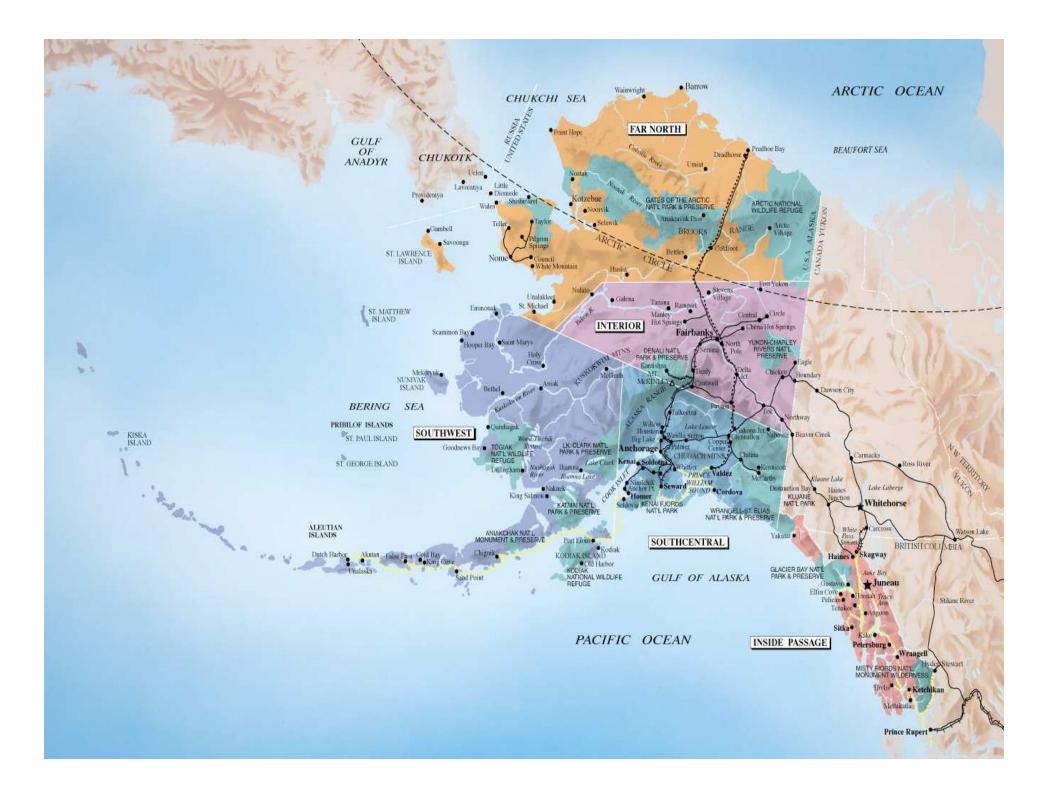


Bill Leighty, Principal
Alaska Applied Sciences, Inc.
Box 20993, Juneau, AK 99802
wleighty@earthlink.net
907-586-1426 206-719-5554 cell





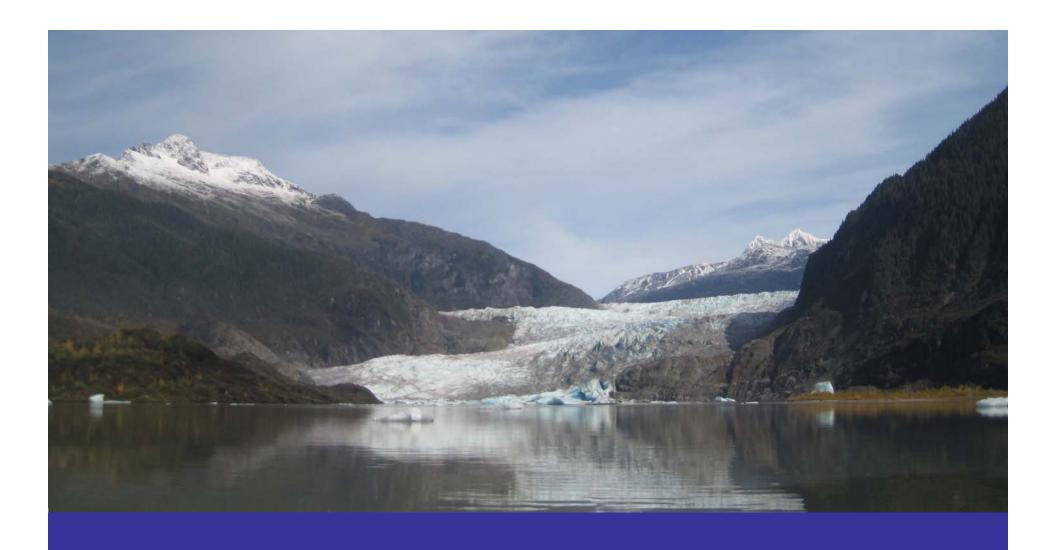


Mendenhall Glacier, Juneau, AK

June '71



Mendenhall Glacier, Juneau, AK 10 October 10



Mendenhall Glacier, Juneau, AK 10 October 10

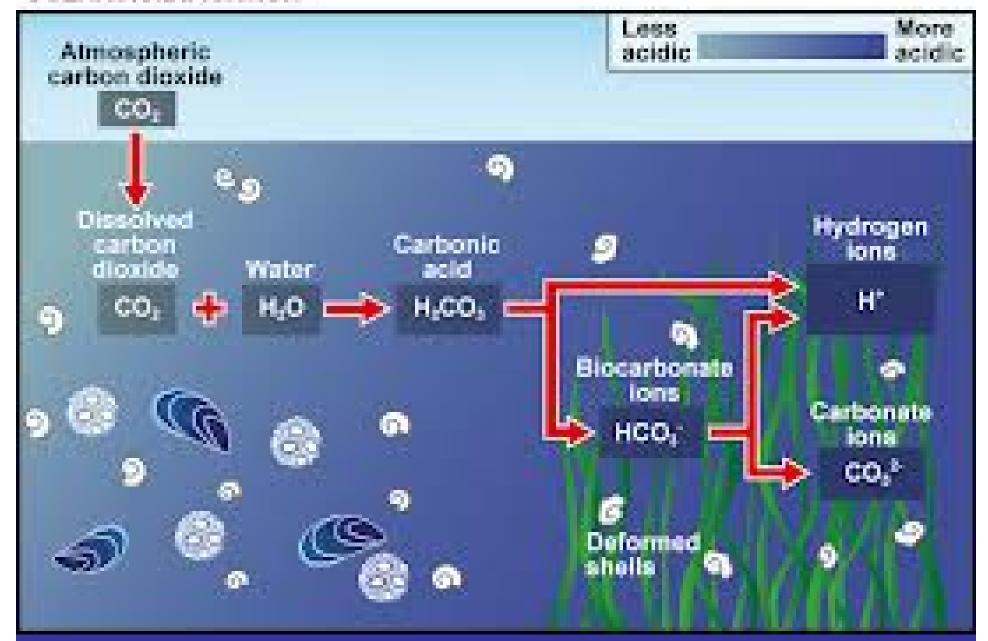


Shishmaref, Alaska Winter storms coastal erosion

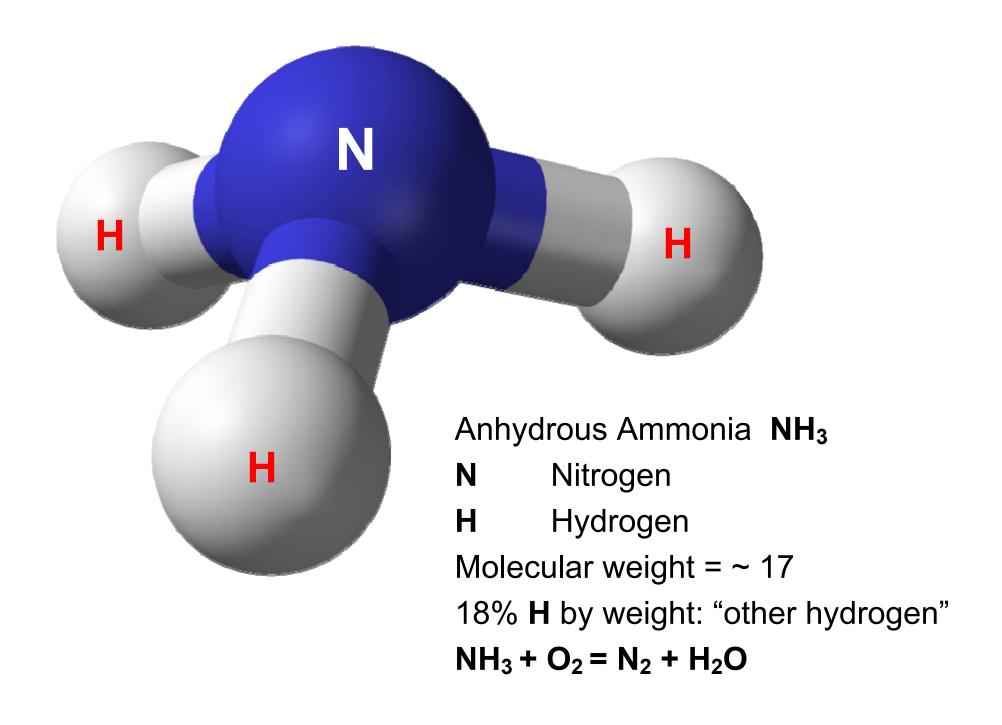
Rapid climate change



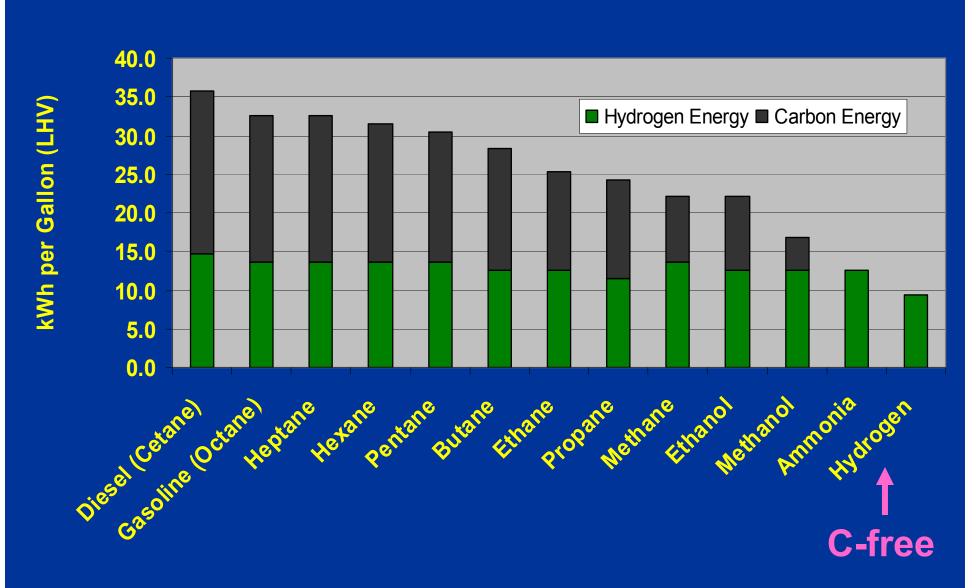
Spruce bark beetle kill, Alaska



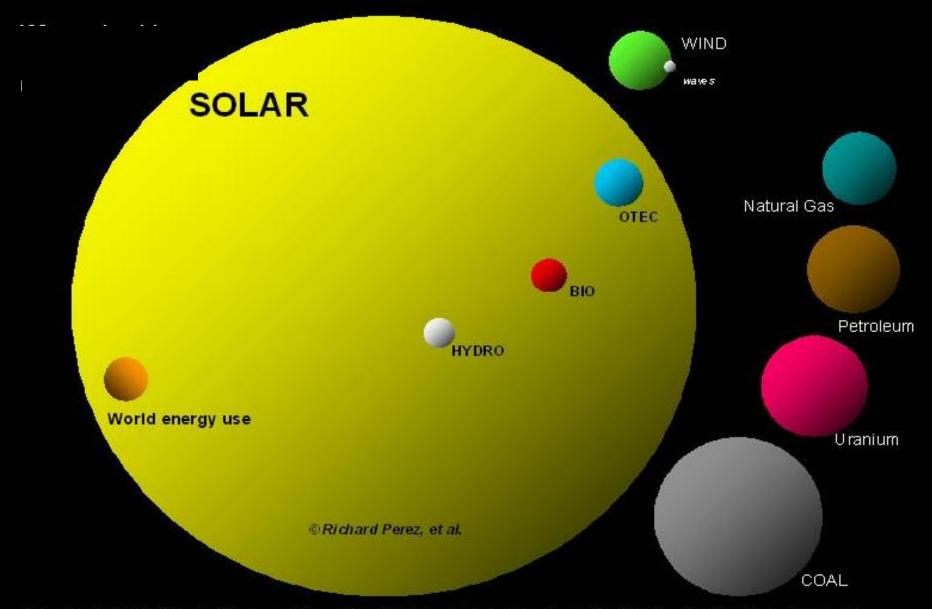
Ocean Acidification



Volumetric Energy Density of Fuels (Fuels in their Liquid State)

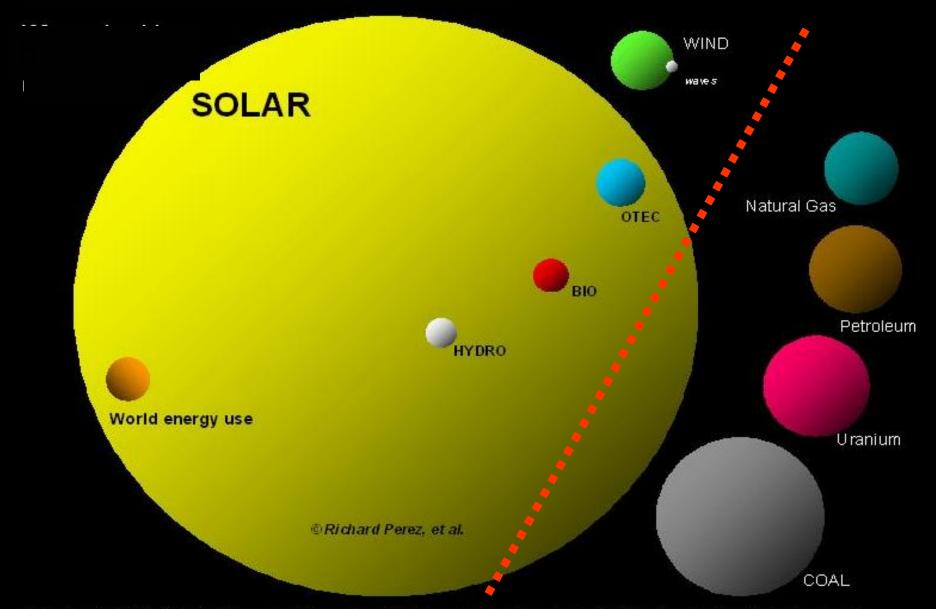


Where to invest for the long haul?



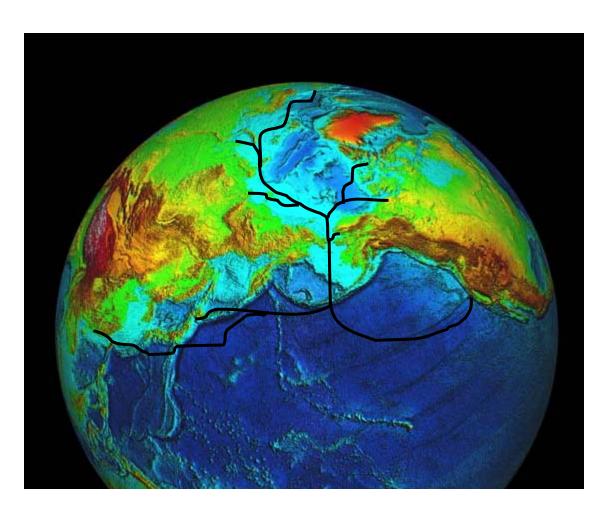
*yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. Word energy use is annual.

Where to invest for the long haul?

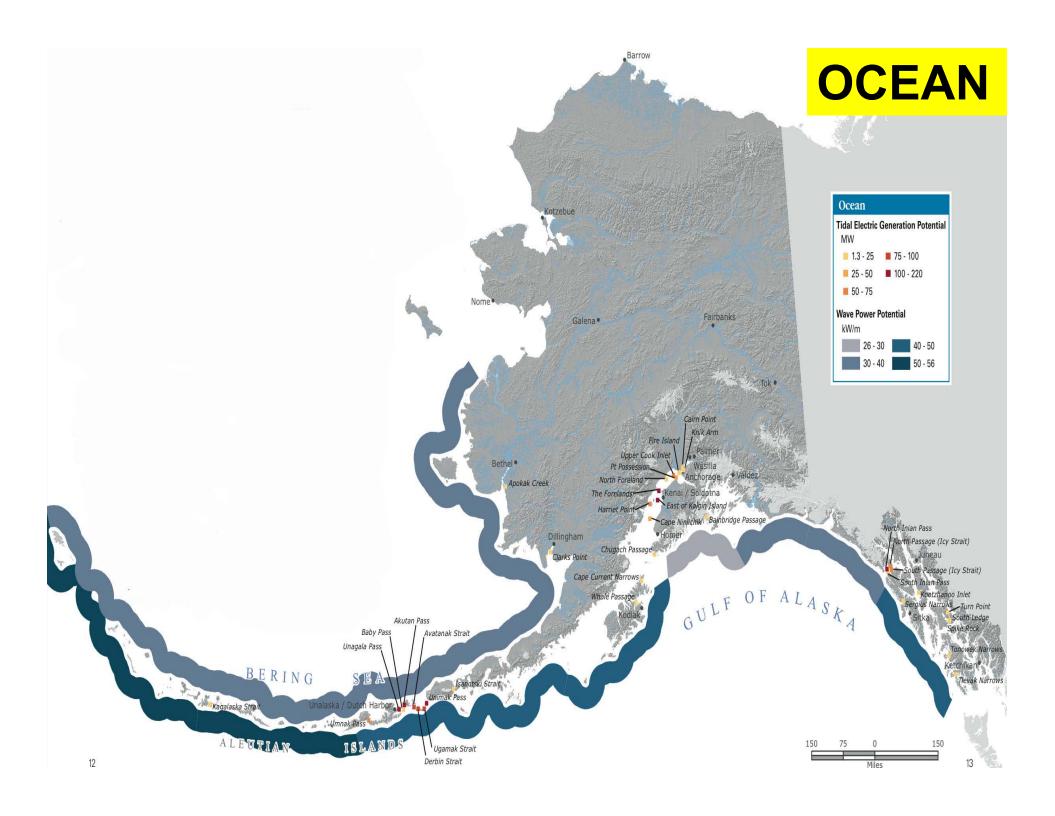


*yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. Word energy use is annual.

Alaska in the future global energy economy









Reinforced concrete Capture Chamber set into the excavated rock face. The Wells Turbines rotate in the same direction regardless of the direction of the air flow. Thus generating irrespective of upward or downward movement of the water column.

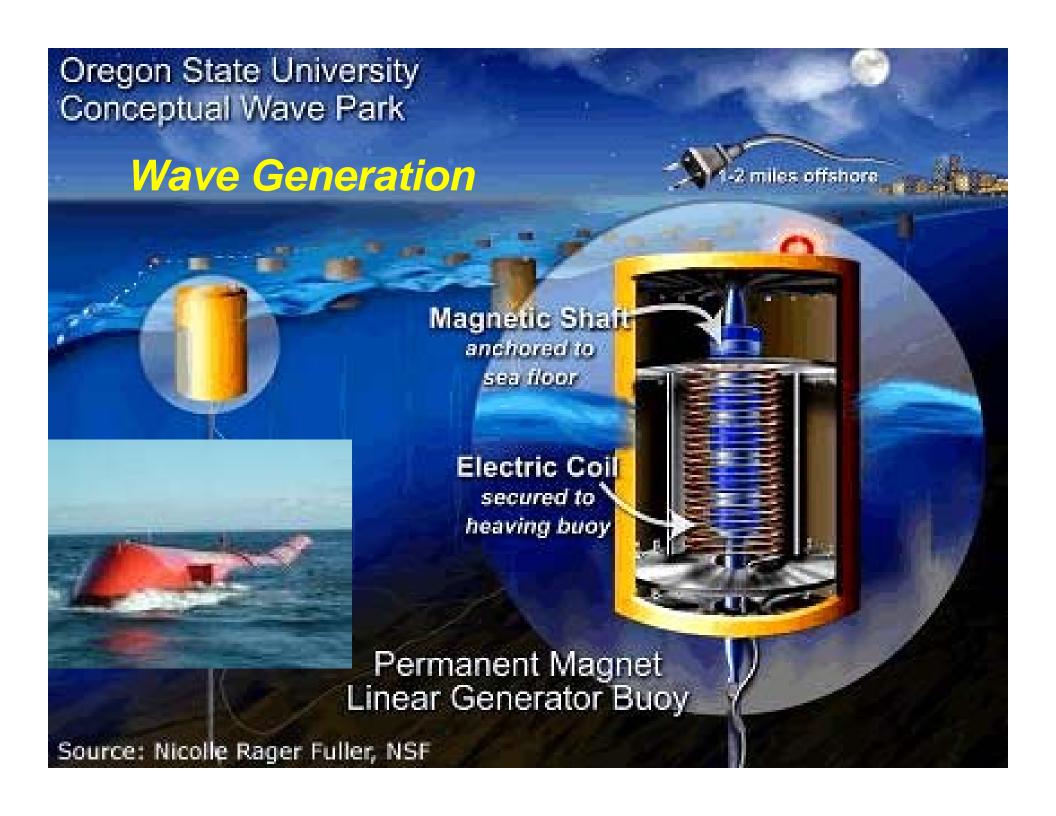
Wave Generation 500 kW





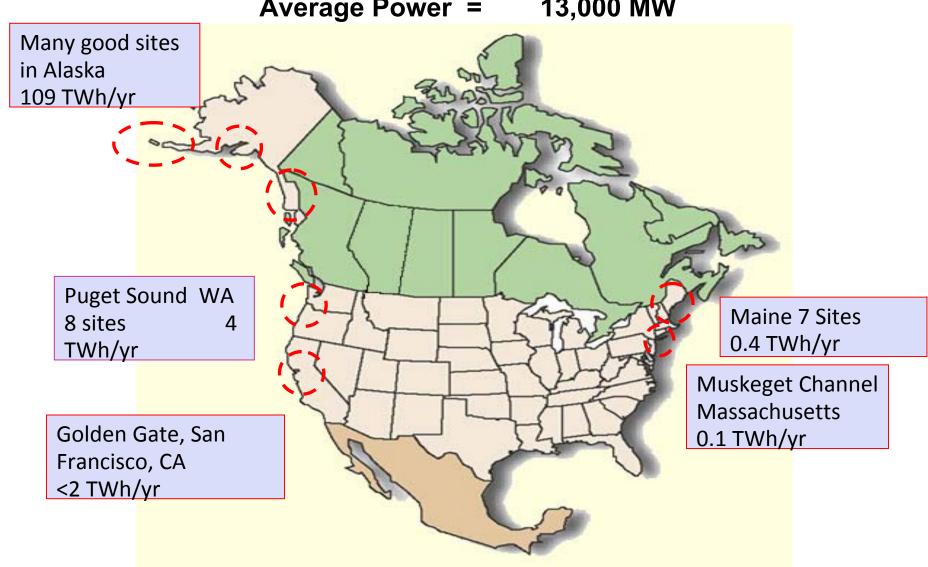
"Limpet": Land Installed Marine Powered Energy Transformer

Air is compressed and decompressed by the Oscillating Water Column (OWC). This causes air to be forced through the Wells Turbine and is then drawn back through the Wells Turbine.

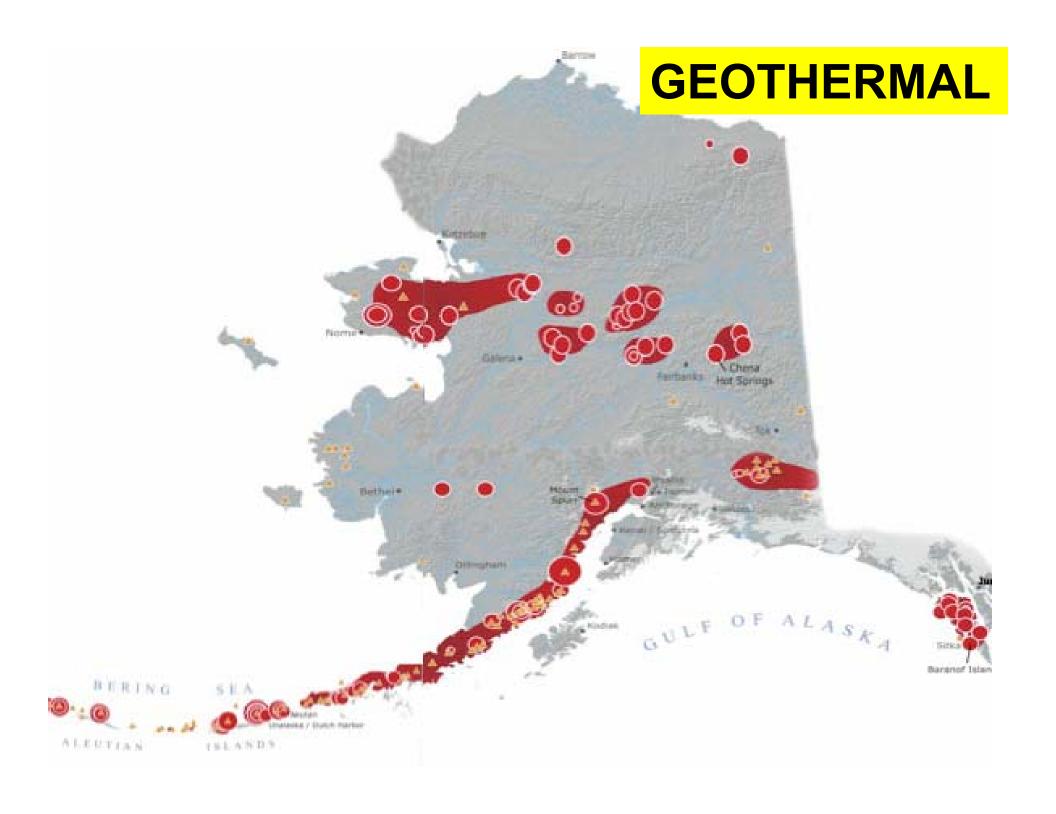


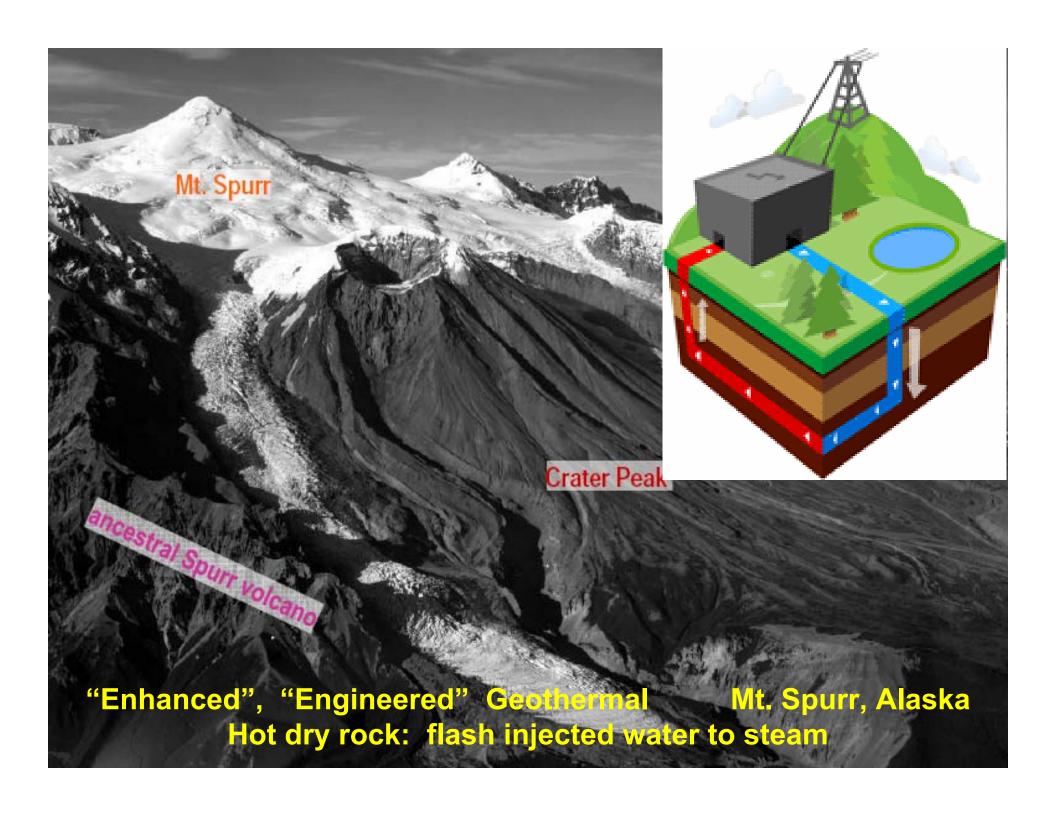
Tidal Current Energy: USA TOTAL

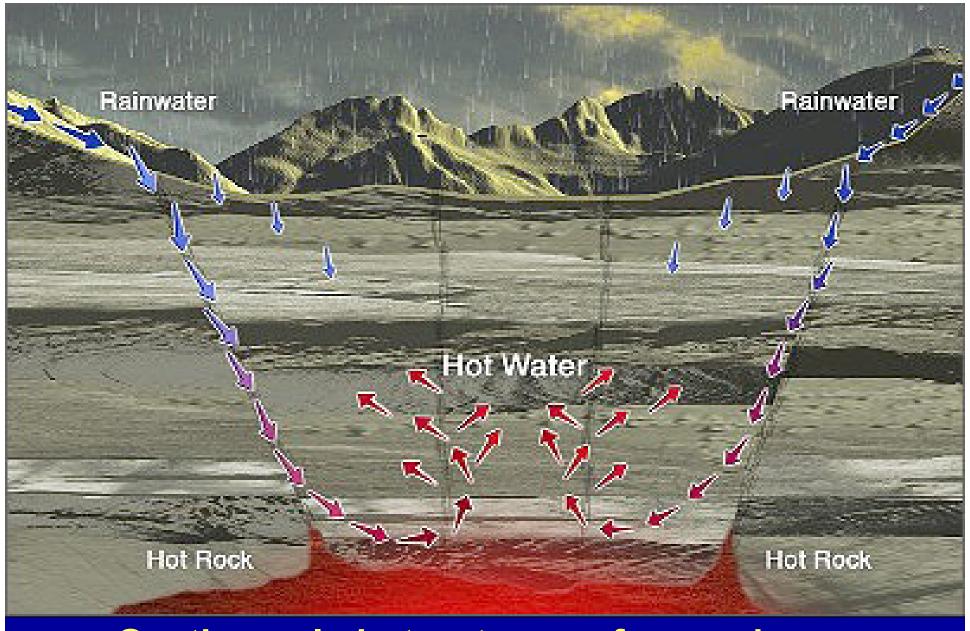
Primary Energy = 115 Twh/yr Average Power = 13,000 MW



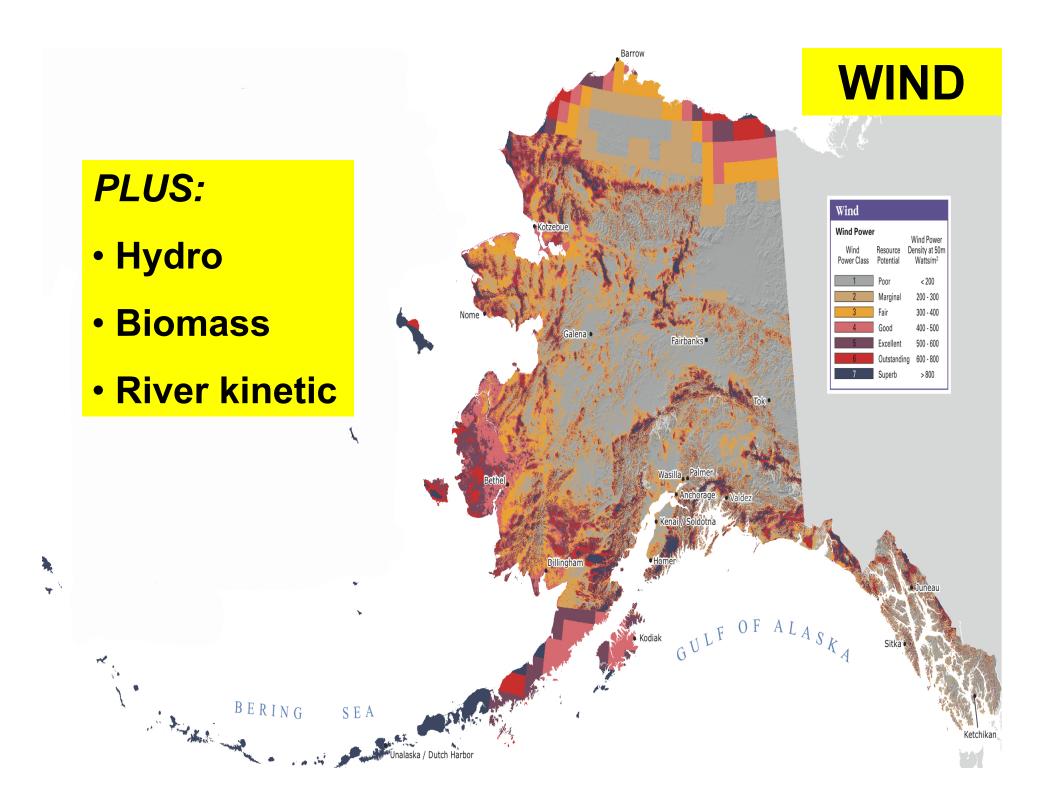








Geothermal: hot water, surface recharge



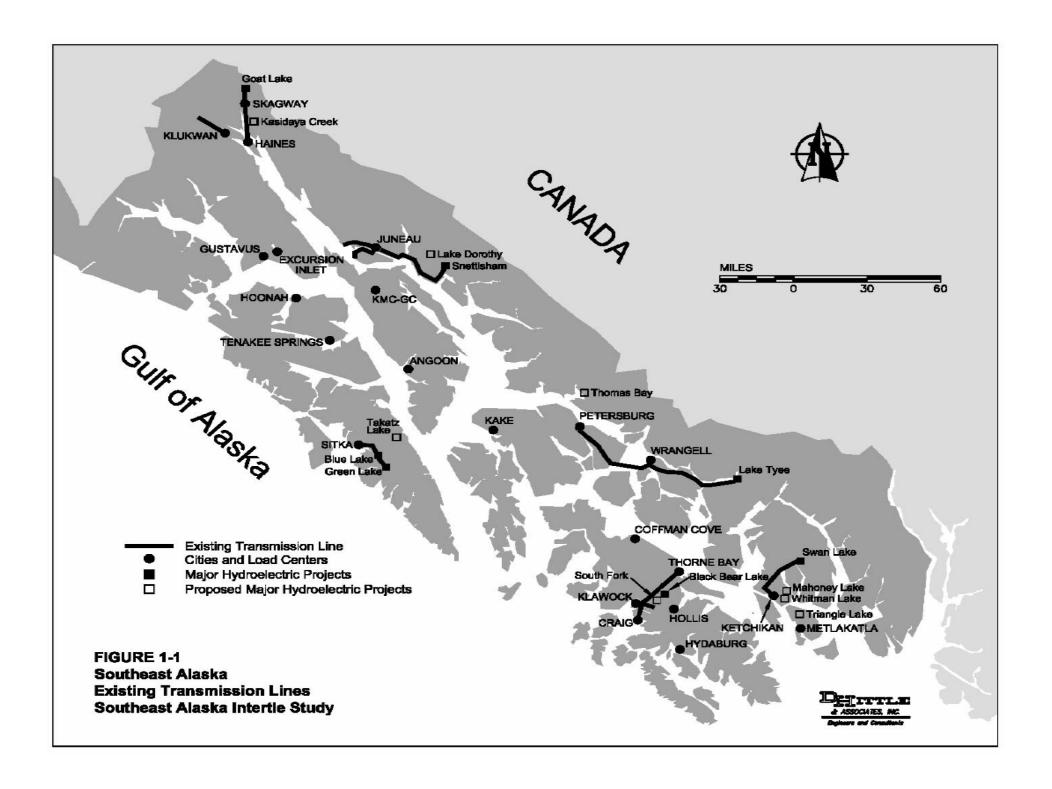


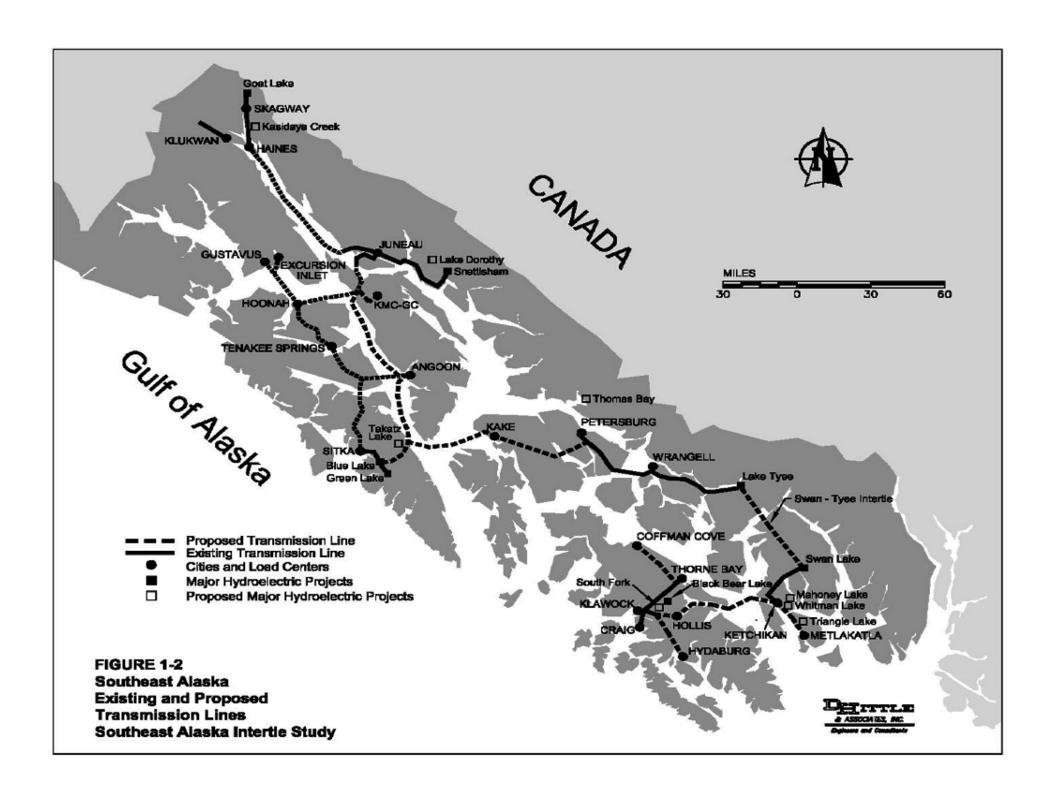
Proposed ANS* Gas Pipeline

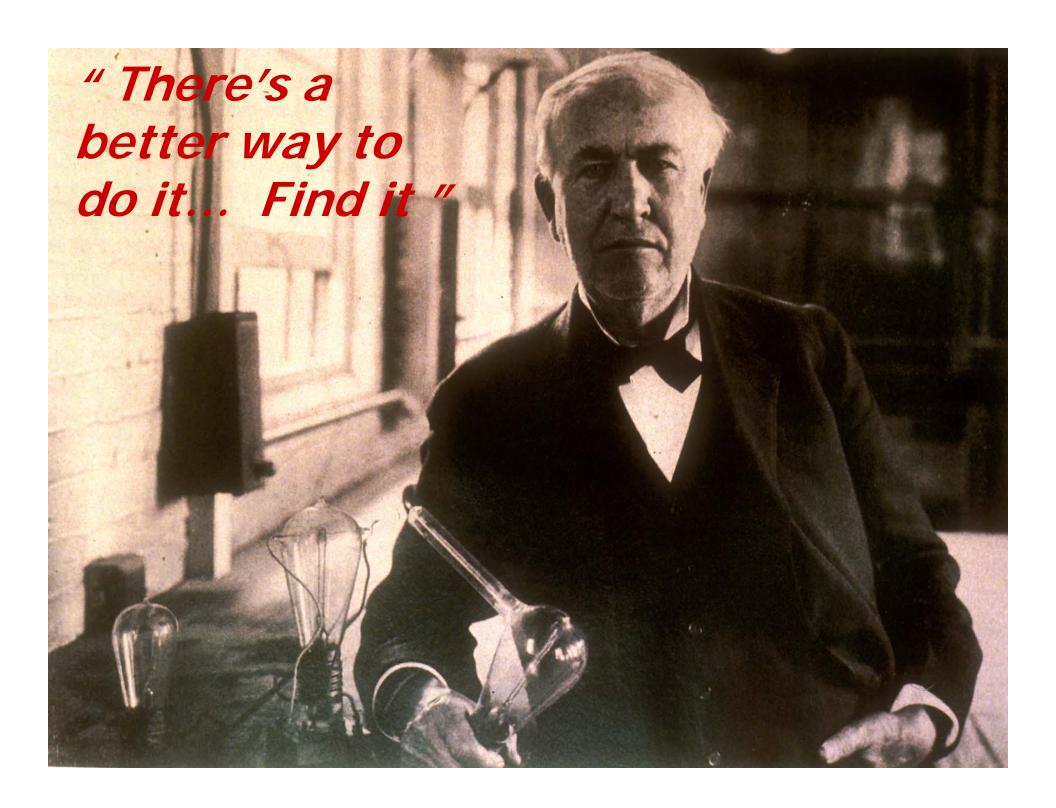
"ALCAN" Alaska Highway Route

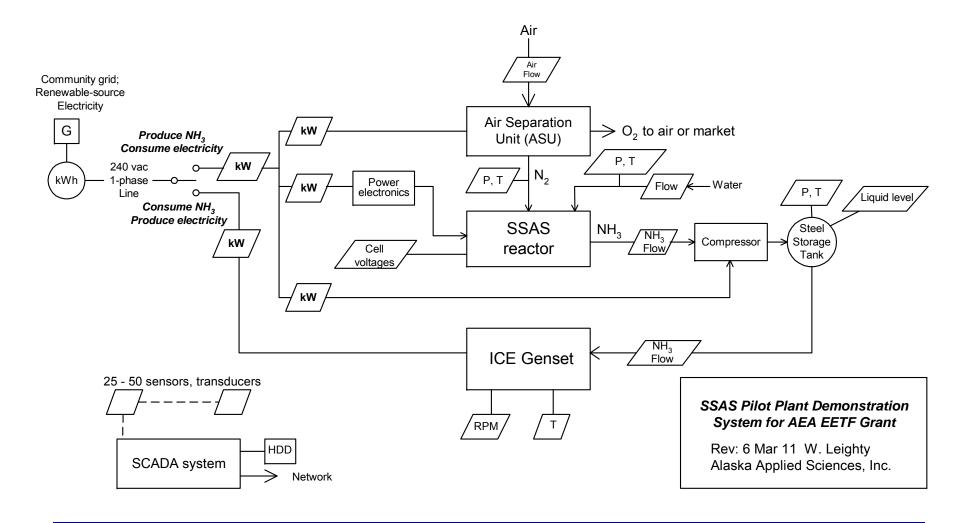
TransCanada Pipelines

* Alaska North Slope



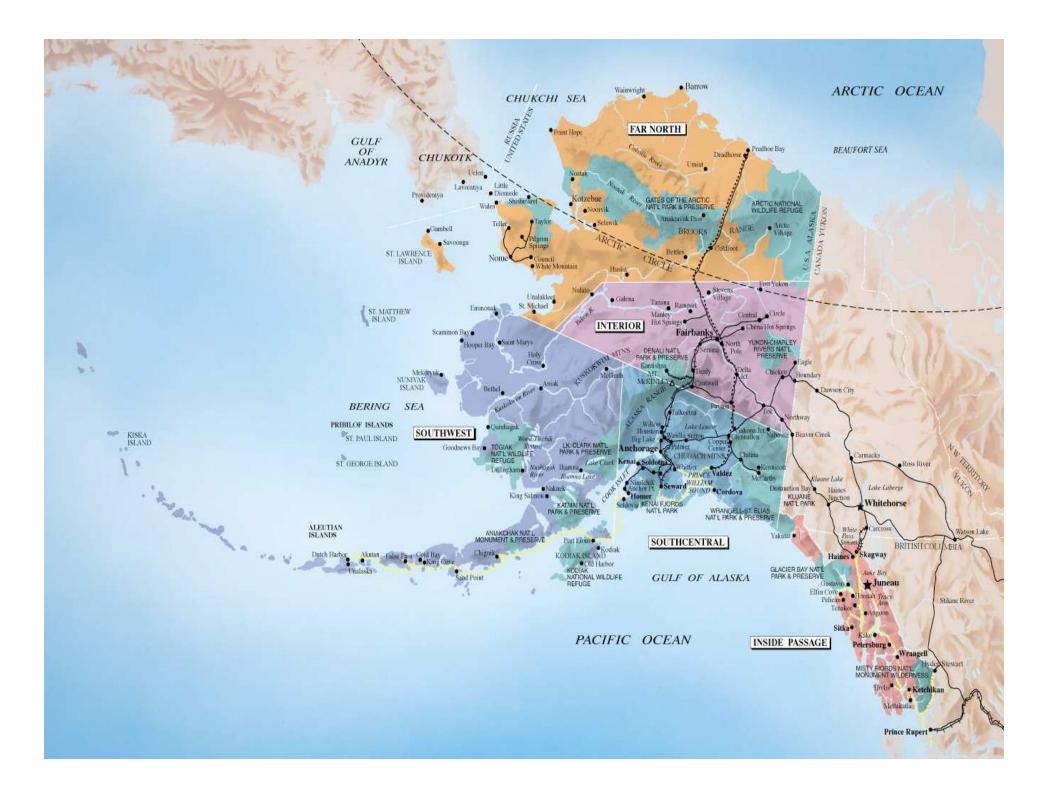




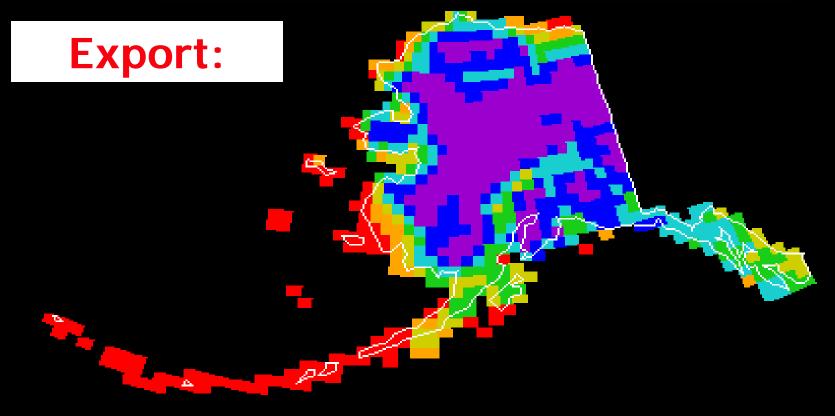


PROJECT: Complete RE - NH₃ SSAS Storage System

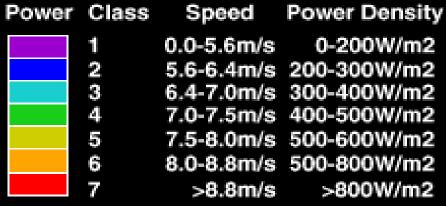
- > NH3 synthesis from RE electricity, water, air (N₂)
- > Liquid NH₃ tank storage
- > Regeneration + grid feedback
- > SCADA instrumentation -> UAF ACEP

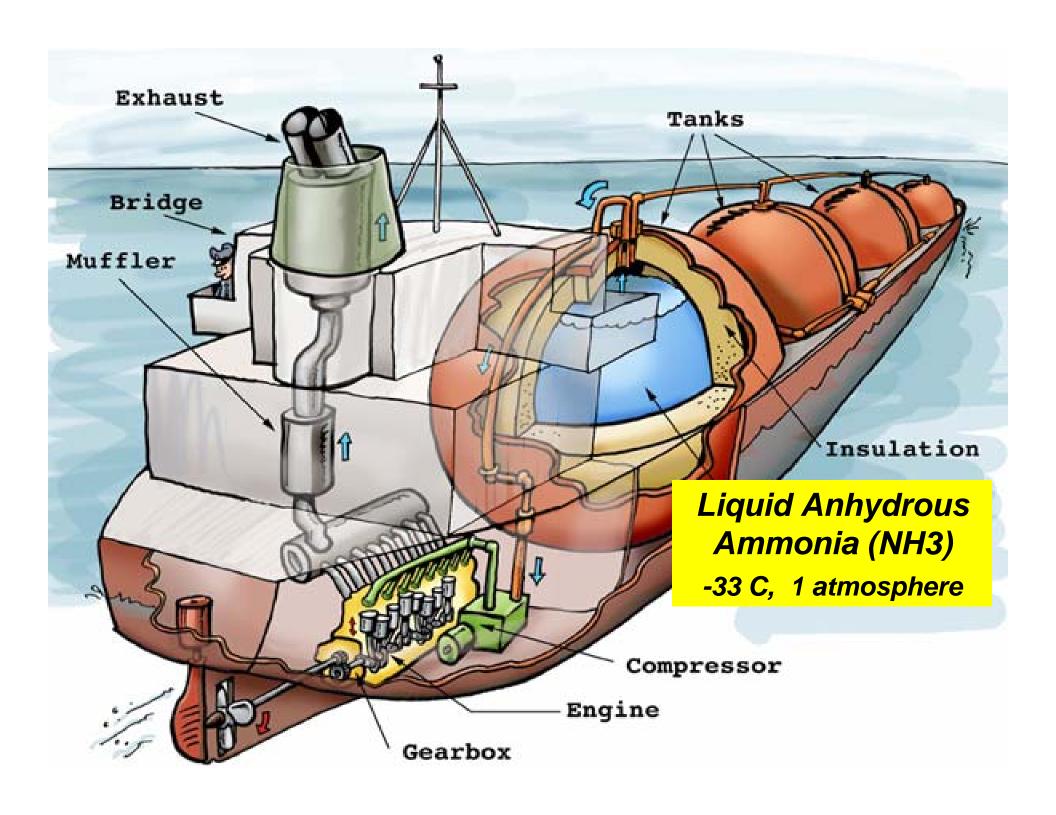


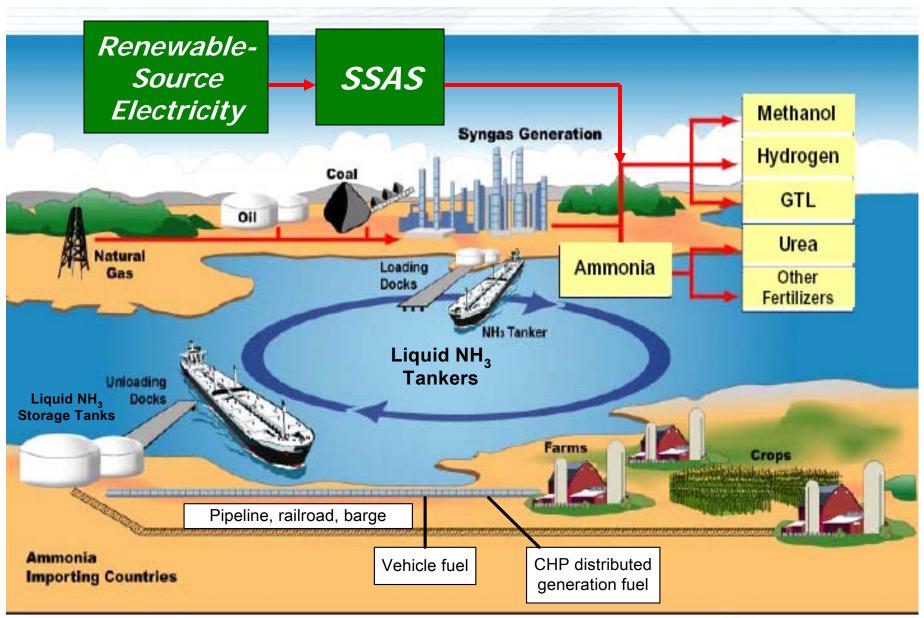
Wind Power Class

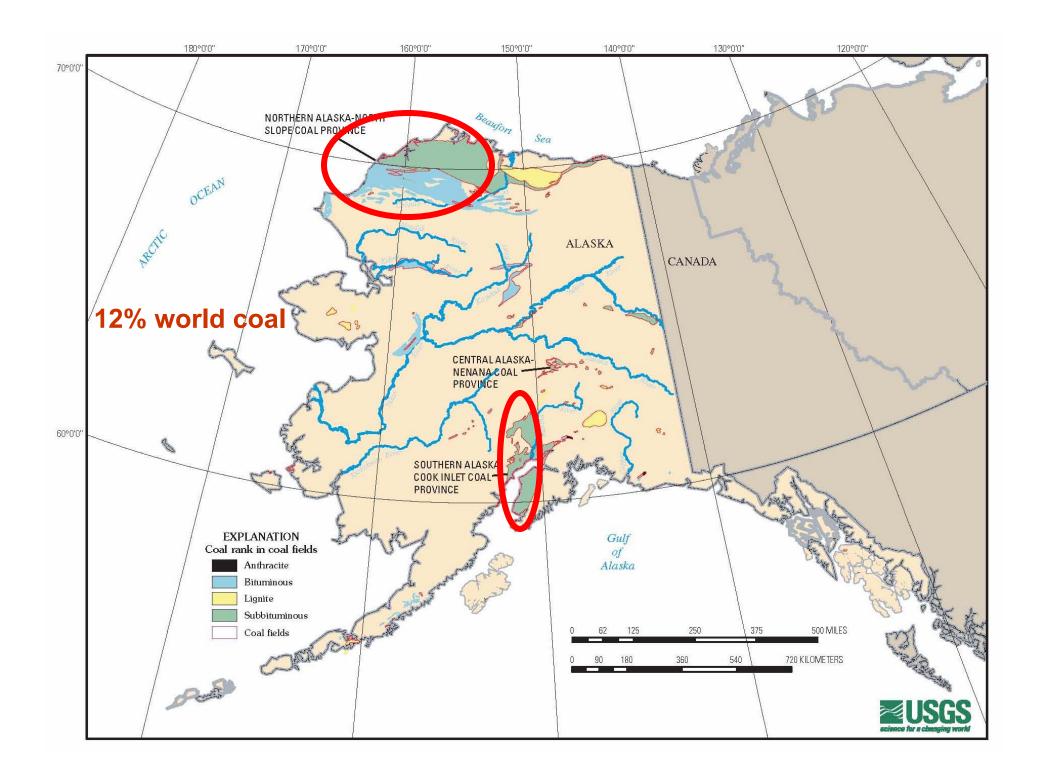












Project Fundamentals

- Anhydrous ammonia (NH3) is a fuel and transmission and low-cost energy storage medium
- 2. NH3 made from renewable energy (RE) electricity, water, and air (Nitrogen, N2) by:
 - a. Electrolysis + Haber-Bosch (EHB)
 - b. Solid State Ammonia Synthesis (SSAS)
- 3. SSAS should best EHB in:
 - a. Capital cost per kWe in, kg NH3 out
 - b. Energy conversion efficiency
 - c. System simplicity, low O&M cost
 - d. AK value

Project Fundamentals

- 4. SSAS unproven: needs proof-of-concept, small pilot plant
- 5. Design and build pilot plant:
 - a. Complete
 - b. SCADA instrumented
 - c. Containerized & transportable
 - d. Upgradeable
- 6. Success:
 - a. Great value to AK, beyond
 - b. Next steps to commercial
 - c. SA AK "RE Cluster Industry" via USFS, JEDC

Project Goals

- 1. Does SSAS system "work"?
- 2. Competitive with EHB?
- 3. Useful in Alaska?
- 4. Build proof-of-concept pilot plant:
 - Self-contained
 - Transportable
 - Plug + Play: RE sources

Project Goals

- 1. Estimate efficiency
- 2. Estimate capital cost:
 - a. PCC tube area, tube
 - b. Reactor
 - c. Power electronics drive
- 3. Dynamics
- 4. TRL 5 6
- 5. Attract RE industry: AK, US, global, ARPA-E

Project Objectives

- Run AK, world on RE: all energy, beyond electricity
- Discover and demo SSAS potential
- Demo complete RE storage system
- Begin commercialization
- Attract funding

1. Decrease Cash OUT: Village "Energy Independence" via RE Generation + Storage

- What's Annual Average RE Cost of Energy (COE) ?
- Competitive ?
- What degree of "energy independence"?
- Is SSAS required ?

2. Increase Cash IN: Export AK GW-scale RE as "Green" Ammonia

- Can RE compete with "brown"?
- What would C-tax need to be ?
- What would global NG price need to be?

SSAS Pilot Plant Budget

| EETF via AEA | \$ 750 K |
|--------------------------|----------|
| NHThree LLC in-kind | \$ 100 K |
| Wind2Green (W2G) in-kind | \$ 100 K |
| AASI in-kind | \$ 50 K |
| TOTAL | \$ 1 M |

EETF Emerging Energy Technology Fund, State of Alaska

AEA Alaska Energy Authority, State of Alaska

AASI Alaska Applied Sciences, Inc.

SSAS Pilot Plant Schedule

- 1. Test PCC tubes; accept
- 2. Build and test multi-tube reactor
- 3. Build and test BOS
- 4. Instrument with SCADA, remote read at UAF
- 5. Add regeneration: NH3 → electricity to grid
- 6. Package in insulated CONEX
- 7. Acceptance test
- 8. Transport to Juneau, AK for demo
- 9. Demo at other AK sites as budget allows
- 10. Upgrade as budget allows

Project Hardware Components

- 1. 7 PCC tube reactor, pressure vessel
- 2. NH3 separation
- 3. Power electronics: reactor DC drive
- 4. ASU or bottled Nitrogen
- 5. SCADA system
- 6. NH3 storage tank
- 7. NH3-fueled ICE genset + auto switch
- 8. Insulated CONEX

Project Status: 18 June 13

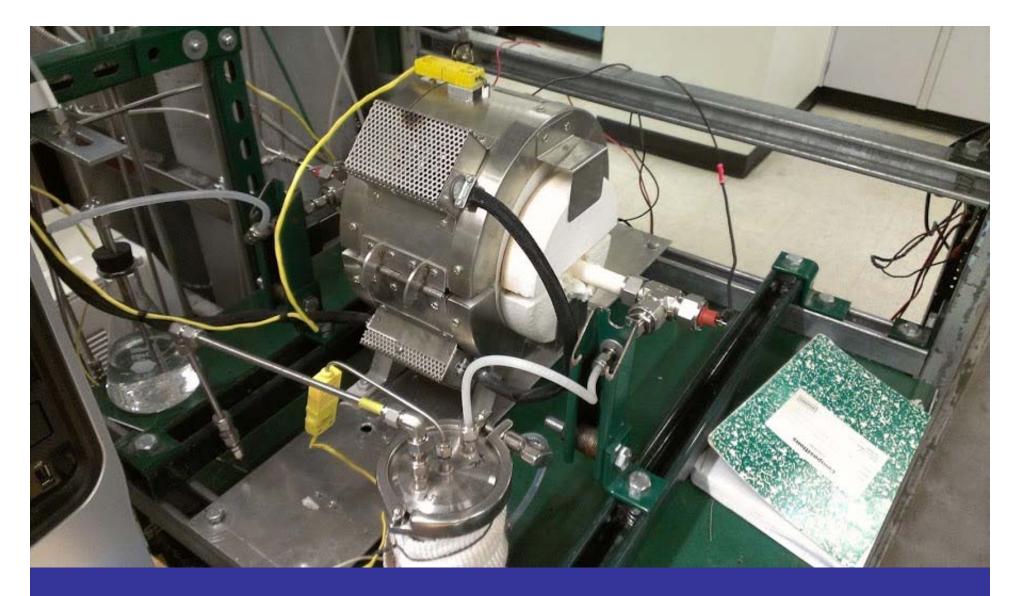
- 1. PNNL, Richland, WA "Technical Assistance Program" approved
- 2. PCC prototype tubes from NHThree LLC
- 3. Reactor adapter socket this week
- 4. SSAS mode testing next week
- 5. Results by ~ 30 June
- 6. Milestone 1 achieved?
- 7. Launch project: 2 year, \$1M
 - \$ 750K cash Alaska Energy Authority
 - \$ 100K in-kind PCC tubes from NHThree
 - \$ 100K in-kind reactor design from WindToGreen LLC
 - \$ 50K in-kind from Alaska Applied Sciences, Inc.



PNNL, Richland, WA 25 Feb 13

L to R: John Holbrook, NHThree Bill Leighty, AASI Greg Coffey, PNNL

Test reactor is above Bill's left shoulder



Tube assembly installed in test fixture.

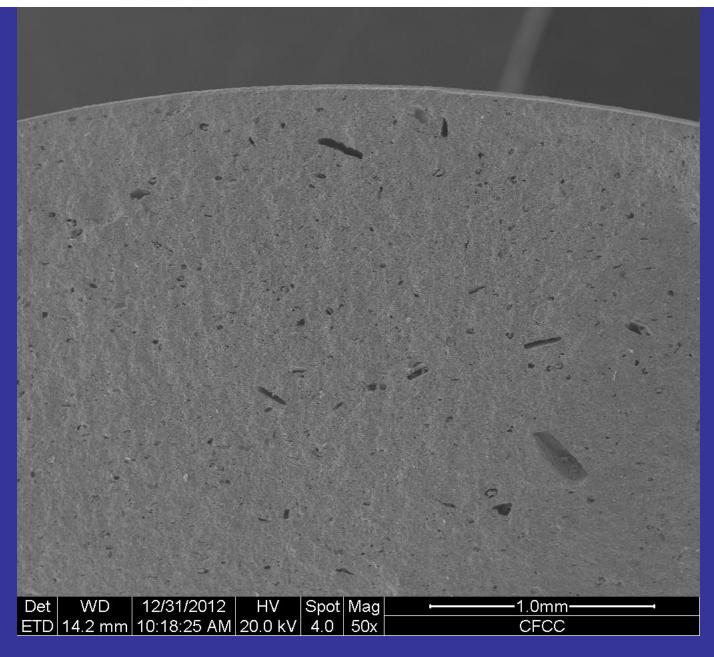
Nickel oxide cathode coating (tube interior) reduced by hydrogen to metallic nickel, ready for subsequent tests.



Center: PCC tube 33 cm² active area.

Current collectors installed.

Sealed to alumina support tubes. Setup is leak-free.



50x PCC tube cross-section, anode layer (exterior)

Great Reward, and Risk

Project success: SSAS "works"

- Reactor, multi-tube
- Power electronics drive
- Regeneration from stored NH3
- SCADA: UAF ACEP download
- Complete system functions, efficient
- Complete system durable, reliable
- Cost estimates: capital, O&M

Next steps?

Great Reward, and Risk

AK renewable energy (RE) opportunities:

- 1. Village energy "independence"
- 2. Annual-scale firming storage
- 3. Transmission for:
 - a. Intrastate AK
 - b. RE export
- 4. Fuel for military land and sea

Scales: Village → Susitna → Global export

Opportunity: Alaska Applications

- 1. Village energy "independence": degree
 - a. Internal, external energy economies
 - b. Diverse renewable sources
 - c. Low-cost tank storage
 - d. CHP, transportation fuels
- 2. Firming storage: annual scale
 - a. Susitna hydro
 - b. Other
- 3. Export large, diverse, stranded renewables
 - a. Cryo tankers: global trade
 - b. "Green" NH3 premium? C-tax required?
 - c. SE AK "Cluster Industry"
 - d. Aleutians cargo ship fueling
- 4. Military fuel: ground, marine
 - a. USCG, Navy
 - b. Other services
 - c. DOD Assistant Secretary Sharon Burke visit 3-7 Aug 12

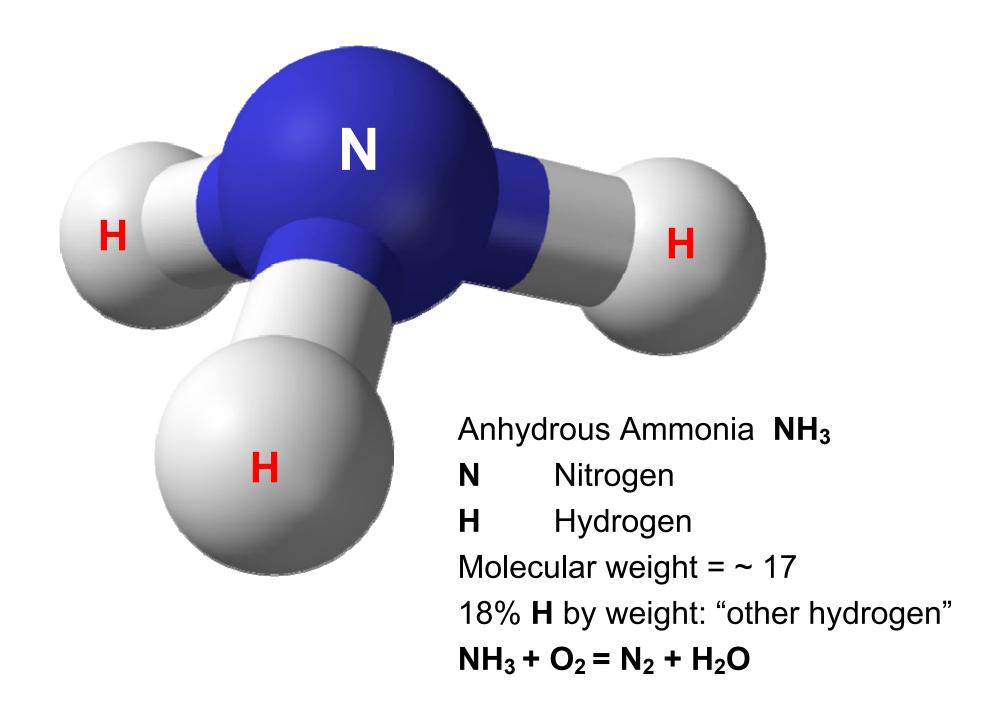
Why Ammonia? Fertilizer and Fuel

Only liquid fuel embracing:

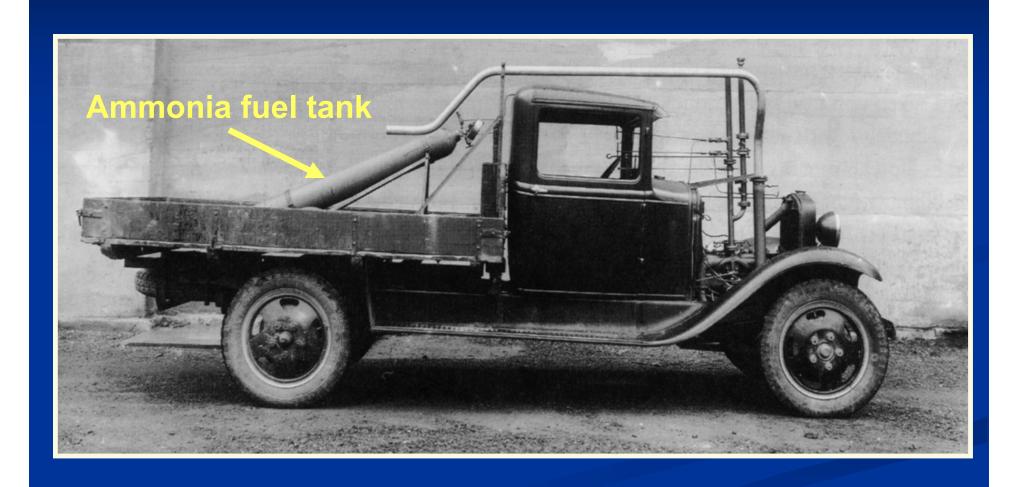
- Carbon-free: clean burn or conversion; no CO₂
 - Excellent hydrogen carrier
 - Easily "cracked" to H₂
- Reasonably high energy density
- Energy cycle inherently pollution free
 - Potentially all RE-source: elec + water + Nitrogen
 - Cost competitive with hydrocarbon fuels?
- Decades of global use, infrastructure
 - Practical to handle, store, and transport
 - End-use in ICE, Combustion Turbine, fuel cell
 - Safety: self-odorizing; safety regs; hazard

Ammonia Fuel Uses

- 1. Internal Combustion Engine (ICE)
 - Diesel: NH₃ gas mixed with intake air
 - Spark-ignition: 70%+ NH₃ plus
 gasoline, ethanol, propane, NG, hydrogen
 - NOx ~ ½ gasoline engines
- 2. Combustion Turbines
- 3. Direct Ammonia Fuel Cells:
 - Combined heat + power (CHP)
 - No NOx
- 4. Reform ("crack") to liberate hydrogen for fuel cells: 2NH₃ → 3H₂ + N₂



Ammonia fueled - Norway





Ammonia Fueled Bus: Thousands of Problem-free Miles 1943





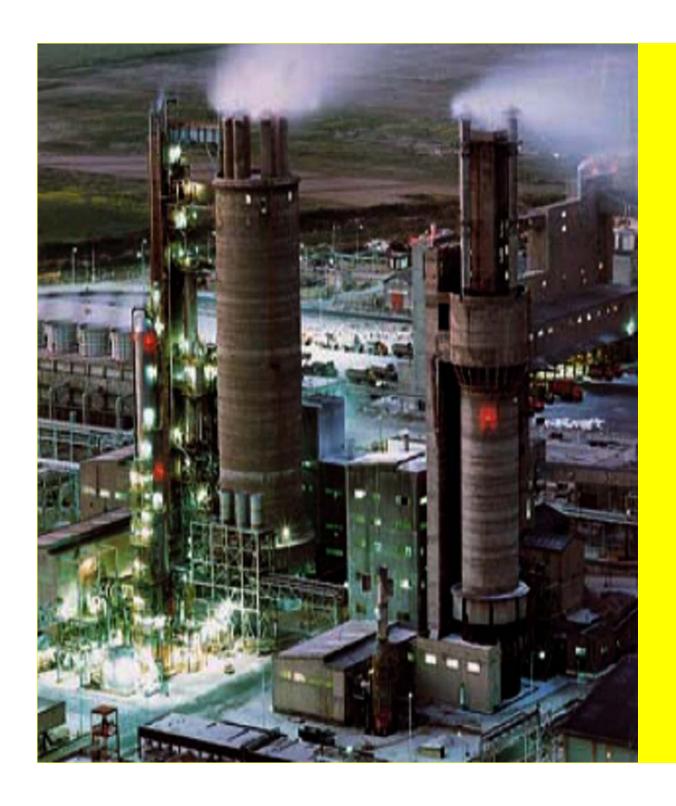
Ammonia + Gasoline Powered

Idle: gasoline

• Full power: 80% ammonia

Summer '07 Detroit → San Francisco

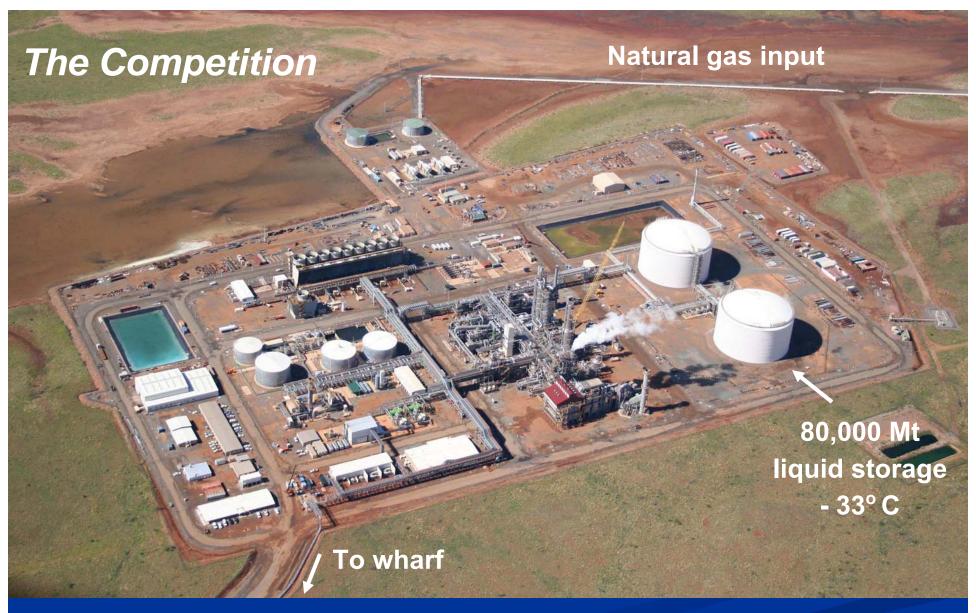
2007



95% Global Ammonia

Synthesis
Plant
Natural Gas
1 – 3,000 tpd

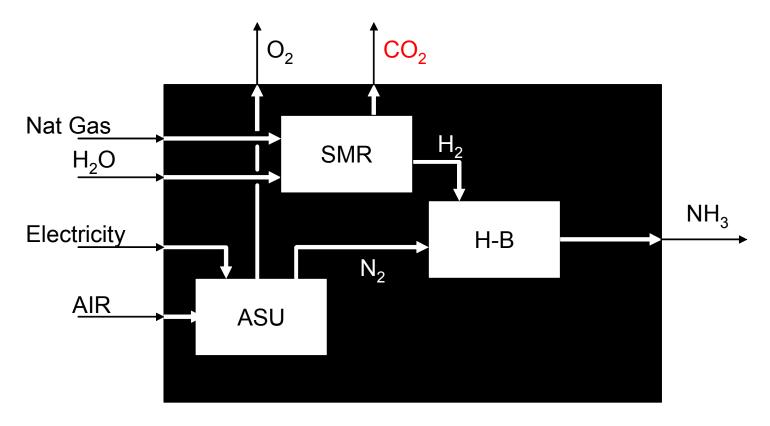
Haber-Bosch process



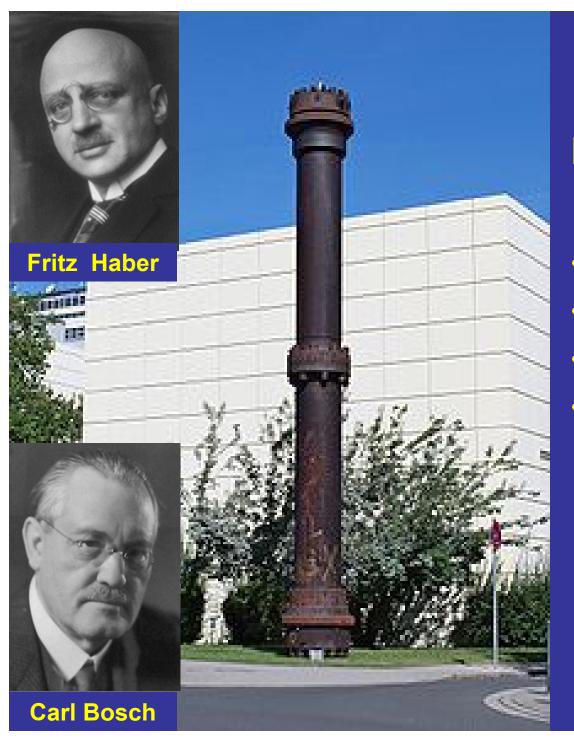
Burrup Peninsula, NW Australia, Natural Gas to Ammonia Plant 760,000 Mt / year \$US 650 million capital cost '06

Inside the Black Box: Steam Reforming + Haber-Bosch (H-B)

$$3 \text{ CH}_4 + 6 \text{ H}_2\text{O} + 4 \text{ N}_2 \rightarrow 3 \text{ CO}_2 + 8 \text{ NH}_3$$



Energy consumption ~33 MMBtu (9,500 kWh) per ton NH_3 Tons CO_2 per ton NH_3 = 1.8



Haber-Bosch Process 1909 – 1913 BASF

- NH₃ synthesis
- Coal gasification → H2
- WW I explosives
- 40% humanity: N fertilizer

Haber-Bosch Reactor 1921

Ludwigshafen, Germany

Ammonia Tanker Burrup Peninsula Western Australia



Opportunity: Alaska Applications

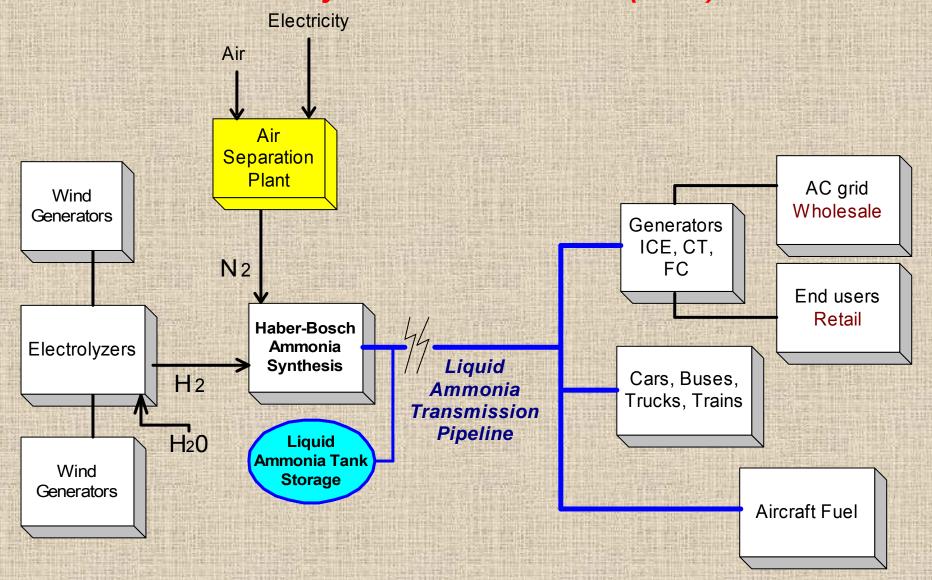
- 1. Village energy "independence": degree
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 - a. Susitna hydro
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- 4. Military fuel: ground, marine
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 - b. Other services
 - c. DOD Assistant Secretary Sharon Burke visit 3-7 Aug 12

Military: Land + sea fuel

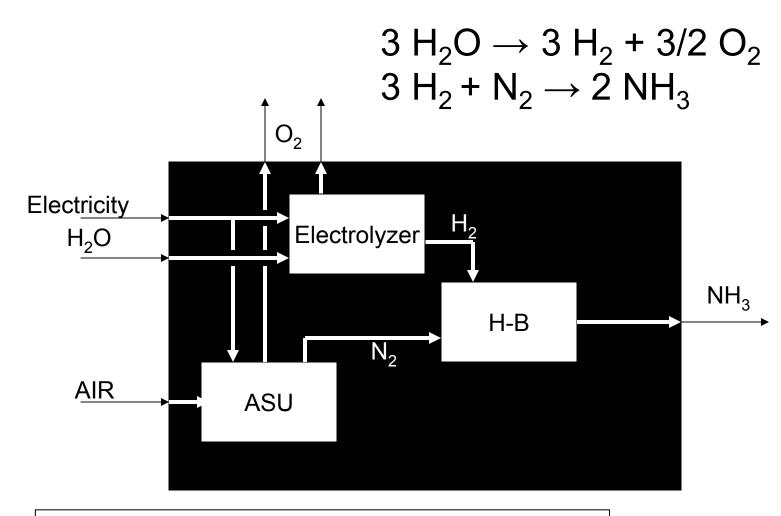
- USCG, Navy ships
- Land vehicles: road, rail
- Recip engines modify: multifuel, Sturman



RE Ammonia Transmission + Storage Scenario: Electrolysis + Haber-Bosch (EHB)

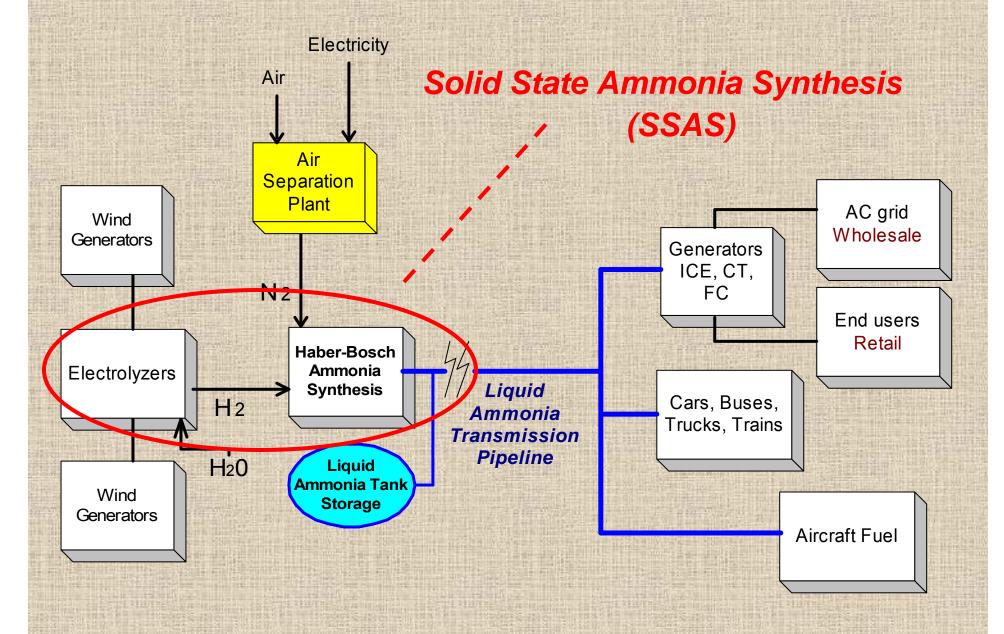


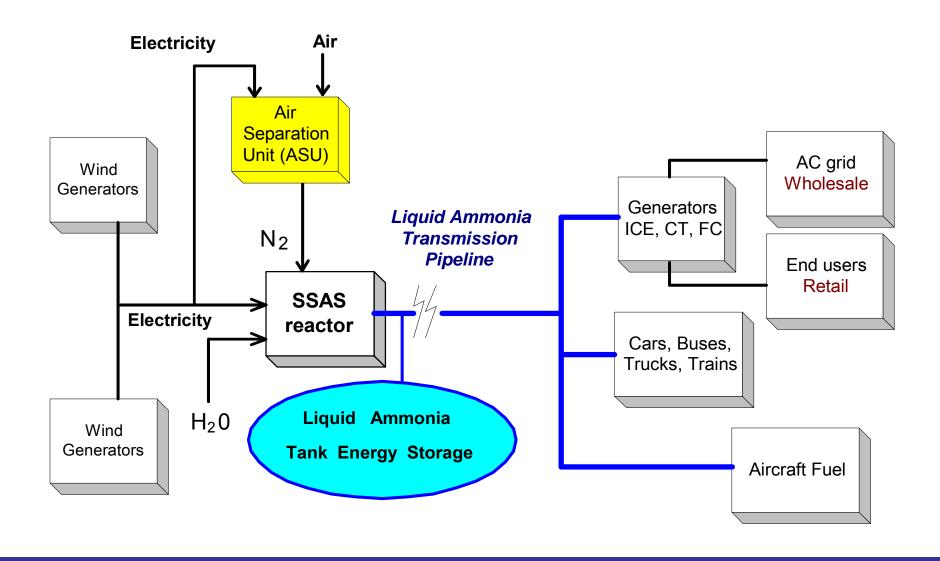
Inside the Black Box: HB Plus Electrolysis



Energy consumption ~12,000 kWh per ton NH₃

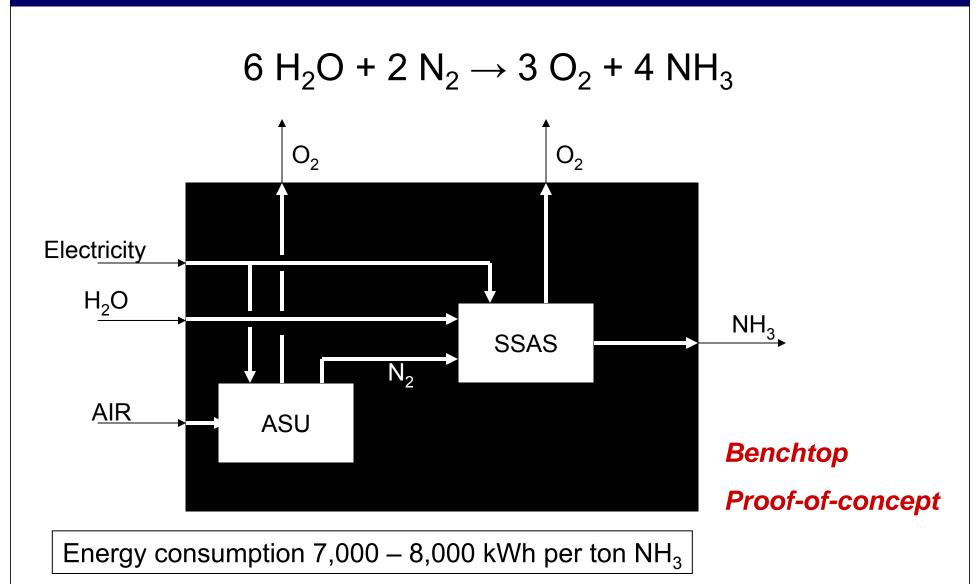
RE Ammonia Transmission + Storage Scenario



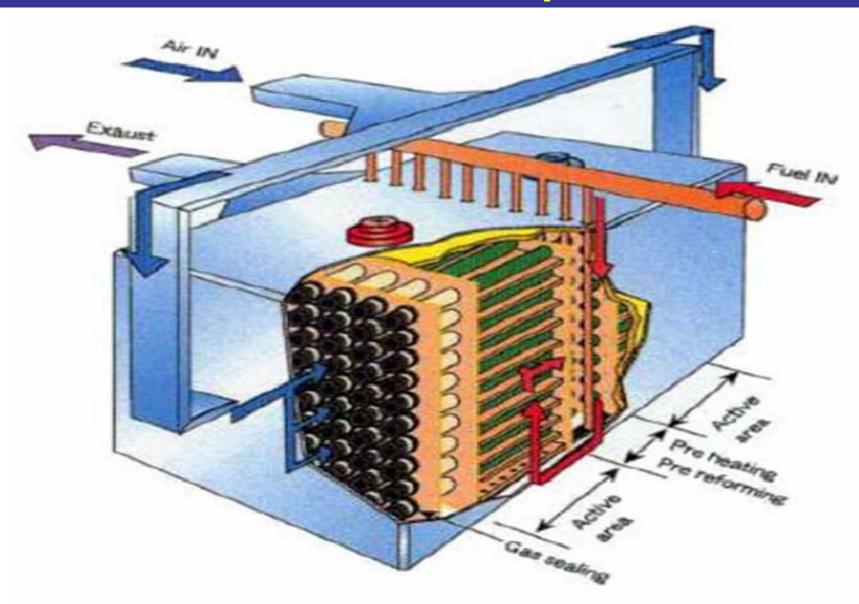


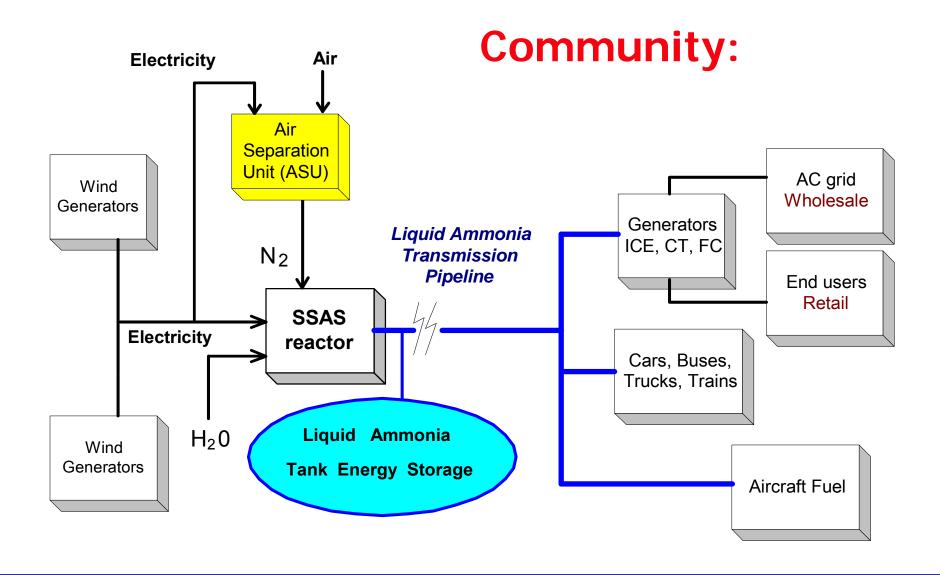
Solid State Ammonia Synthesis (SSAS)

Inside the Black Box: Solid State Ammonia Synthesis



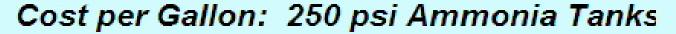
Solid State Ammonia Synthesis (SSAS) NHThree LLC patent

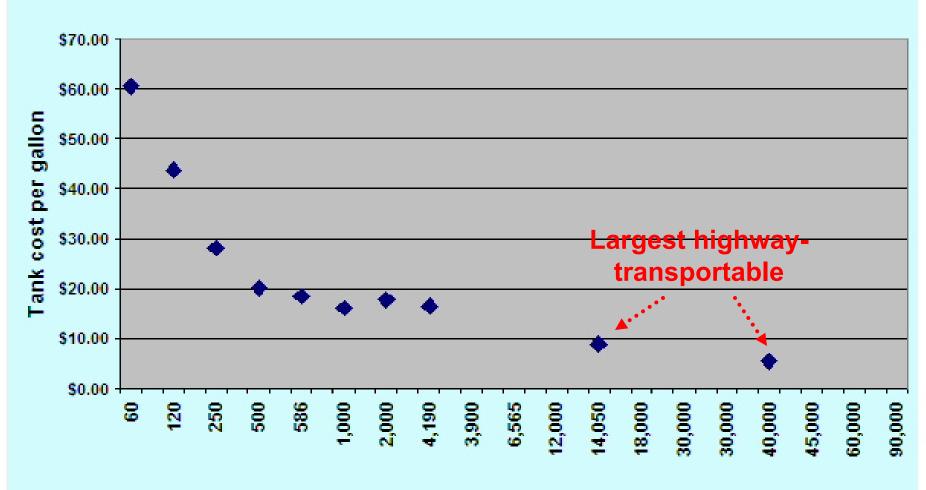




Solid State Ammonia Synthesis (SSAS)

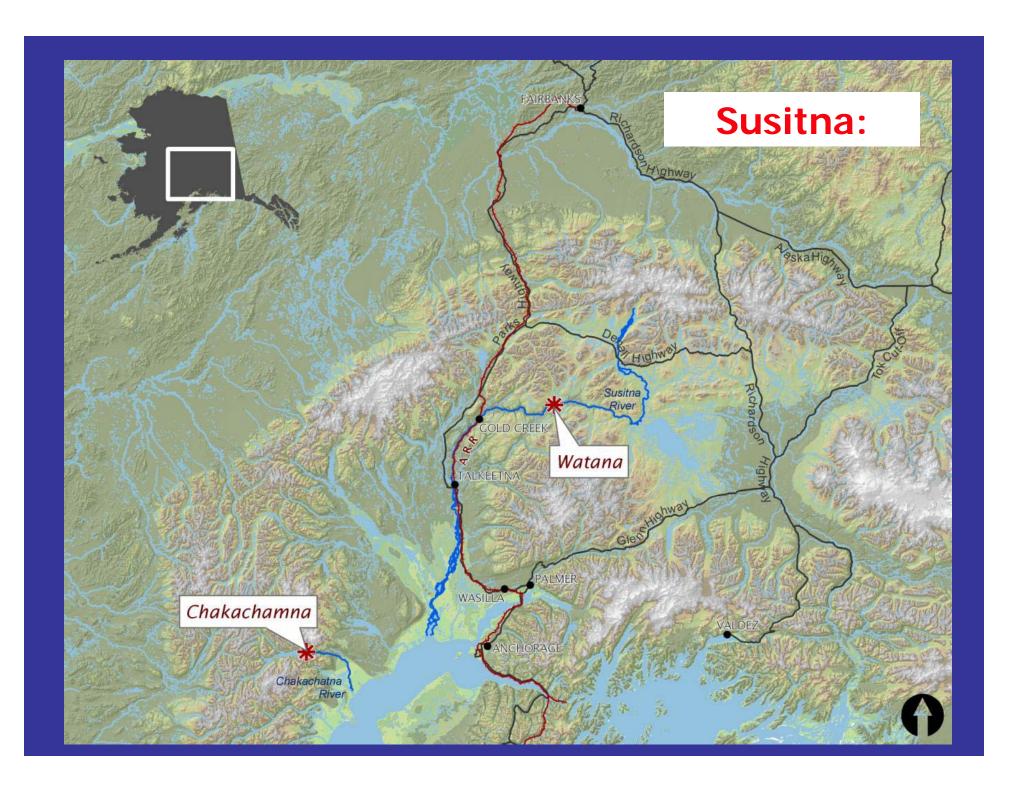
Liquid Ammonia Tank Storage

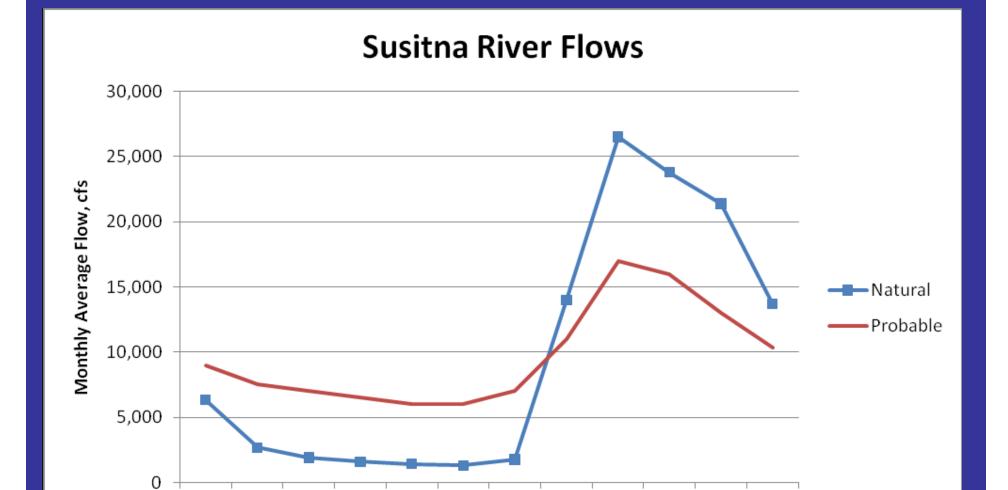




Tank capacity, gallons



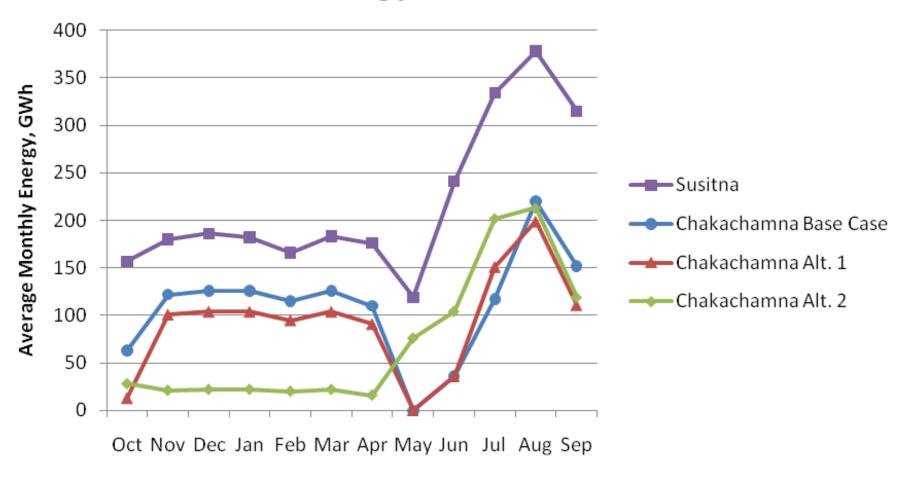




Jul Aug Sep

Oct Nov Dec Jan Feb Mar Apr May Jun

Energy Production



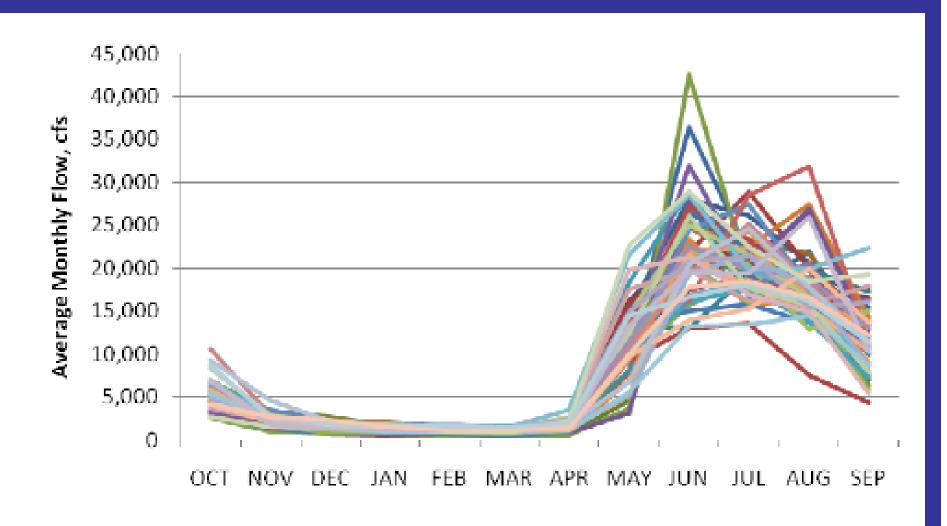
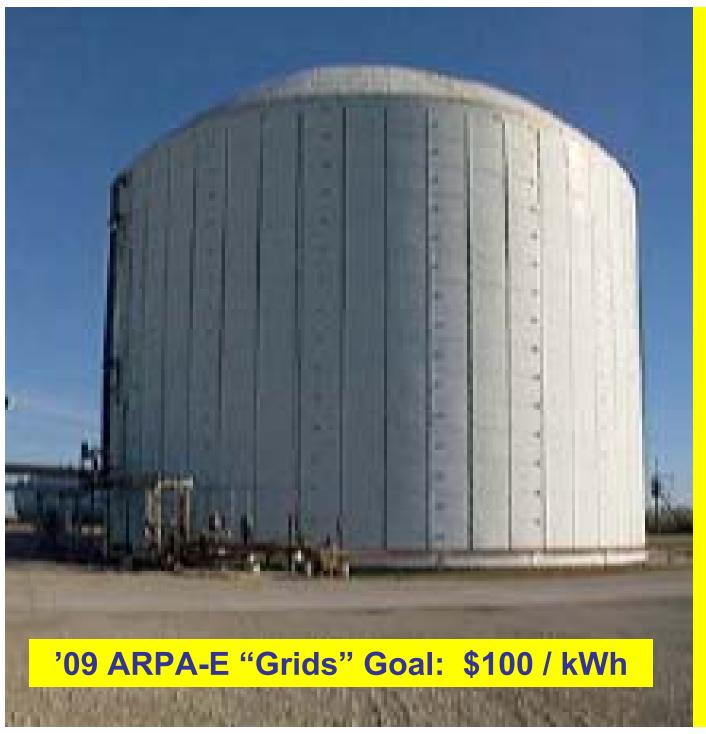


Figure 1 - Susitna River at Watana Hydrologic Variation

Annual Firming for Susitna: Liquid NH3 in "atmospheric" tanks

- 400 MW @ 50% CF = 1,752 GWh / year (AEA: 2,600)
- Store 40% = 700,800 MWh
- 3 tanks @ ~ \$20M each = \$60M
- SSAS plant:
 - 200 MW nameplate
 - \$300 / kWe input capital cost
 - \$600M capital cost
- Regeneration plant:
 - 200 MW nameplate
 - \$300 / kW output capital cost
 - \$600M capital cost
- Total NH3 storage system \$ 1,260 M



"Atmospheric"
Liquid
Ammonia
Storage Tank
(corn belt)

30,000 Tons 190 GWh

\$ 15M turnkey

\$ 80 / MWh

\$ 0.08 / kWh

-33 C

1 Atm



"Atmospheric" NH3 tank construction

320,000 MWh storage Annual firming 1,000 MW wind

- Electricity
 - VRB (Vanadium Redox Battery)
 - O&M: 80% efficiency round-trip
 - Capital: \$500 / kWh = \$ 160 Billion
 - CAES (Compressed Air Energy Storage)
 - O&M: \$46 / MWh typical
 - Iowa Stored Energy Park:
 - Power = 268 MW
 - Energy capacity = 5,360 MWh
 - Capital: 268 MW @ \$ 1,450 / kW = \$ 390 M
 - @\$ 40 / kWh = \$ 13 Billion
 - @ \$1 / kWh = \$325M
- GH2 (3 hydrogen caverns) Capital \$70 Million
- NH3 (2 ammonia tanks)
 Capital \$30 Million

10" NH3 liquid pipeline cost

- Industry sources, all costs:
 - \$750 900 K per mile, 10", "uncongested area"
 - \$250K per mile "small diameter"
- 1,000 mile pipeline @ 10" = \$ 400M
- Capacity 2 GW
- Capital cost = \$200K / GW-mile

Capital Cost per GW-mile

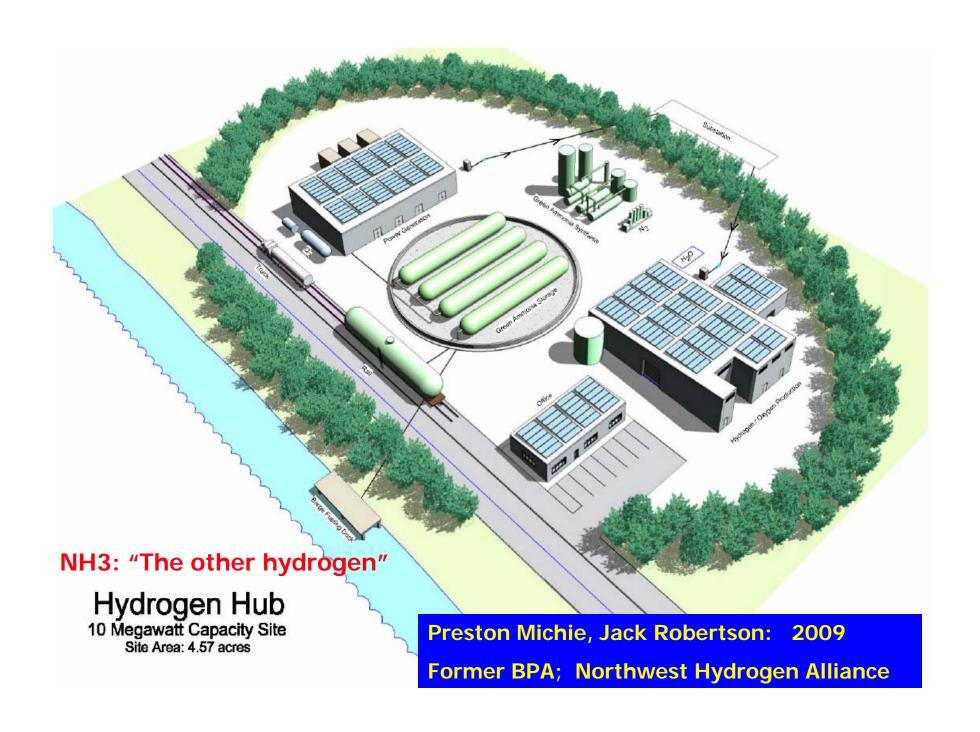
| Electricity: | | | Capacity | ty |
|--------------|----------|-----------|----------|---------------|
| | | <u>KV</u> | MW | \$M / GW-mile |
| • | SEIA: | 765 | 5,000 | 1.3 |
| | | 345 | 1,000 | 2.6 |
| • | AEP-AWEA | 765 | 5,000 | 3.2 |
| Consensus? | | | 2.5 | |

Hydrogen pipeline:

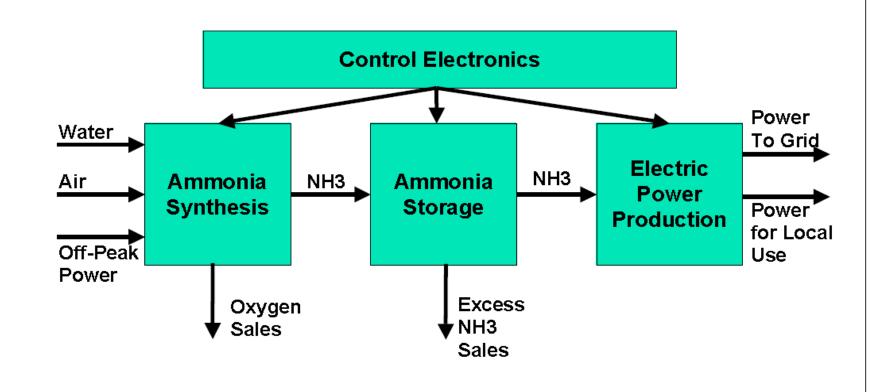
36", 100 bar, 500 miles, no compress 0.3

Ammonia pipeline:

10", liquid, 500 miles, with pumping 0.2



Hydrogen Hub Concept



State of the Art; Competition

- Electrolysis + "Haber-Bosch" = EHB
 - Proton Ventures
 - Freedom Fertilizer
 - NH3 United, TX + Canada NH3
- Other "SSAS"
 - Hydrogen Engine Center
 - Other?

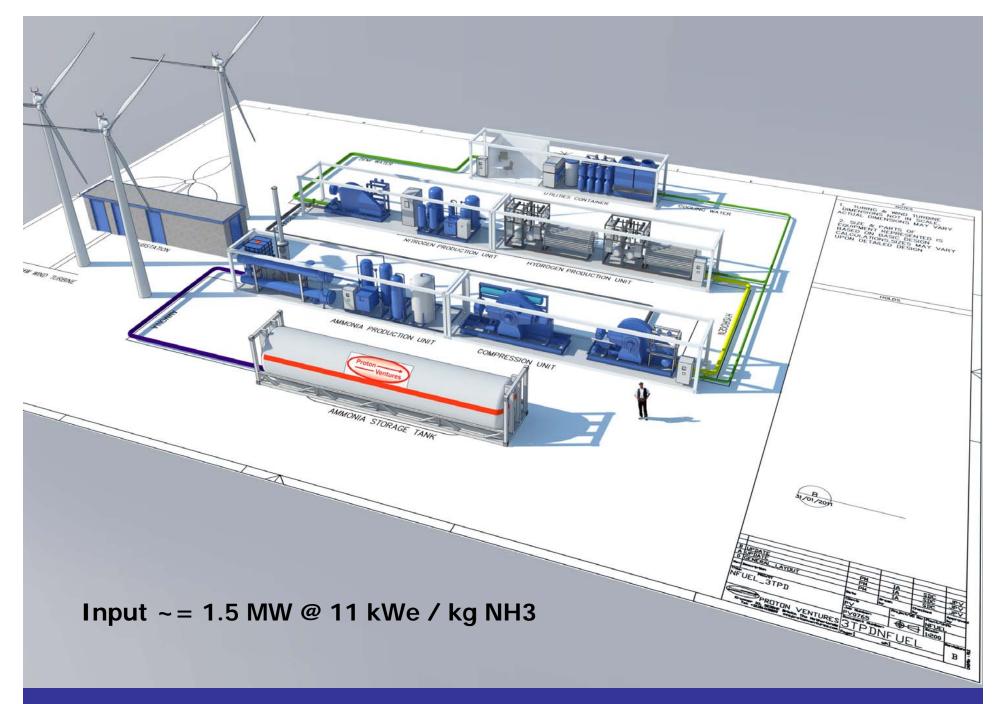
EHB vs SSAS prelim estimates

EHB:

```
11-12 kWh / kg
$1,000 / kWe input capital cost
```

SSAS:

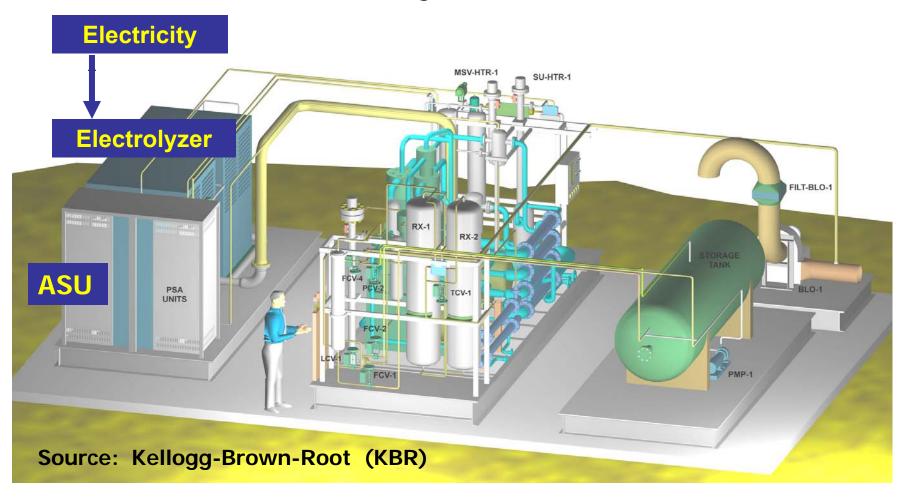
7-8 kWh / kg \$500 / kWe input capital cost \$200K / Mt / day capital cost



3 Mt / day Electrolysis + Haber-Bosch (EHB) NH3 plant by Proton Ventures

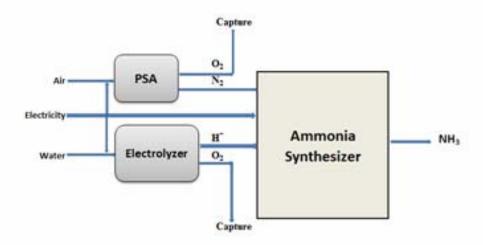


Village-scale 3 Mt / day Mini-NH3 Plant RE Electricity Haber-Bosch





Ammonia Production Process



The NH₃ United equipment "cracks" steam into oxygen and hydrogen and extracts nitrogen from the air in separate process steps. These elements are combined in a pressure chamber in the presence of a catalyst to form anhydrous ammonia (NH₃).

Patent pending: US 2011 / 0243828



Commercial

- 310 kg/day unit available for delivery o/a April 2013
- Currently requires ~11kWh/kg; projected to be reduced to <9.7 kWh/kg within 24 months
- Unit price US\$459,200
- Development warranty
- FOB, Fredericton, New Brunswick
- Site prep, engineering & installation to be quoted separately, if needed

AASI note: 310 kg / day = 142 kWe input

459K / 142 kW = 3,200 / kWe input

Opportunity: Other Alaska

- 1. Energy "independence": ALL energy
 - a. Indigenous
 - b. Diverse RE
 - c. Intrastate transmission and storage
- 2. SE "RE Cluster Industry"
 - a. USFS, diversify Tongass
 - b. Under what conditions?
 - c. Draft IRP: SE Intertie "infeasible"

Opportunity: Global Applications Alaska pioneers

- 1. Diverse, stranded RE
- 2. Solves Big Three problems:
 - a. Transmission
 - b. Storage
 - c. Integration
- 3. Regional, continental pipeline systems
 - a. Gathering
 - b. Transmission
 - c. Distribution
- 4. Low-cost storage: \$ 0.10 / kWh capital
- 5. End-use fuel
 - a. CHP, stationary
 - b. Transport fuel, ground + sea
 - c. Need NH3-ready equipment

Project Risks

1. Technical

- a. PCC tubes: catalysis, fragile
- b. SSAS reactor design: thermal, gas manage
- c. Electric drive: low-Z tube load
- d. Scalability: MW

2. Business

- a. Three small companies
- b. Small capital, small staff, low overhead
- c. Senior management
- d. \$750K adequate?

3. Economic, market

- a. RE-source NH3 cost / kg
- b. Competition from NG, coal NH3 plants
- c. No NH3-fueled equipment; no demand for "green" NH3
- d. Need C-tax or subsidy
- e. AK exception: energy islands, stranded RE, high prices
- f. NH3 not a "fuel"
- g. NH3 "inhalation hazard", toxic

Risk mitigation

- 1. Technical: select the best
 - a. PCC tube suppliers
 - b. Designers and consultants
 - c. Fabricators
- 2. Technical: extensive testing, upgradeable
- 3. Business:
 - a. Frequent milestones, reviews, go-nogo
 - b. Seek other funding for similar workplans
- 4. Market:
 - a. Demand: Encourage NH3-fueled equipment
 - b. Supply: Attract RE gen industry
 - c. Demonstrations
 - d. Conference papers: RE Industry
 - e. ARPA-E: Dane Boysen (REAP BCEA 2012)
 - f. SE "RE Cluster Industry" action initiatives

CONCLUDE: Great Reward / Risk

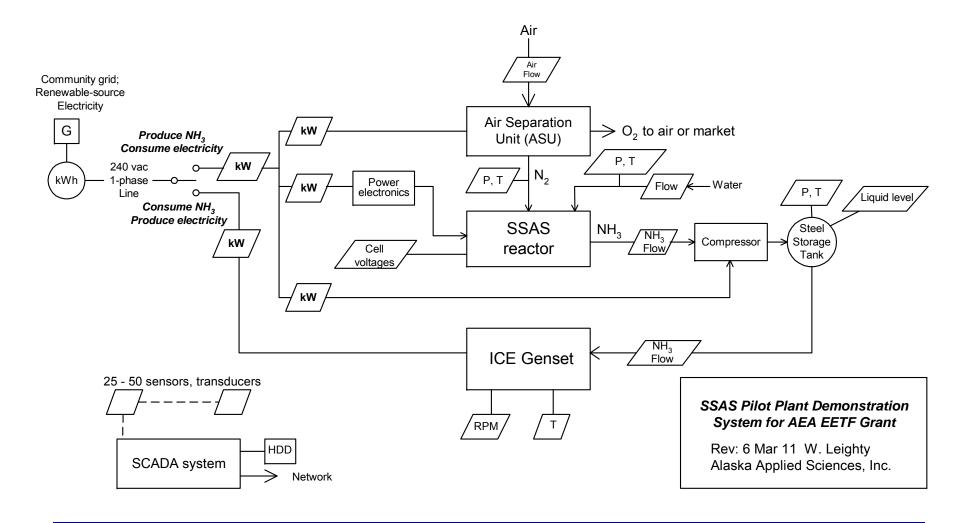
AK RE opportunities:

- 1. Village energy "independence"
- 2. Annual-scale firming storage
- 3. Transmission for:
 - a. Intrastate AK
 - b. RE export
- 4. Fuel for military land and sea

Alternatives? RE transmission, storage, integration

Need SSAS discovery and demo, now

Senior Partner Team: Run World on Renewables



PROJECT: Complete RE - NH₃ SSAS Storage System

- > NH3 synthesis from RE electricity, water, air (N₂)
- > Liquid NH₃ tank storage
- > Regeneration + grid feedback
- > SCADA instrumentation > UAF ACEP

Alaska's Solid State Ammonia Synthesis
Pilot Plant (SSAS-PP)
Demonstration System
for Renewable Energy (RE) Firming
Storage, Transmission, and Export

Handouts DVD's

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End of presentation 18 June 13 Hydrogen and Fuel Cell 2013 conference, Vancouver, BC

The following slides are supplemental

MUST Run the World on Renewables – plus Nuclear?

- Global
- Indigenous
- Firm: available
- C-free
- Benign
- Abundant
- Affordable
- Equitable
- Perpetual:
 - solar
 - geothermal
 - tidal



Next, if Success

- Gen 2 reactor
- NH3-optimized ICE genset

NH3 Synthesis Plant Cost

3,000 tpd NH3 = 675 tpd H2 @ 80% efficiency: Need TWO plants for 2,000 MW windplant

- Industry sources:
 - 2,000 mtd NH3, NG source, all costs \$500M
 - 2,200 mtd NH3, NG source, all costs \$466M
 - 140 mmscfd H2 plant costs ~ \$200M
 - NG conversion, all processes: ~ 60% of total capital cost
 - Delete NG conversion, must add N2 plant (ASP) (estim: \$75M)
- 3,000 tpd NH3 plant, from renewable-source H2, costs:

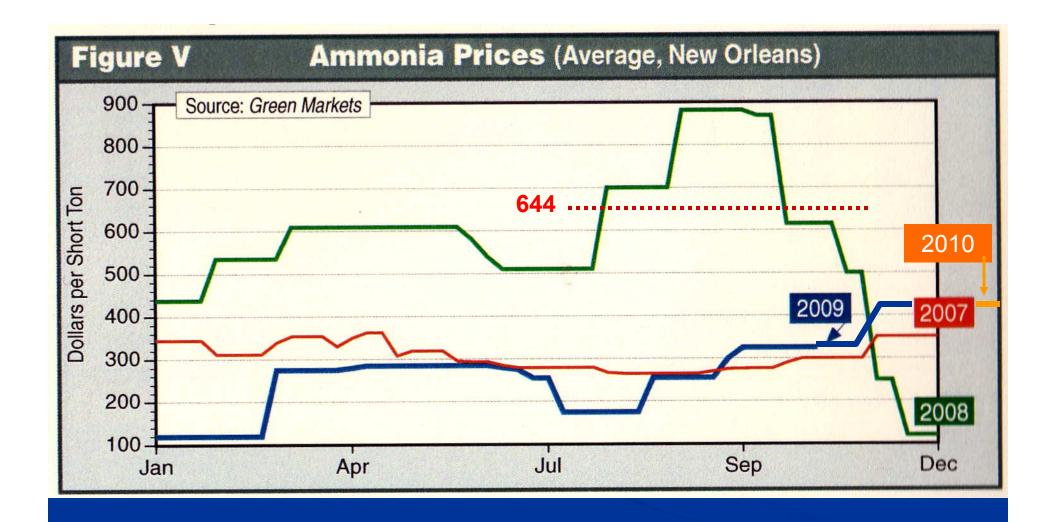
| NG conversion (SMR +) | \$ 0 |
|--|----------|
| H-B reactor | \$ 225 M |
| Balance Of Plant | \$ 75 M |
| Add Air Separation Plant, for N2 | \$ 75 M |
| Add H2 compressor (30 → 100 bar) | \$ 5 M |
| TOTAL | \$ 380 M |
| TWO PLANTS | \$ 760 M |

USA NH3 Infrastructure

- USA imports ~60% of 14 MMt / year
- 3,000 miles pipelines
 - ~ 250 psi liquid
 - Smaller diameter than NG or hydrogen
- 4.5 MMt large "atmospheric" tank storage
- Mild steel construction
 - Low cost
 - No corrosion or embrittlement

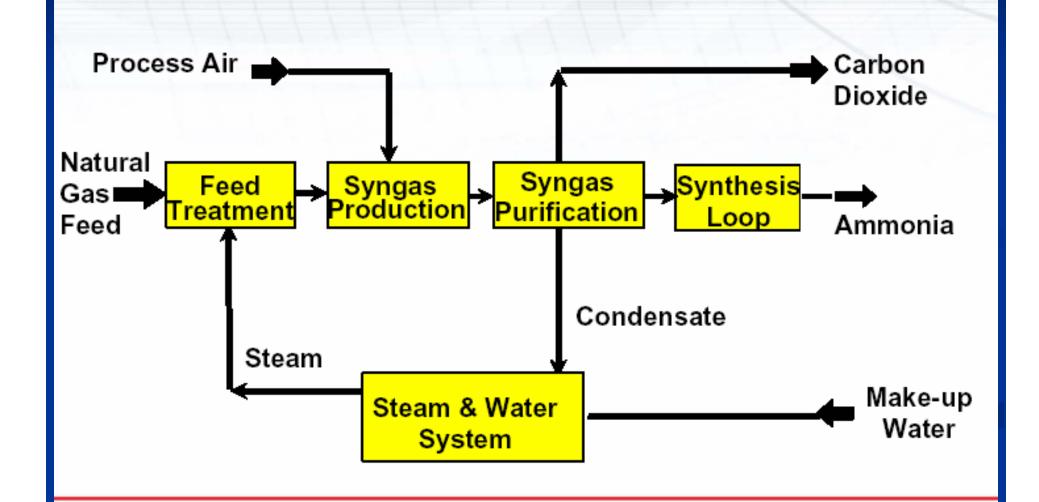
Opportunities

- Collaboration
 - International: "Run world on renewables"
 - RE systems: sources to end uses, firm and dispatchable
 - USA lead ? Korea ?
 - R&D
 - Demonstrations & pilot plants
- Solid State Ammonia Synthesis (SSAS)
 - RE electricity + water + N₂ → NH₃
 - Proof-of-concept pilot plant
 - Technical + economic promise?
 - Several processes ?
 - NHThree LLC patented PCC
 - Hydrogen Engine Center lithium
 - Other?
- End use: stationary, transportation, fertilizer
- Commercialization



Anhydrous Ammonia (NH3) wholesale price, NOLA (New Orleans, LA)

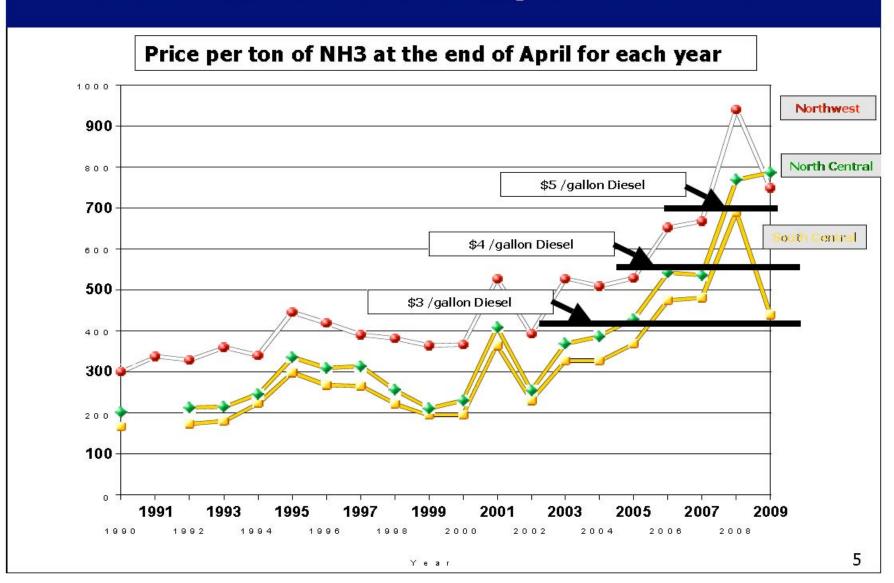
Sections in an Ammonia Plant



KBR

Energy and Chemicals

Ammonia Can Be Cheaper Than Diesel



Humanity's Goal

A global, sustainable, benign-source, equitable, energy economy

- CANNOT with only electricity transmission
- "Transmission" must include GH2, NH3, other

Beyond "Smart Grid"

- Primarily DSM
- More vulnerable to cyberattack?
- Adds no physical:
 - Transmission, gathering, distribution
 - Storage
- Next big thing; panacea
- Running the world on renewables?
- Must think:
 - Beyond electricity
 - Complete energy systems