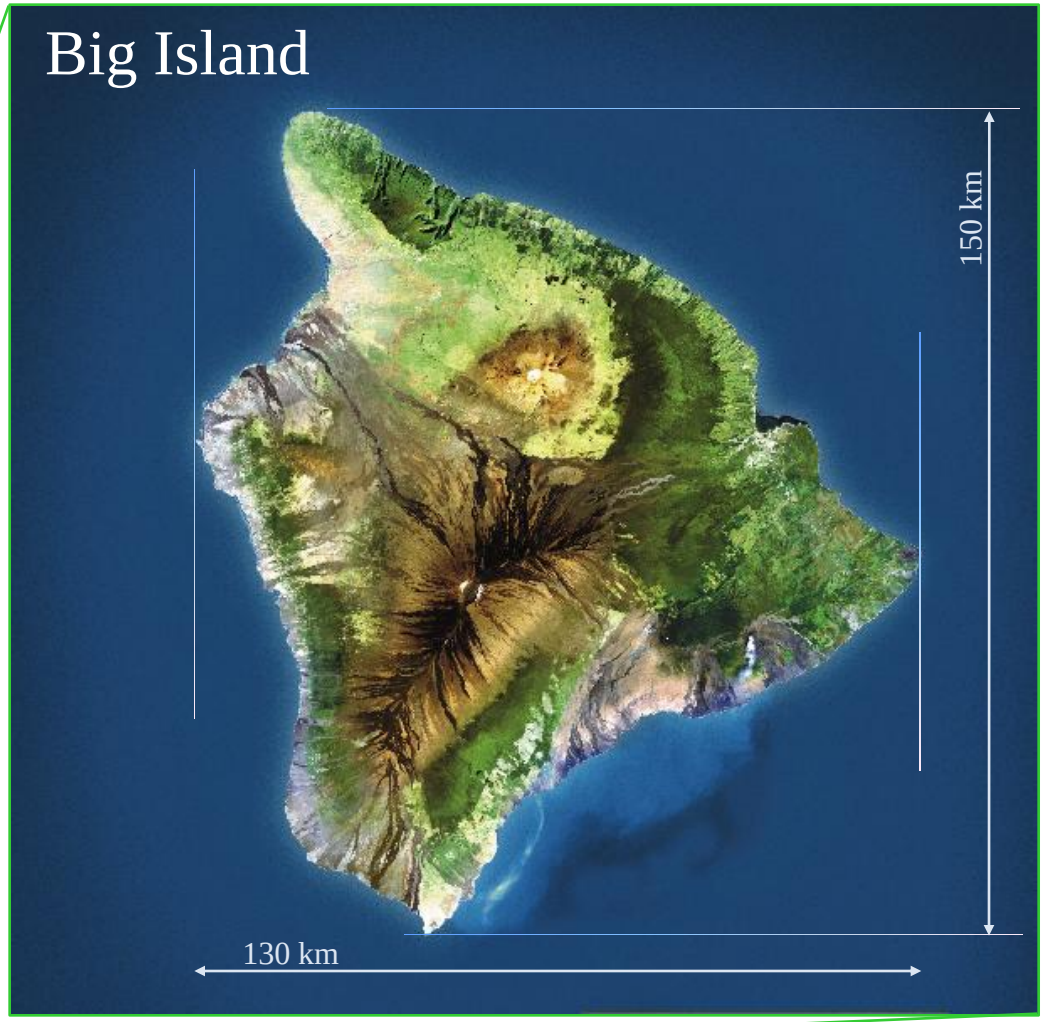

OIL
© 2010 Europa Technologies
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
© 2010 Tele Atlas
©2009 Google

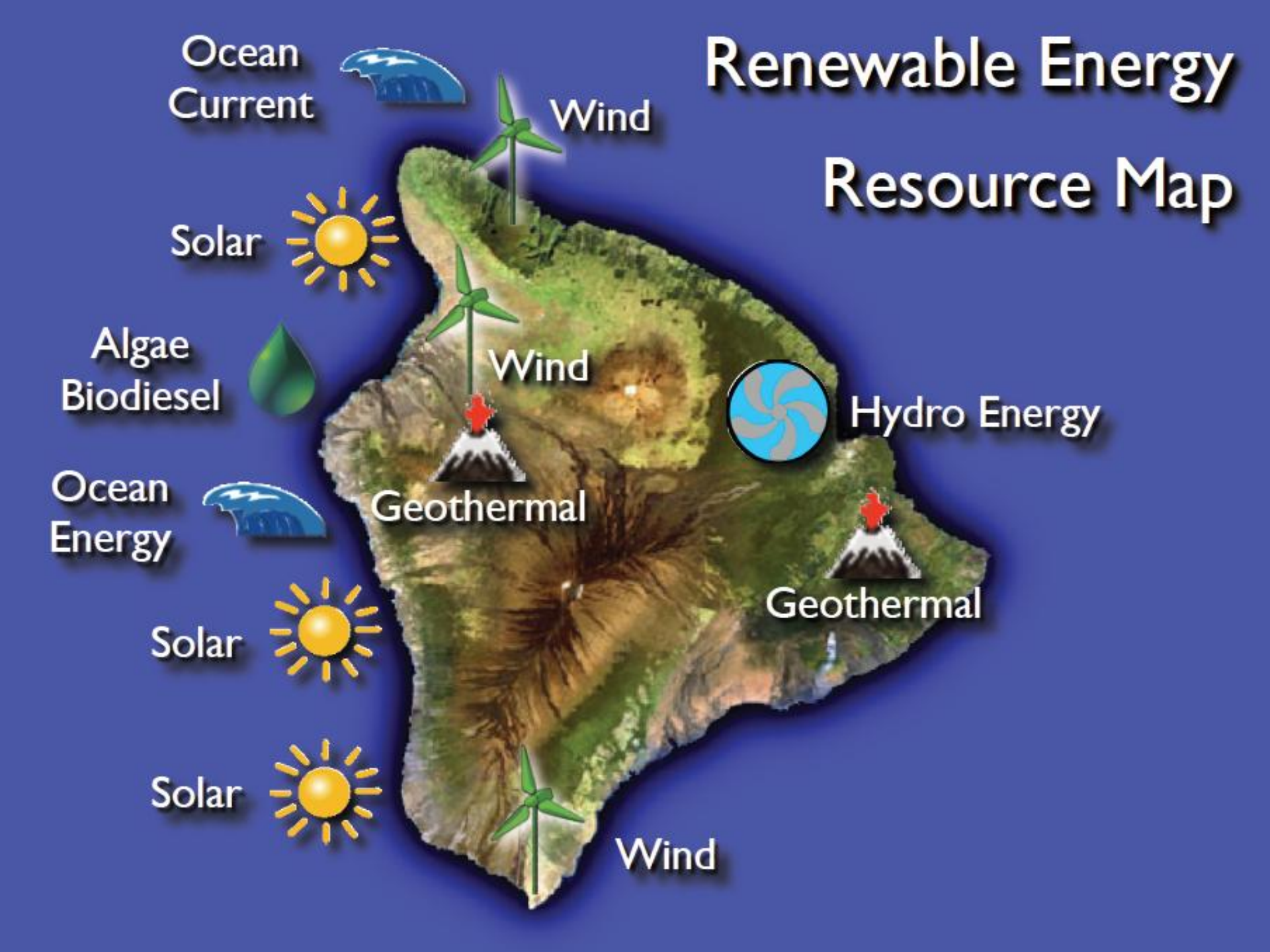

Kauai
Oahu
Molokai
Lanai
Maui
Kahoolawe
Hawaii

The Island of Hawai'i (Big Island)

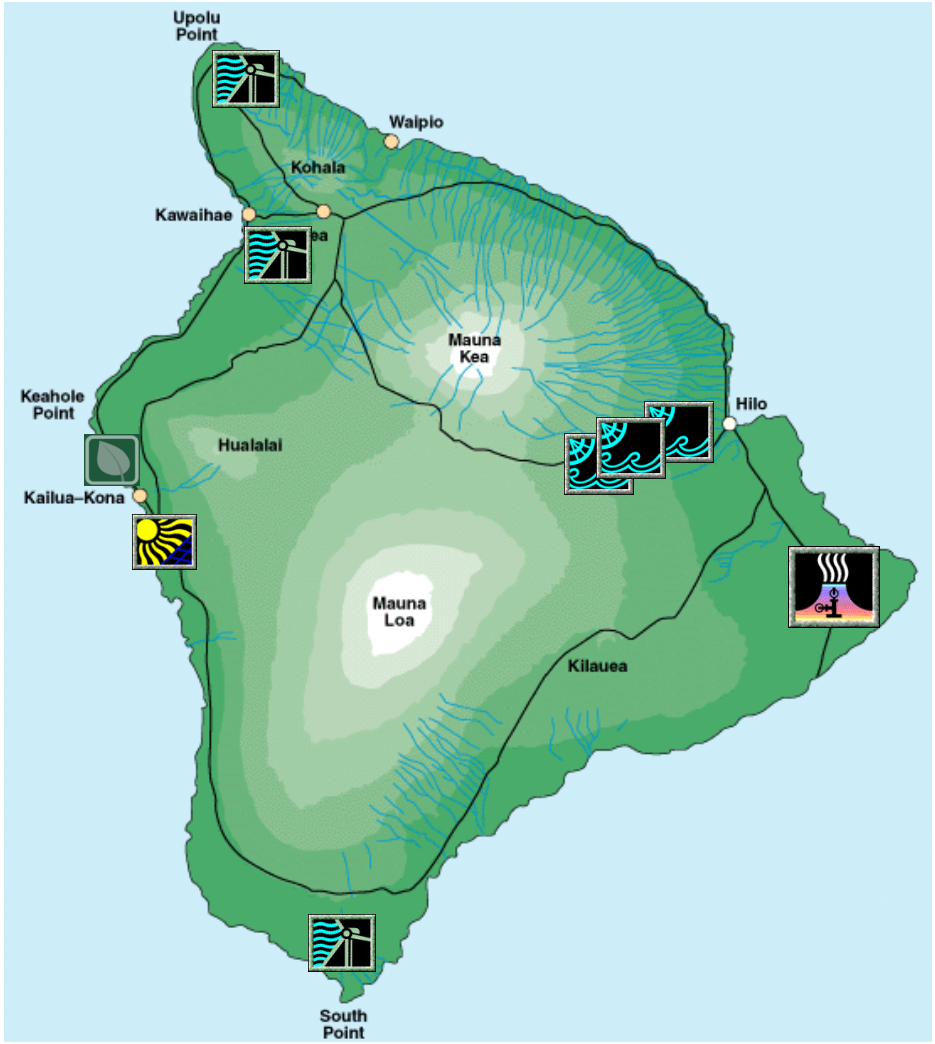
- **Large land mass**
- **Low population density**
- **High quality wind**
- **>1500MW of geothermal potential**
- **Ample hydro-electric potential**
- **Tourism economy**
- **Go to bed early**






Renewable Energy
Resource Map
Ocean
Current
Wind
Solar
Algae
Biodiesel
Wind
Hydro Energy
Ocean
Energy
Geothermal
Geothermal
Solar
Solar
Wind

Hawaii – Existing Renewable



- 269 MW capacity
- 203 MW peak demand
- 70 MW off-peak baseload

- Puna Geothermal – 41 MW
- Sopogy – 500kw - NELHA
- Solfocus – TBD - NELHA
- Hawi – 10.5 Wind – Upolu Point
- Pakini Nui – 20.5 MW Wind – S Point
- Lalamilo Wind – 1.2 MW – Waimea
- Puueo Hydro – 3.25 MW – Wailuku
- Waiau Hydro – 1.1 MW – Wailuku
- Wailuku River Hydro – 12.1 MW
- Cellana – Biofuel TBD – NELHA
- Small Hydro – 300 KW – Various
- Distributed Solar Thermal – 13GWh
- Distributed Solar Electric – 7.5 MW

Electricity market on the Big Island is saturated

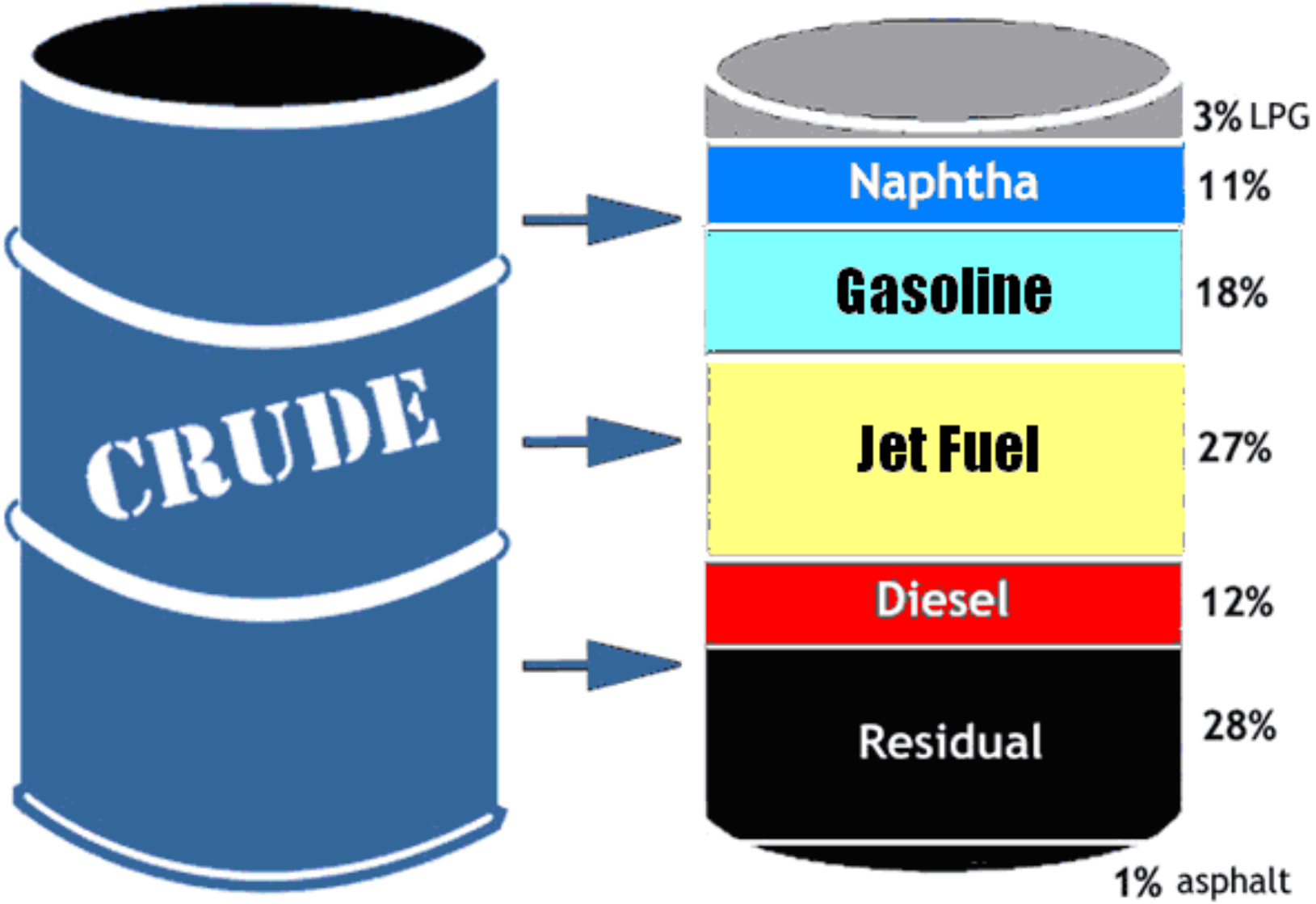
Need to find ways to <u>utilize curtailed power from geothermal to allow expansion</u> of geothermal use on Hawaii

Evaluate near-term use of electrolyzers for:

- Hydrogen production
- Ammonia production
- Peak power production

Geothermal + Wind + Hydro
[off-peak hours]
=
Curtailment = Waste
↓
Curtailment = Fuel/Fertilizer

Energy Currencies Hawaii



Distillation Fraction of Products

Renewable Fuel Strategy for Hawaii

- **Hydrogen**
  - Fuel Cell Vehicles and Stationary Power
- **Ammonia**
  - Fertilizer for Farming Industry
  - Hydrogen Carrier
  - Stationary Power Gensets
- **Methanol (via Hydrogenation of CO2)**
  - Transesterification
  - Oxygenate for gasoline 10%
  - US Army DMFC
  - Methanol to Gasoline (MTG)
  - Methanol to Aviation Fuel

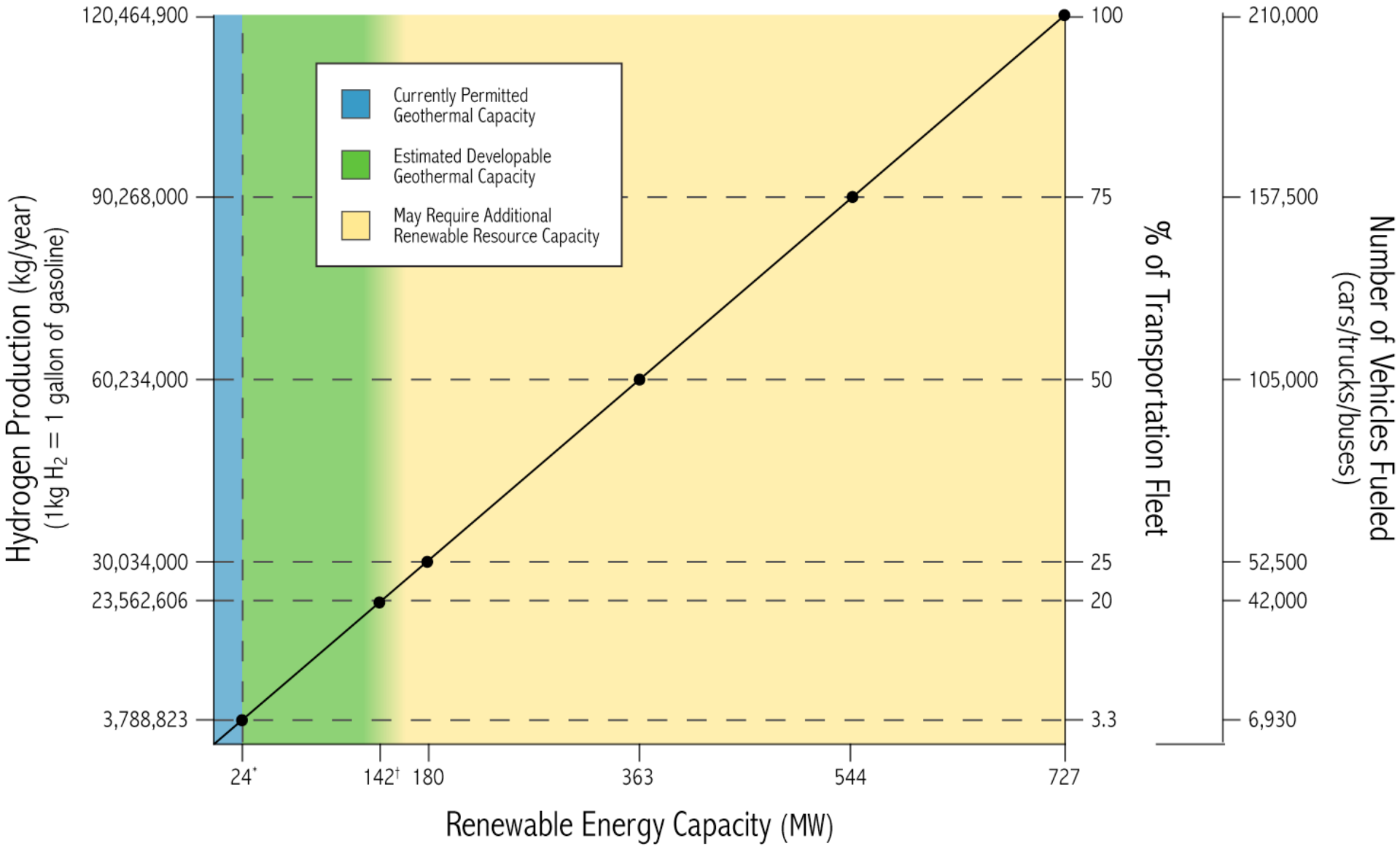
Market Drivers Through Legislation
HRS 196-10: Hawaii Renewable Hydrogen Program

- **Objective: transition state to a renewable hydrogen economy by:**
  - **Strategic R&D, testing & deployment of renewable hydrogen technologies;**
  - **Engineering & economic evaluations & near-term project opportunities;**
  - **Electric grid reliability & security projects to increase penetration of renewable energy on Big Island**
  - **Hydrogen demonstration projects including infrastructure, storage, and refueling hydrogen vehicles**
  - **Promote Hawaii renewable hydrogen resources to potential partners & investors;**

Investment Incentives Through Legislation
SB 772: Renewable Fuel Facility Investment Tax Credit

- **Objective: Create an incentive for development of local non-fossil renewable fuel plants in Hawaii:**
  - **100% of investment returned to investor as tax credits;**
  - **Tax credits can be taken in 1 year or rolled over;**
  - **Must be a Hawaii based company**
  - **Company must be a "Qualified High Technology Business" as deemed by the State of Hawaii Dept of Taxation**

Hydrogen Production Potential on the Big Island

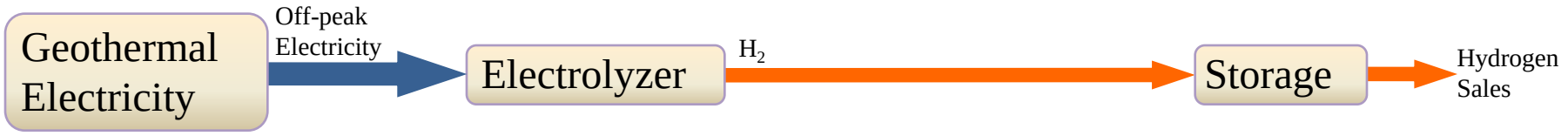


* 24 MW of 60 MW currently permitted geothermal capacity is utilized for H_2 production

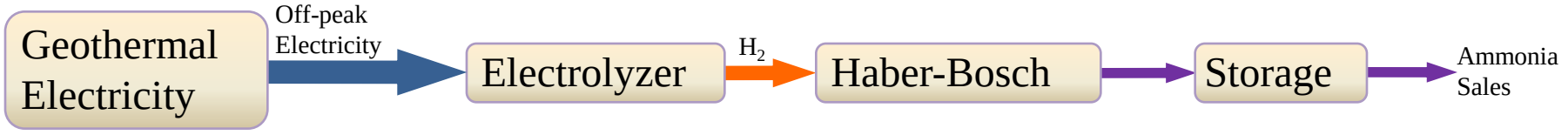
† 142 MW of total 180 MW developable capacity is utilized for H_2 production

System Components

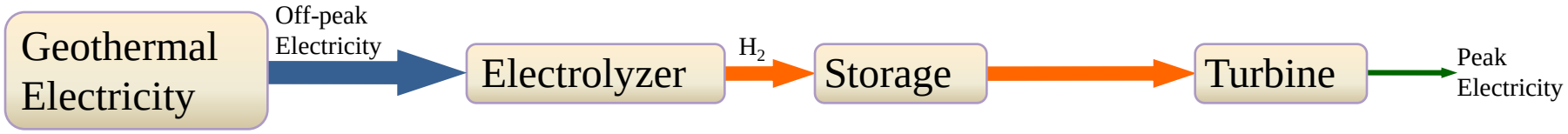
Hydrogen Production



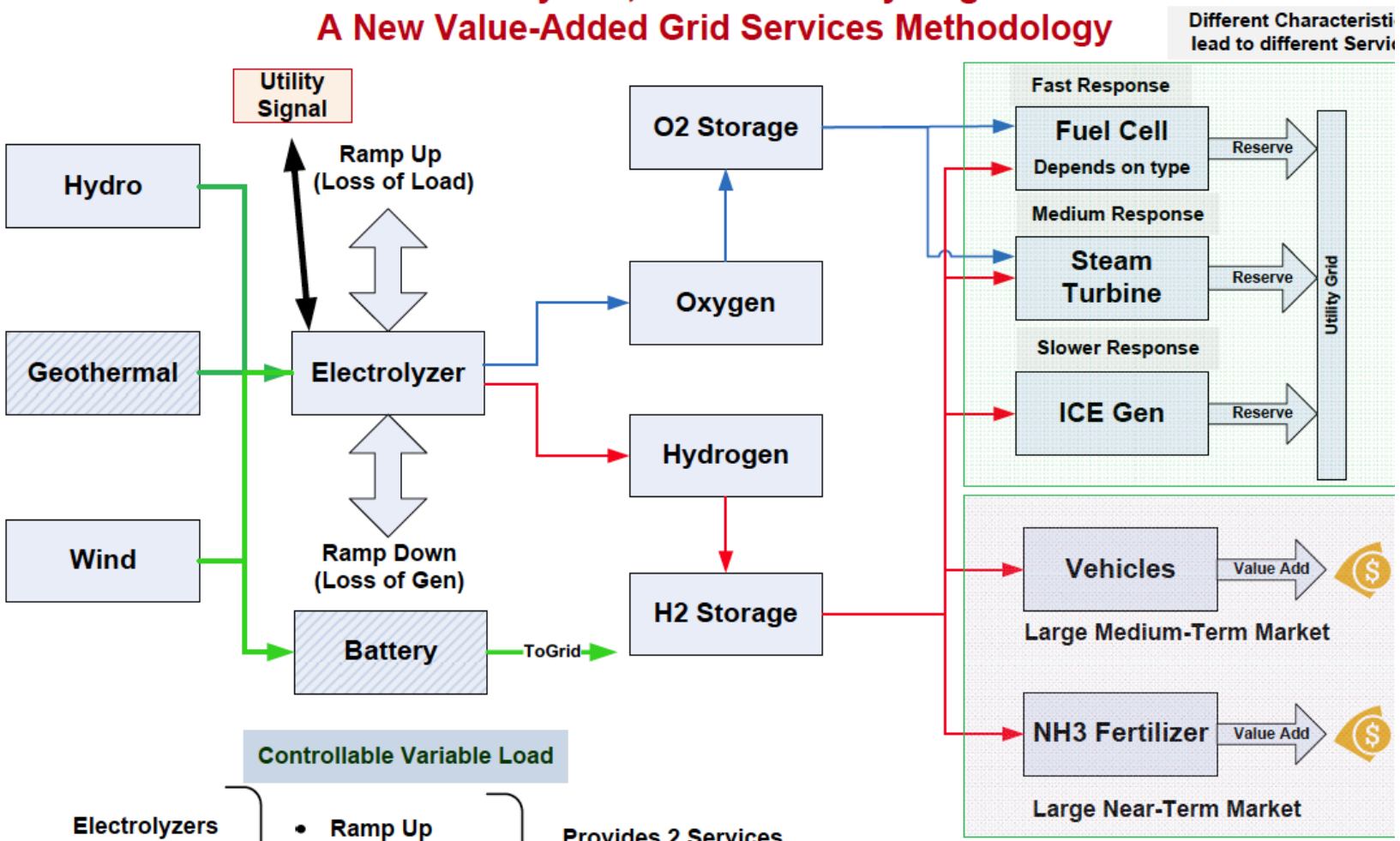
Ammonia Production



Peak Power Production



Electrolyzers, Fuel Cells & Hydrogen
A New Value-Added Grid Services Methodology



Controllable Variable Load

Electrolyzers
- PEM
- Alkaline

- Ramp Up
- Steady State
- Ramp Down

Provides 2 Services
- Down Regulation
- Up Regulation

Value Proposition – Change Operating Rules

- FROM: Wind up = Reserve up
- TO: Reduce Reserve requirement by throttling electrolyzer up and down
- PLUS: Electrolyzer producing valuable products while providing grid regulating ancillary services = potentially more value than just H2?

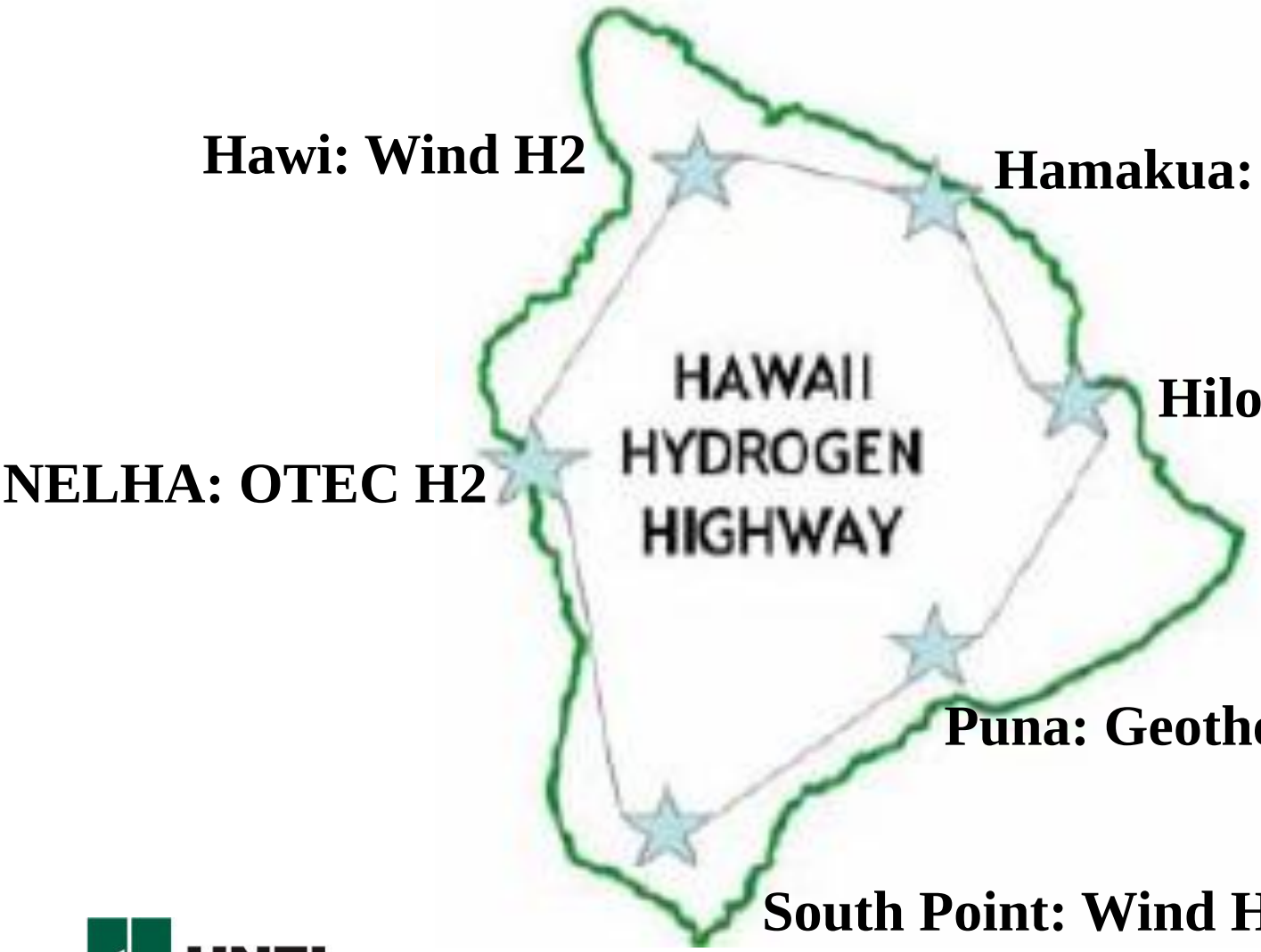
Hydrogen Vehicles have arrived and Infrastructure coming soon.

Ford H2ICE Shuttle Van for MTA

- Engine 225 hp
- 12 passengers + driver
- Compressed hydrogen – 5,000 psi
- Range – 150 miles

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

Hydrogen Infrastructure – Renewable H2



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

A need to localize fertilizer production using available resources

Immediate Demand for Ammonia in Hawaii

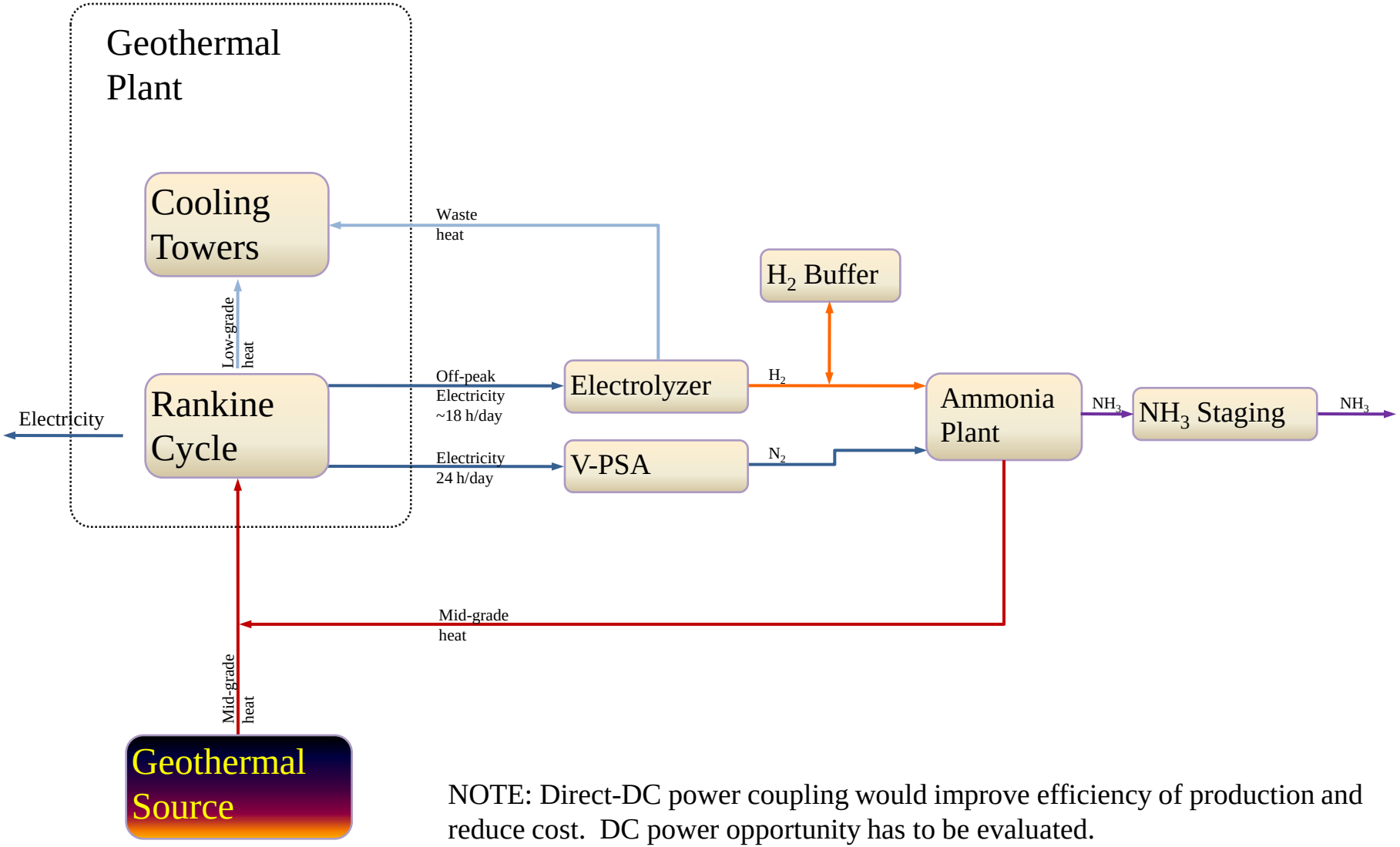
HC&S 6.8 T/D of Urea

↓

3.8 T/D of NH3

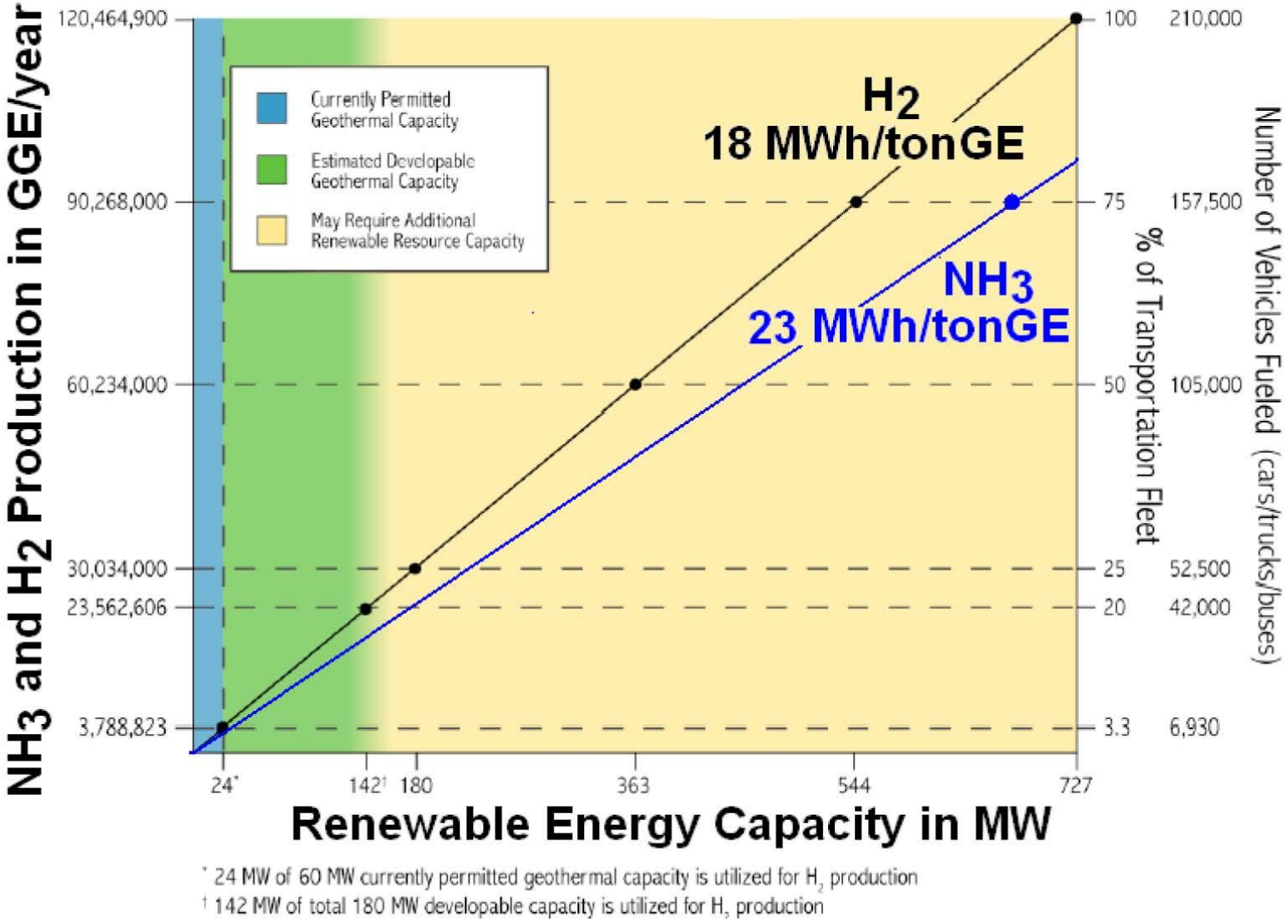
Analyst est. to be 9-10 T/D of NH3

Ammonia Production



NOTE: Direct-DC power coupling would improve efficiency of production and reduce cost. DC power opportunity has to be evaluated.

NH_3 and H_2 Production Potential for the Big Island



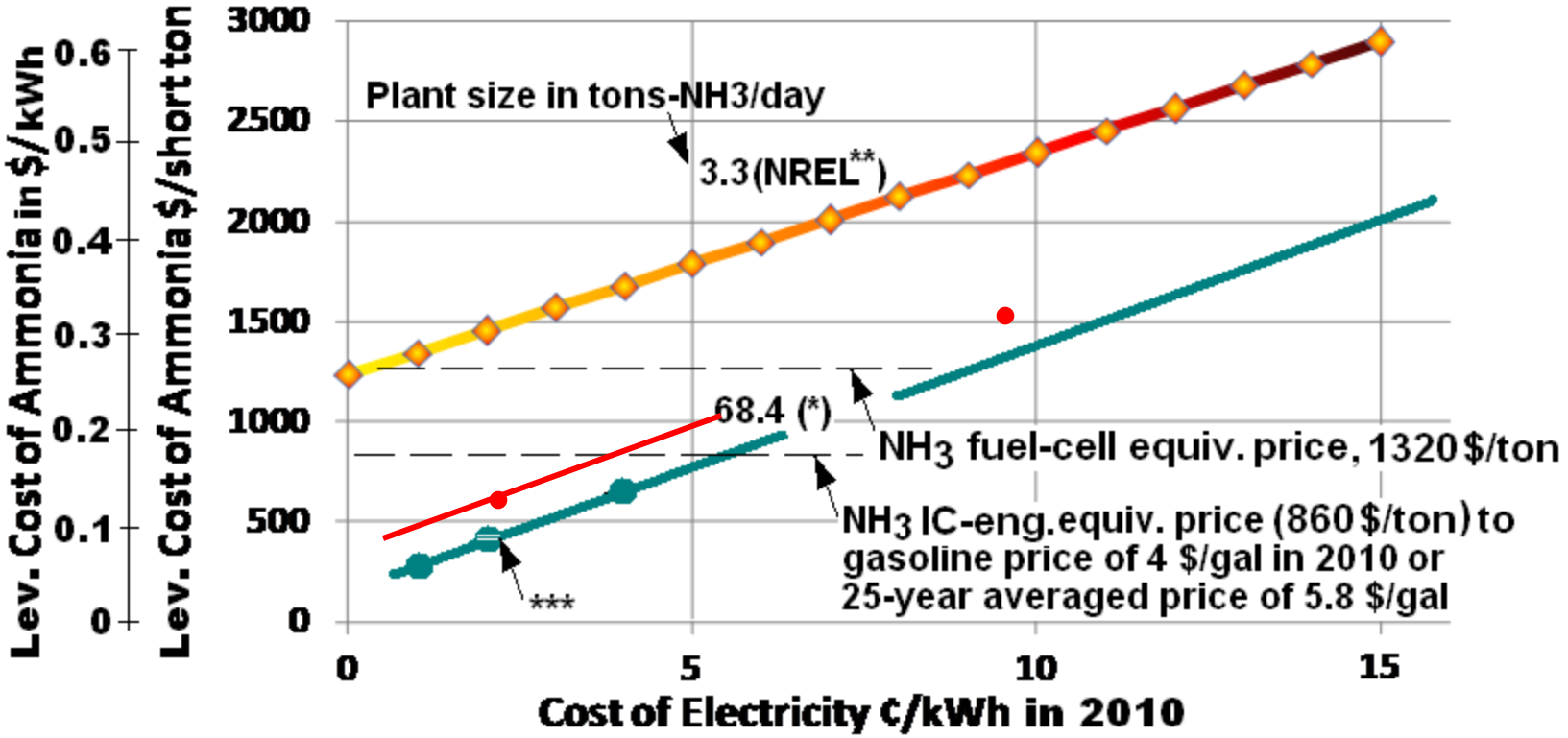
* 24 MW of 60 MW currently permitted geothermal capacity is utilized for H_2 production

† 142 MW of total 180 MW developable capacity is utilized for H_2 production

Levellized Cost of NH_3 as a Function of Electricity Cost

Assumptions*:

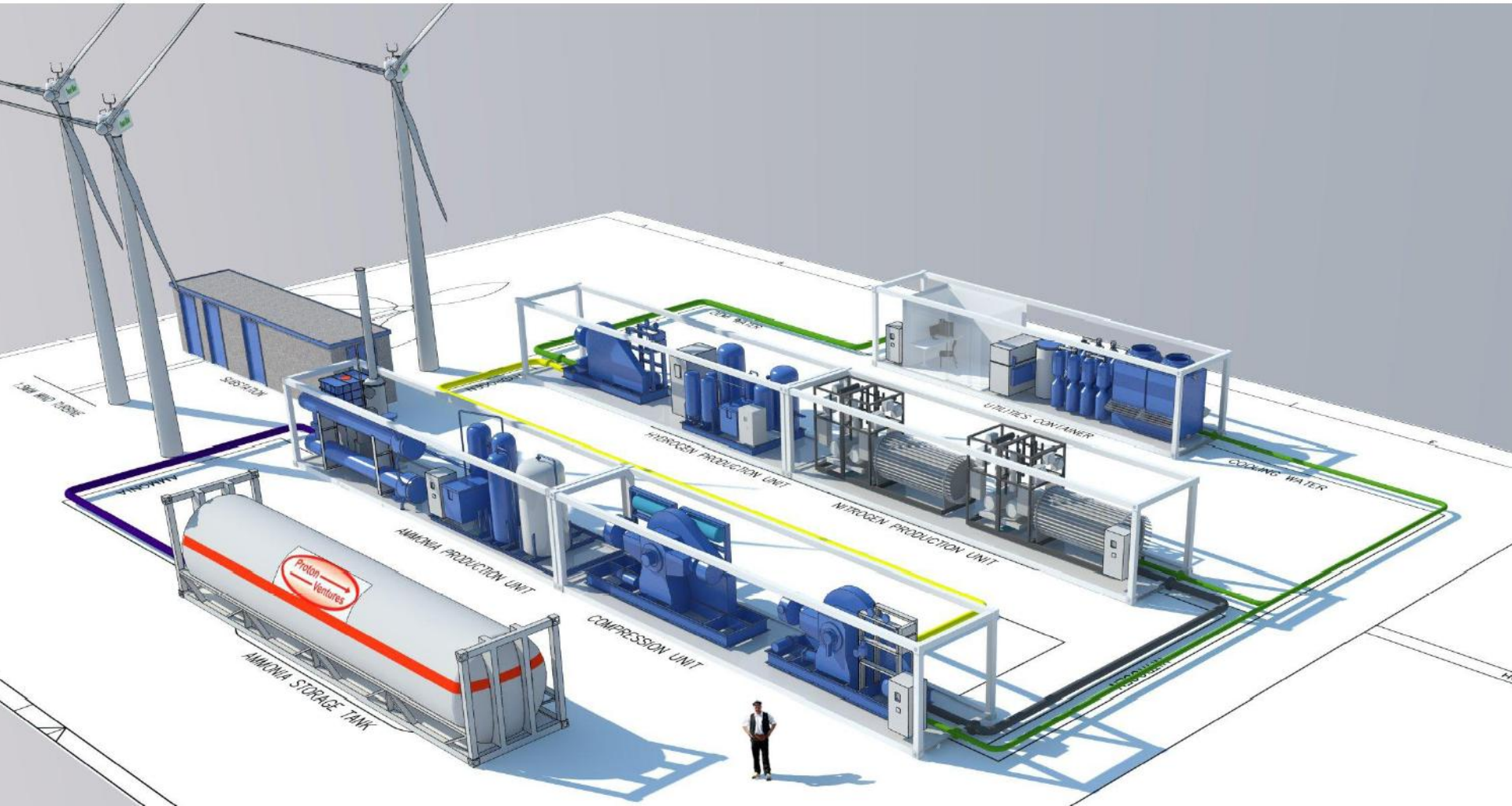
NH_3 plant input: 30 MW or 720 MWh/day; efficiency: 10.5 MWh/ton-NH3,
NH_3 plant cost: 6 $/(gal/y) or 52.7 M$, installed; loan: 5%/y; 1.76 $/W
NH_3 Plant output: 68.4 tons-NH3/day; 25-year service. O&M: 3.9% capital/y
Gasoline 2010 price & escal.; 4 $/gal & 3%/y; electricity & O&M escal.: 1.5%/y
Benchmarking: US GDP tot. energy use: 4.2 $/W; GDP electr. use: 3.6 $/kWh



*** Increase due to engine conversion cost of $10 k per bus

guy@h2-techs.com & ulrichbonne@msn.com

Proton Ventures 3.3T/D Pilot



Challenges

- **Low Acceptance by Farmers**

  -High Cost

  -Not suitable for many of Hawaii's crops

  -Perceived as too dangerous

  -Ag industry (with exception of HC&S) not used to handling NH3

- **Not Used as Fuel Yet**

  - Concerns by DOH Clean Air Branch

  -High Cost

Ammonia-Based Economy Program for HI

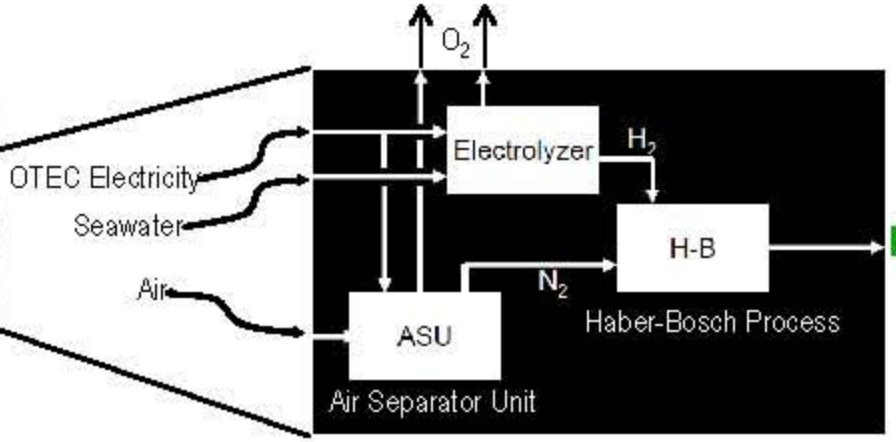
Objectives: Demonstrate ammonia-based mini-economy

Approach and Tasks: Team with "shovel-ready" businesses

	k$
Analysis: Complete a more in-depth analysis of the overall economics and economic sensitivities. Model and support plant performance and infrastructure	1,000
Environmental Agreements: Negotiate agreement for 25+ years of low-cost electricity with PGV and wind generators. Insure a role for HELCO and get PUC's blessing. Upgrade grid lines between PGV and NELHA.	
NH3-Vehicles: Team with automotive conversion (University of Hiroshima) to build and deliver 3-4 ammonia vehicles (AVs)	2,000
Install Mini-Plants: Acquire, install and operate 2 mini-plants of 3.2 tons/day (120kg/hour, 3.2*2000/5.69*0.42 = 472 GGE/day, enough to drive 15-25 vehicles 20-30 miles each day, if plant runs 24/7) to demo how much lower in cost the second one will be, and to have redundancy, so that one plant can make and sell ammonia; the other to develop process improvements, NH3 fuel cell, and explore new applications (energy storage, fertilizer, refrigerant, etc)	7,000
Developments: Develop and demo dual use SSAS for fuel cell use and to make ammonia production cheaper and maximally efficient	2,000
Permits: Test emissions and get the permits (EPA, DOH, PUC,…),	500
Applications: Develop dispensing/filling of ammonia to vehicles and to farmers. Plan and execute demo of energy storage (bench-top??). Team with farm coop	3,000
Program Mmgt. & Reporting: Prepare and submit comprehensive reports (Monthly, Annual and Final), with technical and regulatory recommendations	3,000
Resources: Time – 3-4 years and 15-20 M$	18,500

guy@h2-techs.com

OTEC Powered NH_3 Fuel System



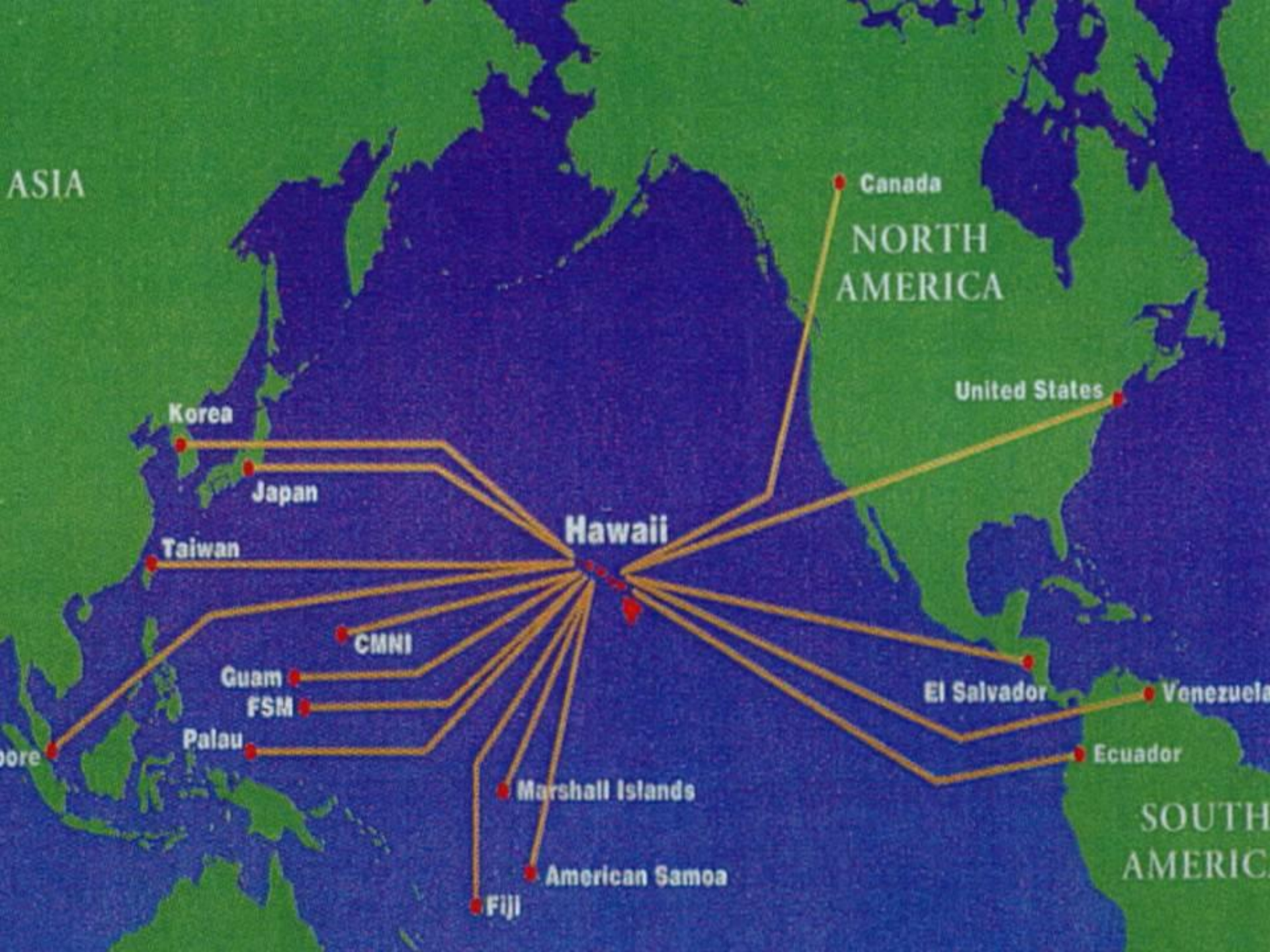
Onboard Ammonia (NH_3) Production Plant

$3H_3 + N_2 \rightarrow 2NH_3$

- Complete creation to end user process : renewable energy to engines
- Easier to transport than H_2
- No carbon
- Technology presently available
- Process only needs air, water and electricity
- Containerized and fieldable fuel system
- NH_3 fuel can be used in conventional engines with slight modification

NH_3 Uses

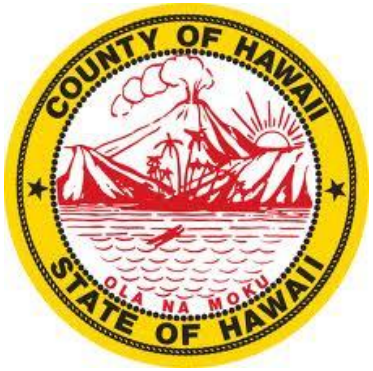
$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$


ASIA
Canada
NORTH
AMERICA
United States
Korea
Japan
Hawaii
Taiwan
CMNI
Guam
FSM
Palau
El Salvador
Venezuela
Ecuador
Marshall Islands
American Samoa
Fiji
SOUTH
AMERIC


R水素コミュニティをつくろう［ハワイ島編］
水素のながれ
電気のながれ
1 自然エネルギー
OTEC
（海洋温度差発電）
地熱発電
（温泉熱利用発電）
電気をつかう
2 水素をつくる
あまった
電力
H2O
H2
3 水素をためる
H2
水素タンク
4 つかう
H2 Station
shopping mall
観光用に水素燃料バスを使用
水素ステーション
アンモニア（NH3）をつくり、肥料に

Kokua Team


PUNA
GEOTHERMAL VENTURE
HAWAII


COUNTY OF HAWAII
OLA NA MOKU
STATE OF HAWAII


STATE OF HAWAII
1959
UA MAU KE EA O KA AINA I KA PONO


MAUI
HC&S
HAWAIIAN COMMERCIAL & SUGAR COMPANY


Proton
Ventures


ENTERPRISE
HONOLULU
O'AHU ECONOMIC DEVELOPMENT BOARD


HAWAIIAN
TUG & BARGE
Ready to Serve


ALOHA
Petroleum, Ltd.


KŪ'OKO'A
Freedom From Fossil Fuel

Mahalo!

Hawi Wind Farm. 10.5MW.
53% Capacity Factor

Go Ducks!