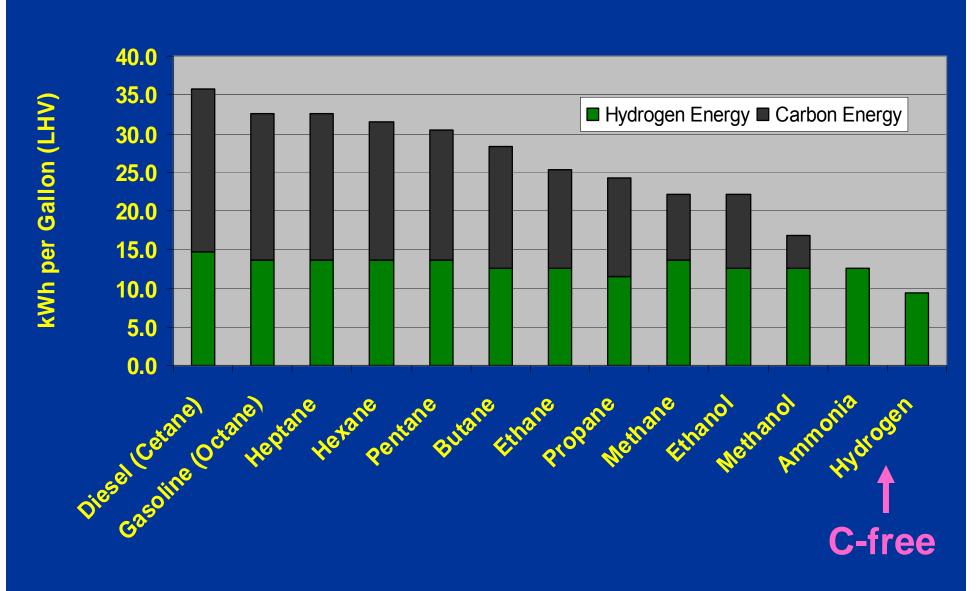


# Volumetric Energy Density of Fuels (Fuels in their Liquid State)



### NH3 Fuel Association Website

	Energy Content (LHV)		Octane Number	300 Mile Range - Tank Size (30 mpg gasoline equivalent)	500 km Range - Tank Size (12.75 km/litre gasoline equivalent)	Maximum Practicle Compression Ratio	
	Btu/gallon	MJ/liter		Gallons	Litres		
Diesel fuel	129,500	36.10	8 - 15	8.8	34.5	23:1	
Biodiesel	118,300	32.98	25	9.6	37.8	23:1	
Gasoline	114,100	31.81	86 - 94	10.0	39.2	10:1	
LPG (propane)	84,300	23.50	120	13.5	53.1	17:1	
Ethanol	76,100	21.21	109	15.0	58.8	19:1	
Methanol	56,800	15.83	109	20.1	78.7	19:1	
NH3	41,700	11.62	130	27.4	107.3	50:1	
CNG (3600 psi)	41,000	11.43	120	27.8	109.1	17:1	
Hydrogen (10 kpsi)	16,000	4.46	130	71.3	279.5		
Hydrogen (5 kpsi)	6,500	1.81	130	175.5	688.1		
Lithium Ion Battlery	3,870	1.08	NA	98.3	385.2	NA	
'corrected for optimal engine off	ciency due to incres	sed compression	on ratio		·	No.	

# NH3 Fuel Association Website (reformatted)

				30 mpg	13 km / I	
				Tank Size	Tank size	ICE
	Energy	Energy		300 mile	500 km	Max
	Content	Content	Octane	Range	Range	Compress
	BTU / gal	MJ / liter	Number	Gallons	Liters	Ratio
Diesel	129,500	36.1	8 - 15	8.8	34.5	23
Biodiesel	118,300	32.98	25	9.6	37.8	23
Gasoline	114,100	31.81	86 - 94	10	39.2	10
LPG, LP, propane	84,300	23.5	120	13.5	53.1	17
Ethanol	76,100	21.21	109	15	58.8	19
Methanol	56,800	15.83	109	20.1	78.7	19
NH3	41,700	11.62	130	27.4	107.3	50
CNG (3,600 psi)	41,000	11.43	120	27.8	109.1	17
Hydrogen (GH2) - 700 bar	16,000	4.46	130	71.3	279.5	
Hydrogen (GH2) - 350 bar	6,500	1.81	130	175.5	688.1	
Lithium Ion Battery	3,870	1.08	NA	98.3	385.2	NA

# NH3 Fuel Association Website (reformatted)

				30 mpg	13 km / I	
				Tank Size	Tank size	ICE
	Energy	Energy		300 mile	500 km	Max
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	BTU / gal	MJ / liter	Number	Gallons	Liters	Ratio
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Gasoline	114,100	31.81	86 - 94	10	39.2	10
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Hydrogen (GH2) - 350 bar	6,500	1.81	130	175.5	688.1	
Lithium Ion Battery	3,870	1.08	NA	98.3	385.2	NA
<b>Uranium, Plutonium, Thorium</b>						
Deuterium, Tritium						
Electricity						

## NH3 Fuel Association Website (All Energy)

				30 mpg	13 km / I	
				Tank Size	Tank size	ICE
	Energy	Energy		300 mile	500 km	Max
	Content	Content	Octane	Range	Range	Compress
	BTU / gal	MJ / liter	Number	Gallons	Liters	Ratio
Diesel	129,500	36.1	8 - 15	8.8	34.5	23
Biodiesel	118,300	32.98	25	9.6	37.8	23
Gasoline	114,100	31.81	86 - 94	10	39.2	10
LPG, LP, propane	84,300	23.5	120	13.5	53.1	17
Ethanol	76,100	21.21	109	15	58.8	19
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Lithium Ion Battery	3,870	1.08	NA	98.3	385.2	NA
<b>Uranium, Plutonium, Thorium</b>						
Deuterium, Tritium						
Other Petrol Fuels						
Coal						
Electricity						

## NH3 Fuel Association Website (All Energy, More Properties)

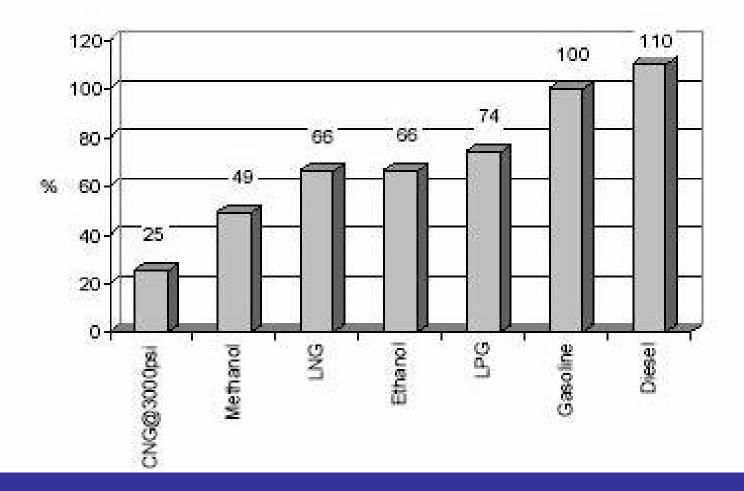
				30 mpg	13 km / I									
				Tank Size	Tank size	ICE								
	Energy	Energy		300 mile	500 km	Max					H2O	CO2	Buoy	Storage
	Content	Content	Octane	Range	Range	Compress	GHG	Nox	H:C ratio	pН	Soluble	Emiss	in air	effic'y
	BTU / gal	MJ / liter	Number	Gallons	Liters	Ratio								
Diesel	129,500	36.1	8 - 15	8.8	34.5									
Biodiesel	118,300	32.98												
Gasoline	114,100	31.81	86 - 94	10										
LPG, LP, propane	84,300	23.5	120	13.5	53.1	17								
Ethanol	76,100	21.21	109	15										
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Hydrogen (GH2) - 350 bar	6,500	1.81	130	175.5	688.1									
Lithium Ion Battery	3,870	1.08	NA	98.3	385.2	NA								
Uranium, Plutonium, Thorium														
Deuterium, Tritium														
Other Petrol Fuels														
Coal		·												
Electricity														

### Compressed fuel tank costs

- Dynetek
- Quantum
- Lincoln
- Toyota
- Baytech Landi-Renzo, Torrance, CA

FUEL	Mas	s Energy De	ensity	Volumetric Energy Density:
Higher Heating Values (HHV)	MJ/kg	BTU / Ib.	BTU / gal.	Percent of Diesel
Diesel, low sulfur	45.600	19,594	138,490	100.0
Gasoline, conventional	46.500	20,007	124,340	89.8
Reformulated Gasoline (RFG)	45.400	19,530	121,848	88.0
Propane	50.200	21,597	91,420	66.0
Liquefied Petroleum Gas	50.200	21,561	91,410	66.0
Ethanol	29.800	12,832	84,530	61.0
Methanol	22.900	9,838	65,200	45.1
Ammonia, NH3 (75% H2)	24.644	10,600	60,282	43.5
Lithium Ion Battery	0.445	940	4134	2.99
Hydrogen, liquid	139.000	60,619	35,815	25.9
Hydrogen, gas, STP	139.000	59,816	42	<0.001

Source: Carl E. Schoder, "Our Carbon Free Energy Future", Aug 12



Volumetric Fuel Energy versus Gasoline

	CNG	Methanol	LNG	Ethanol	Propane	Gasoline	Diesel
Formula	CH4	C30H	CH4	C2H50H	C3H8	C8H16	C12H26
Research Octane #	130	112	130	111	112	91-98	N/A
Motor Octane #	130	91	130	92	97	82-90	
Cetane #	-10	3	-10	8	5-10	8-14	40-60
Boiling Point °F/°C	-259/-162	N/A	-259/-162	N/A	-44/-42	(81-464)/ (27-240)	N/A
Energy Content (volume) (BTU/ft³) / (kJ/L)	213,300/ 7,875	425,000/ 15,688	569,200/ 21,013	570,000/ 21,027	637,500/ 25,535	862,100/ 31,825	950,400/ 35,082
Energy vs Gasoline %	25	49	66	66	74	100	110
Stoich A/F Ratio (mass)	17.3	6.5	17.3	9.0	15.7	14.7	15.0
Autoignition Temperature °F/°C	842/450	N/A	842/450	N/A	1,004/540	428/220	437/225
Peak Flame Temperature °F/°C	3,254/ 1,790	N/A	3,254/ 1,790	N/A	3,614/ 1,990	3,591/ 1,977	3,729/ 2,054
Flammability Lower Limit (volume %)	5.3	4.0	N/A	N/A	2.1	1.4	N/A
Flammability Upper Limit (volume %)	15.0	75.0	N/A	N/A	10.4	7.6	N/A

#### Context: Fuel Definitions

#### **Attributes:**

- Transportable
- Energy storage
- Convertible (energy → exergy)
- Safe, convenient, economical
- USA Fed designation

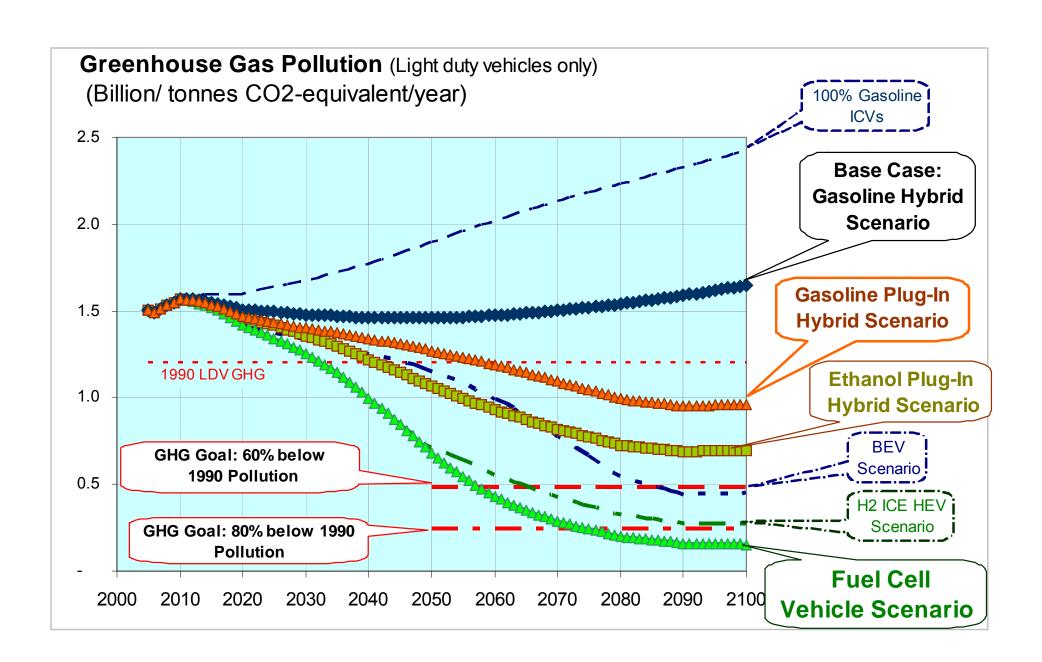
#### **Electricity?**

- Flow of electrons
- 100% exergy
- No storage
- Real-time
- "Smart Grid" symptom



# Phyllis Cuttino Pew Environment

" Electrification of transportation is the only way to get off foreign oil "



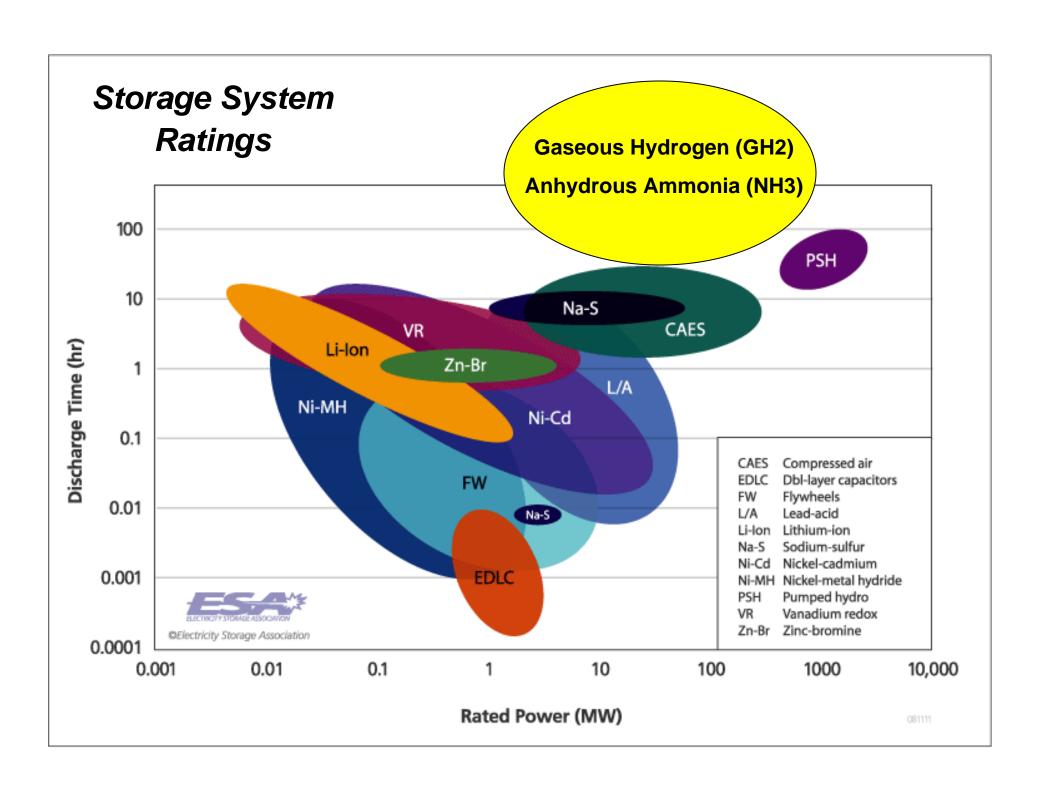
### Context: Fuel Definitions

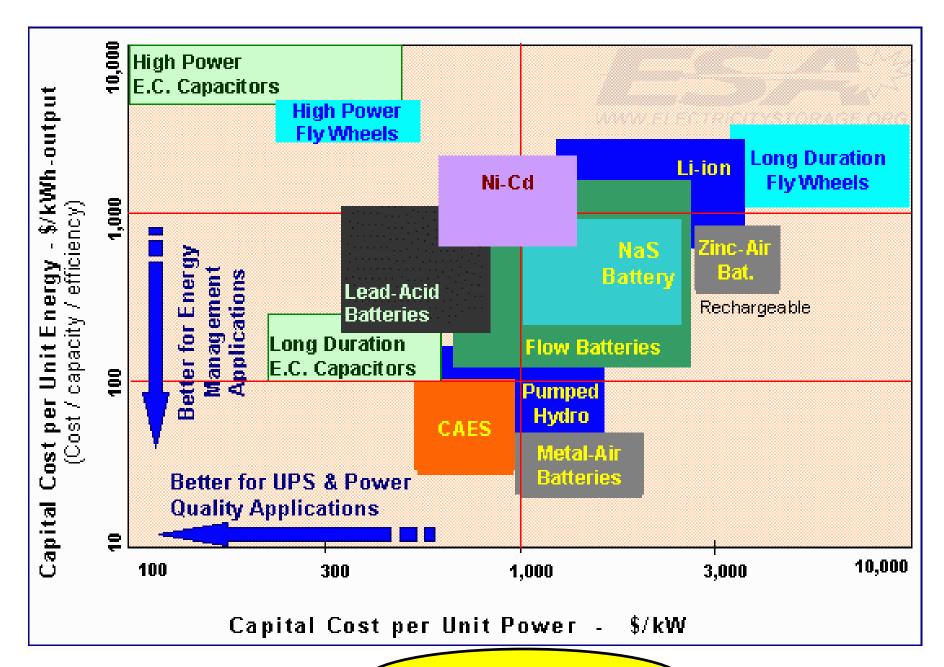
- 1. A material consumed to produce energy, especially:
  - a. Burned to produce heat or electricity
  - b. Fissionable or fusible material used in a nuclear reactor
  - c. Nutritive, food metabolized by a living organism
- 2. A substance that produces useful energy when it undergoes a chemical or nuclear reaction: burning, combustion, oxidation or reduction, metabolism.
- 3. Some radioactive substances:
  - Uranium, plutonium, thorium via fission
  - Deuterium and tritium via fusion
- 4. USA Fed designation
- 5. Electricity? No

### Energy Storage System Characteristics

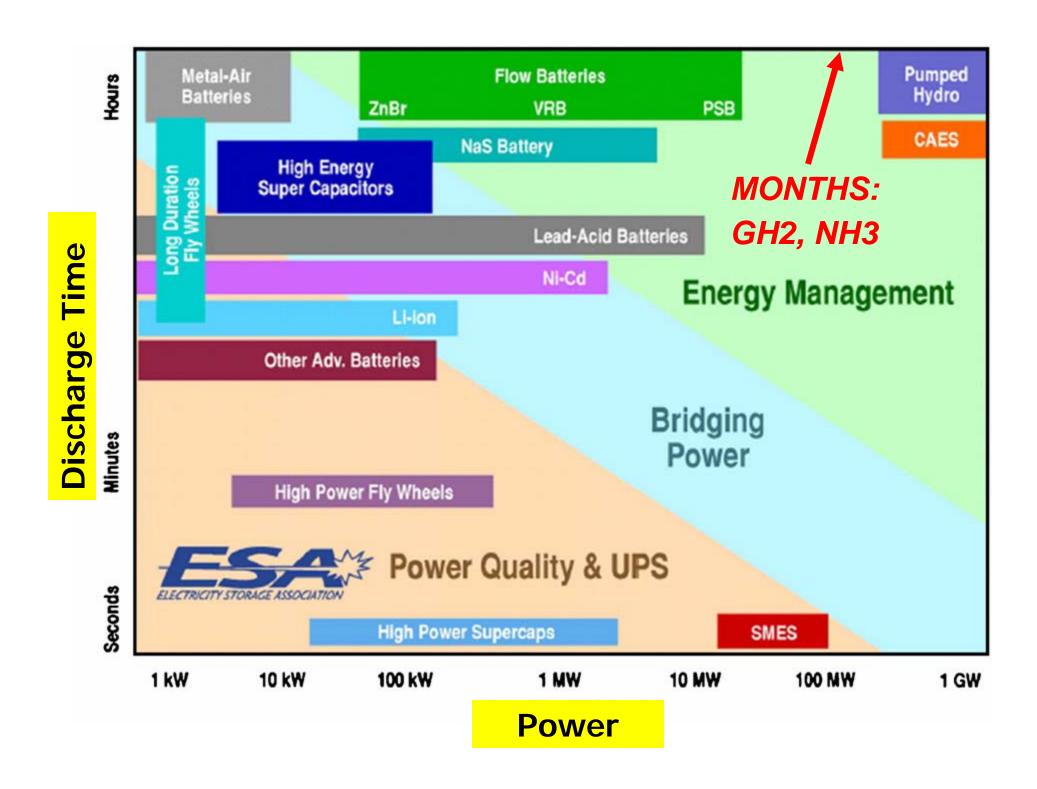
#### Hydrogen and Ammonia off the charts

- Storage capacity (Mwh, scf, nM3, Mt, gallons .... )
- Power (MW, scfm ....) In / Out rate
- Costs
  - Capital
  - O&M
  - Conversion losses
- Efficiency
- Response time
- Durability (cycling capacity)
- Reliability
- Autonomy
- Self-discharge
- Depth of discharge
- Adaptation to the generating source
- Mass and volume densities of energy
- Monitoring and control equipment
- Operational constraints
- Feasibility
- Environmental



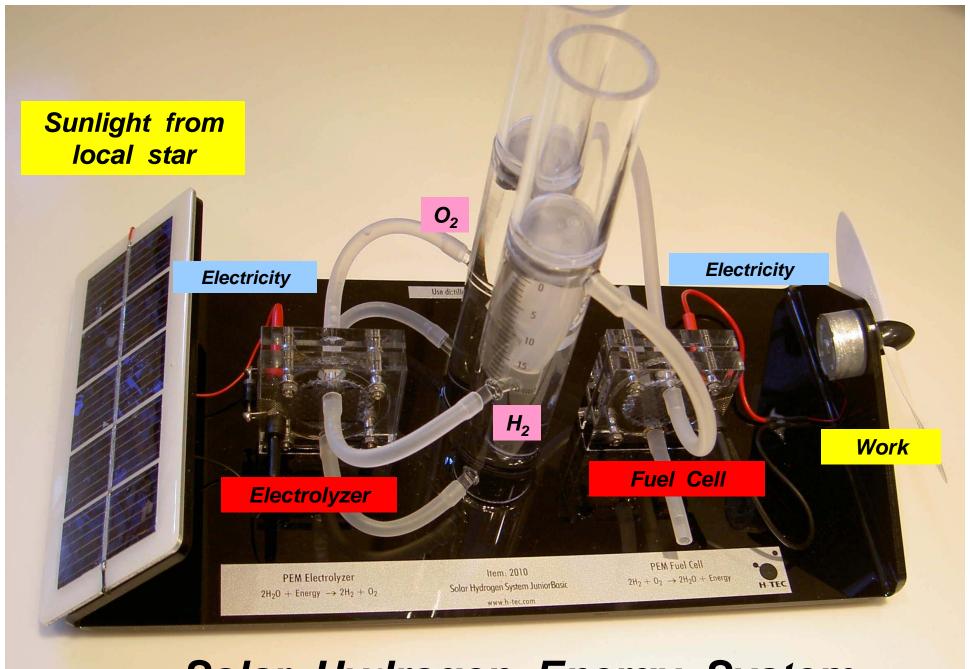


**GH2 and NH3** 



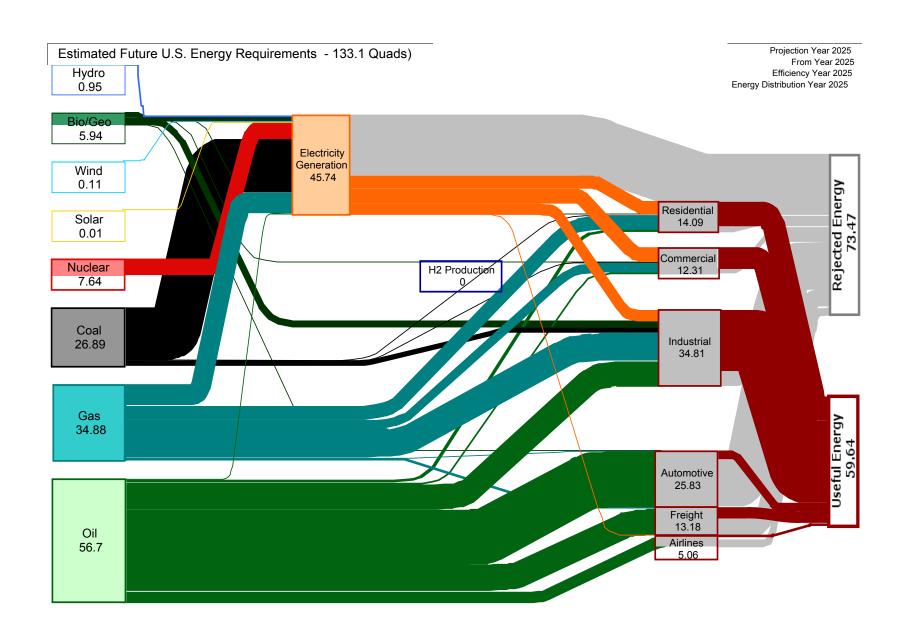
### Context: Complete energy systems

- Photons + moving molecules → energy services
- Extraction: Non-renewable
  - Fossil
  - Nuclear
- Production: Renewable generation, conversion
- Transmission
- Storage
- Supply integration
- Markets, niches



Solar Hydrogen Energy System

### EIA estimated 2025 energy use



# Context: Why Ammonia? Fertilizer and Fuel

### Only liquid fuel embracing:

- Carbon-free: clean burn or conversion; no CO<sub>2</sub>
  - Excellent hydrogen carrier
  - Easily "cracked" to H<sub>2</sub>
- 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

### Markets: Supply, Demand, Price

- Supply Push
- Demand Pull
- Price
  - Competition
  - Substitutes
  - Volume
  - Condition changes

# Market: Transportation

- Land
  - Truck
  - Rail
  - Personal vehicle
  - Military
- Air
- Marine
  - Pleasure, utility
  - Commercial
  - Shipping
  - Military: USCG, Navy

# Market: Transportation

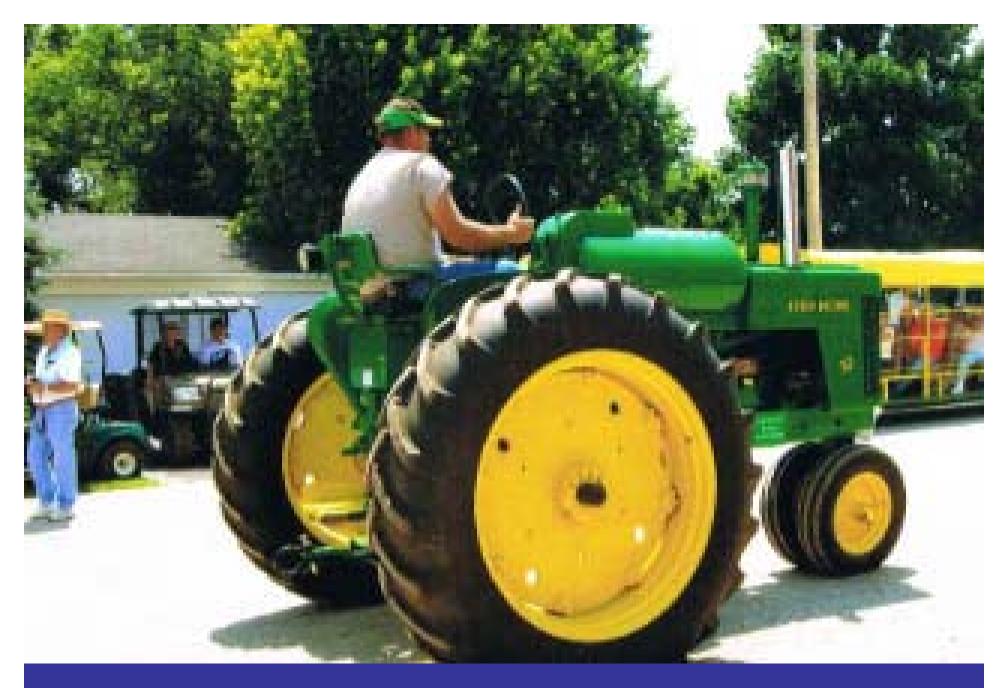
- Land, Marine
  - Liquid HC's
  - CNG, LNG
  - LPG
  - Hydrogen: GH2, LH2
  - Other: Al-Ga, Zinc
- Air
  - Liquid HC's
  - **LH2**



Compressed Natural Gas (CNG) Fueling: ~ 3,000 psi

# Market: Ag + Construction + Industrial

- Liquid HC's
- · CNG, LNG
- LPG
- Hydrogen: GH2, LH2
- Other: Al-Ga, Zinc



John Deere "LP" tractor



### Market: Combined Heat and Power (CHP)

- Firm, quality "power"
  - Elec grid backup
  - Elec grid replace
  - Sub-cycle response
- 80% + fuel energy recovery
- Stationary, on-site
  - Genset (ICE, CT, Fuelcell)
  - Byproduct heat (HI, LO temp)
    - Heat and cool
    - Process

#### Fuels

Natural gas (pipeline)

Liquid HC's (pipeline and / or tank)

Ammonia (pipeline and / or tank)

Nuclear SMR (small modular reactor)

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#### Fuels

Natural gas (pipeline)

Liquid HC's (pipeline and / or tank)

Ammonia (pipeline and / or tank)

Nuclear SMR (small modular reactor)

### Market: Military

- Land
- Sea
- Air
- Scale
  - Major Base
  - Forward Base
  - Ship
  - Aircraft
  - Mini, Micro 1 W → 1 kW

## Market: RE Systems "Big 3"

( RE = Renewable Energy )

- 1. Gathering and Transmission
- 2. Storage
  - Firming
  - Seasonal, annual
  - Dispatchable
  - Cure "intermittent"
- 3. Supply Integration
  - Extant energy systems
  - Cure "intermittent"

### Market: Fertilizer

- N:
  - Embodied energy
  - "Corn ethanol is recycled natural gas"
  - NH3 and products: Urea, DAP, AN, other
- K, P
  - Embodied energy
  - Enables solar harvest via photosynthesis
- Trace minerals
  - Enables solar harvest via photosynthesis

### Market: Chemicals + Explosives

Feedstock

Explosives

# Context: Markets - Where NH3 Compete ?

- Transportation
- Combined Heat and Power (CHP)
- Ag + Construction + Industrial
- Military
- Complete RE systems
- Fertilizer
- Chemicals + Explosives

Fuel, fertilizer, feedstock?
Distributed, centralized, networked?
Determines salient "fuel" properties

Ammonia Demand Pata for two representative areas Worldwide, IEA (6)		From C.E. Schoder Au USA, EIA (7)		
Type of Energy Demand,	Volumetric demand	Gravimetric demand	Volumetric demand	Gravimetric demand
Energy Demand units-→	Cubic meters NH3 per day	Mtonnes NH3 per day	Cubic meters NH3 per day	Mtonnes NH3 per day
NH3 energy demand per day, using NH3 to replace fossil fuels only)	90,711,825	61,856,394	28,437,910	19,391,81
Annual (MMtonnes) (Million metric tons)	Here I To mean miles of with a de table consister	E 1951 ( Se + 3 TT 2014 ( SE 1952 ) F 1952 ) F 1972 )	ATTE AT LEAST THE P. P. LEWIS CO., S. L.	VOIL 1 10 10 VOIL 10 V
	Assuming Solid State	Ammonia Synthesis		
Air Separation Unit input, air	95,519,027	65,134,424	29,944,954	20,419,46
Air Separation Unit output, nitrogen	74,585,077	50,859,564	23,382,218	15,944,33
Air Separation Unit output, oxygen	20,933,950	14,274,860	6,562,736	4,475,13
Annual (MMtonnes) (Million metric tons)				
SSAS input, water	59,744,604	40,739,845	18,729,770	12,771,83
SSAS input, nitrogen	74,585,077	50,859,564	23,382,218	15,944,33
Total inputs	134,329,681	91,599,409	42,111,988	28,716,16
SSAS output, NH <sub>3</sub> per day (fossil fuel replacement only)	90,711,825	61,856,394	28,437,910	19,391,81
SSAS output, oxygen	43,617,856	29,743,016	13,674,079	9,324,35
THE RESERVE OF THE PARTY OF THE	134,329,681	91,599,409	42,111,988	28,716,16

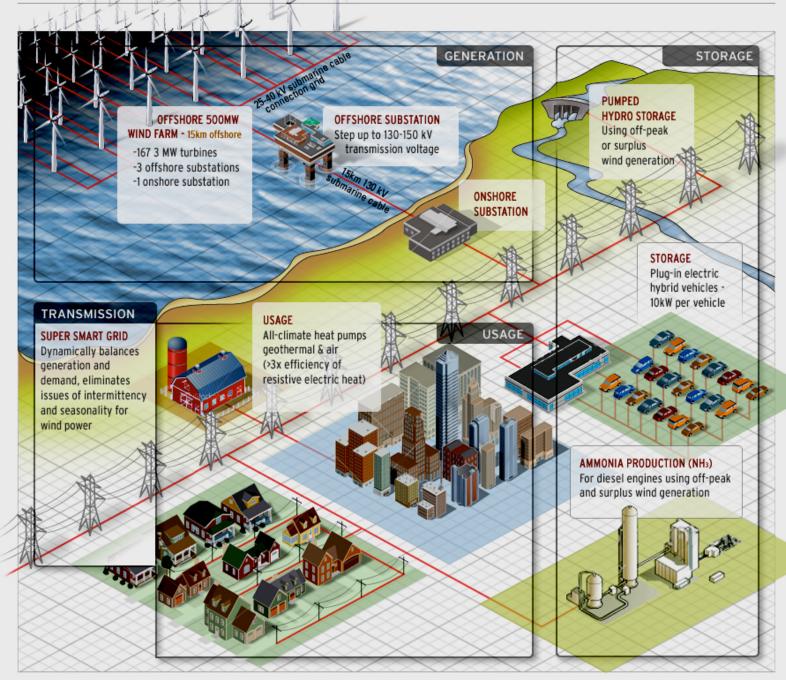
# Complete energy systems

- Photons + moving molecules → energy services
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- Transmission
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- Supply integration
- Markets, niches

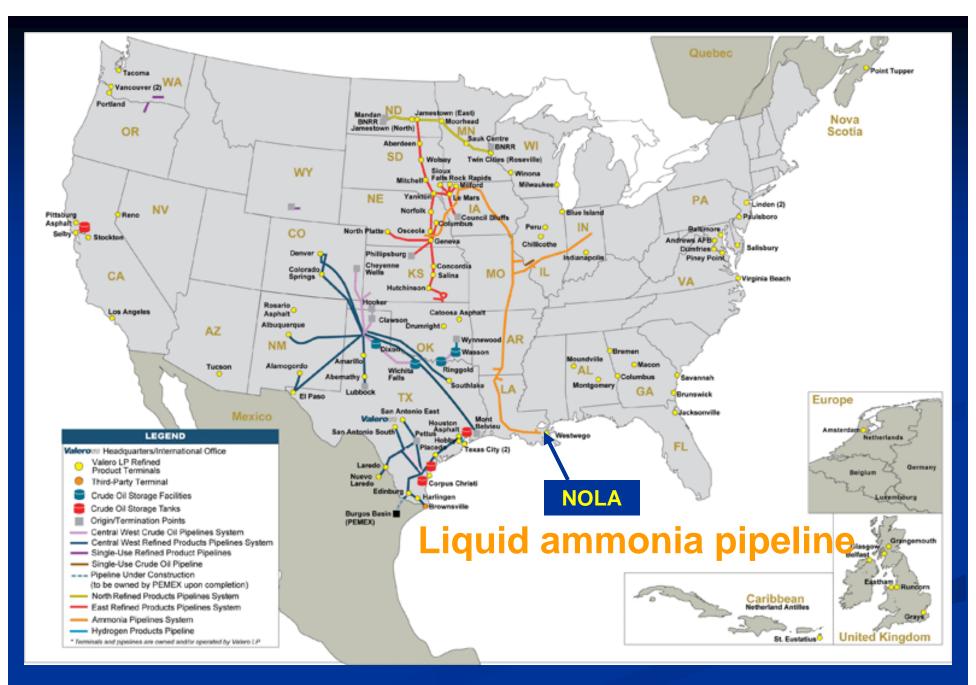
#### NH<sub>3</sub> Ag Fertilizer Tanks, Wind Generators, NW Iowa

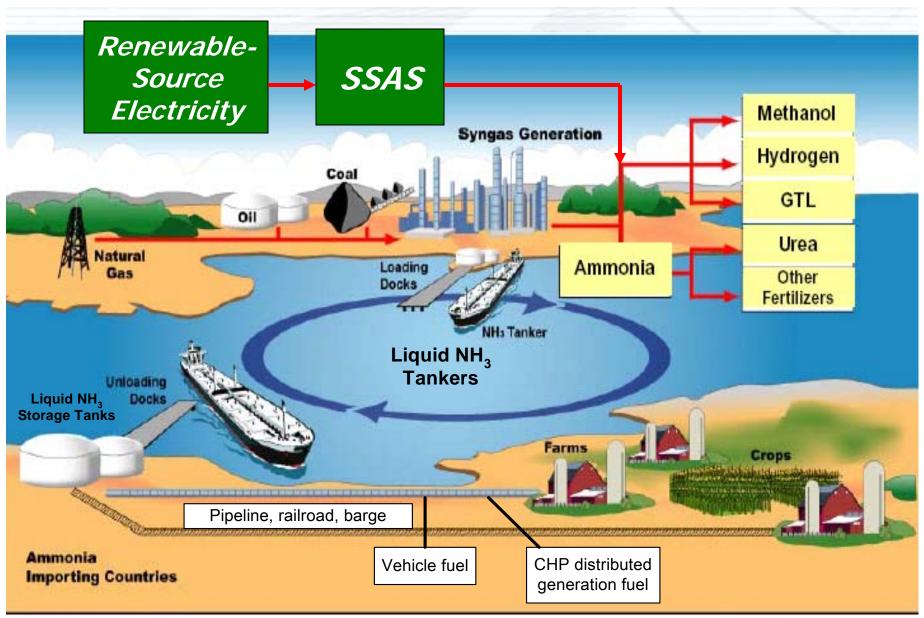


#### Energy as a Complete System: Generation, Usage, Storage, Transmission



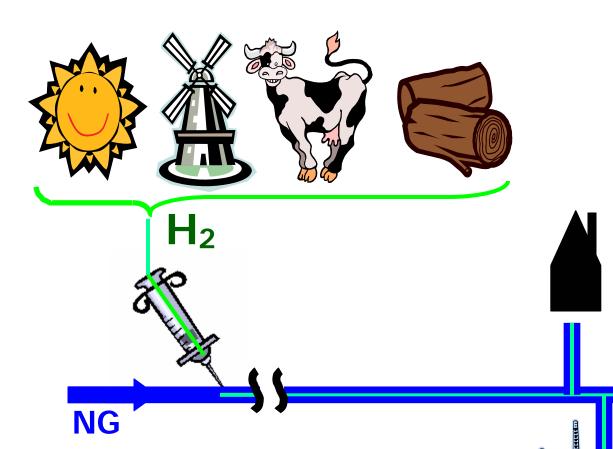
NH3 Storage





#### The NATURALHY approach: EC, R+D



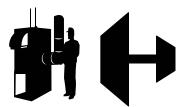




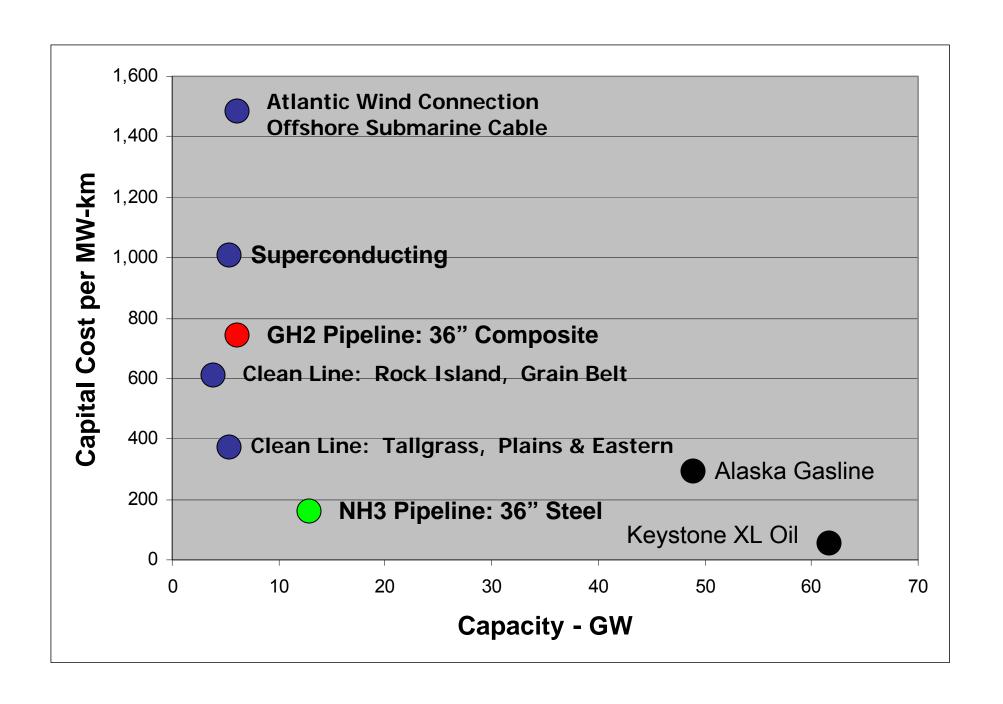
- Breaks "chicken-egg" dilemma
- Bridge to sustainable future

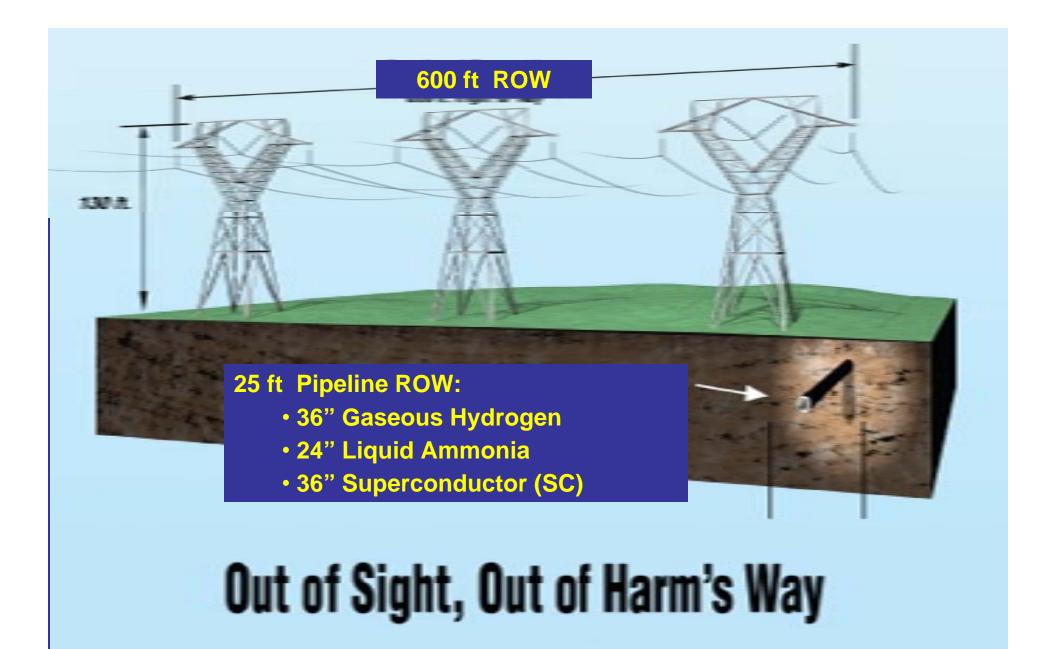




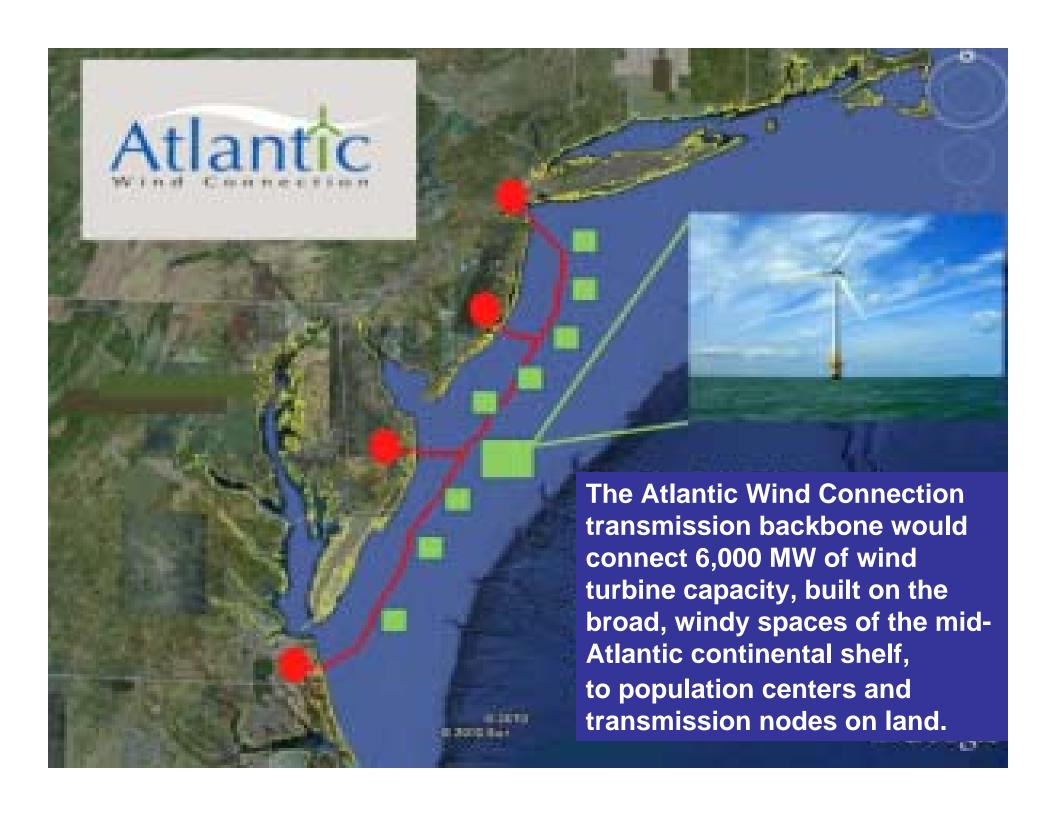


Pure H<sub>2</sub>





5,000 MW alternatives: HVAC vs HVDC superconductor

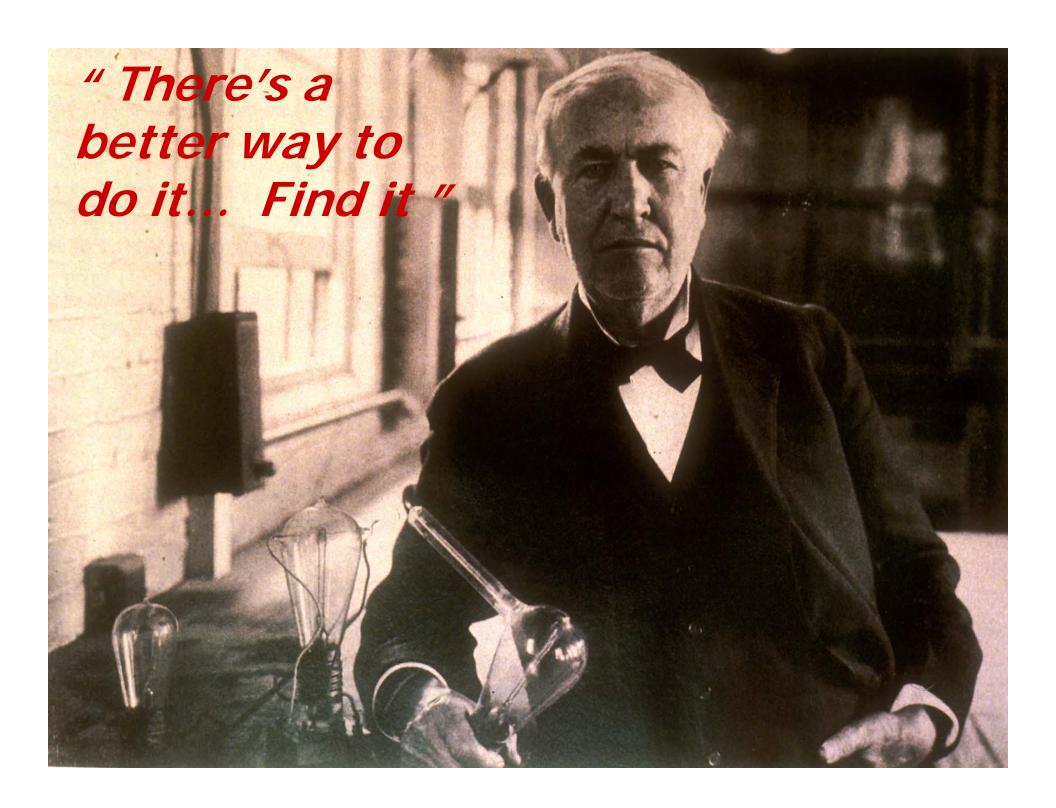


## Hydrogen and Ammonia Fuels

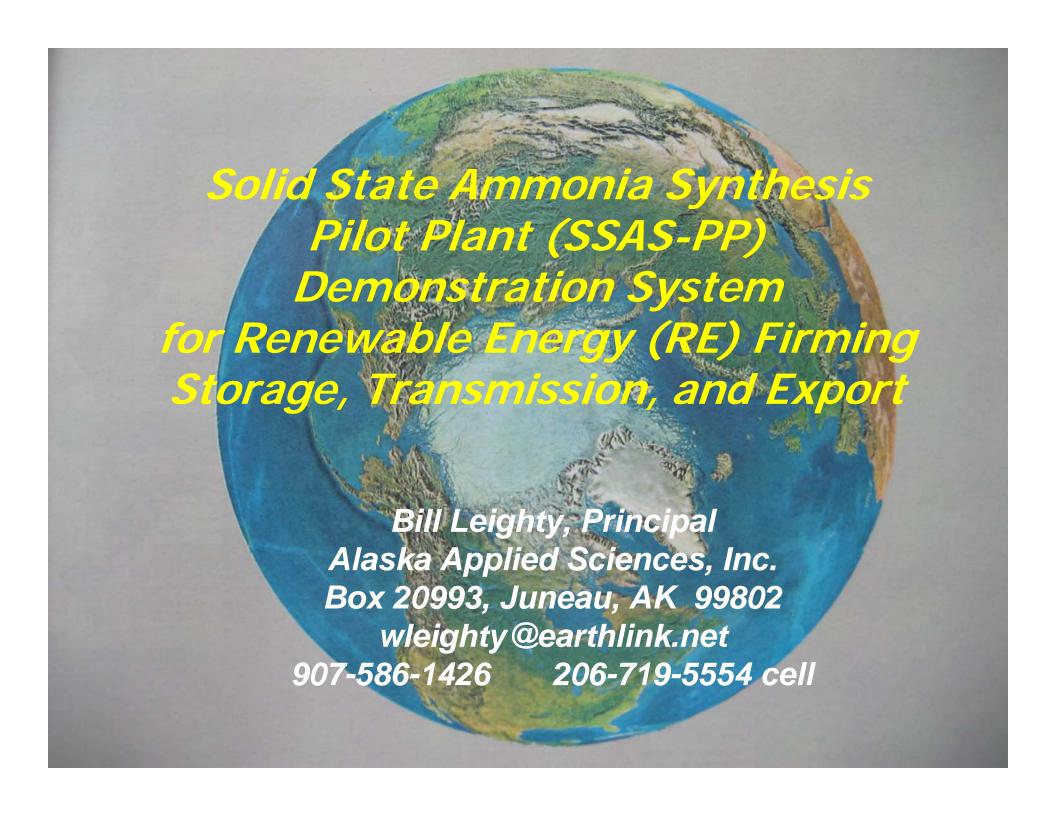
- Solve electricity's RE problems:
  - Transmission
  - Firming storage
  - Grid integration: time-varying output
- Carbon-free
- Underground pipelines
- Low-cost storage: < \$ 1.00 / kWh capital</li>
  - Pipelines
  - GH2 salt caverns
  - NH3 tanks
- Sec'y Chu: reconsidering hydrogen (WREF)

## Annual Fresh Water for Energy

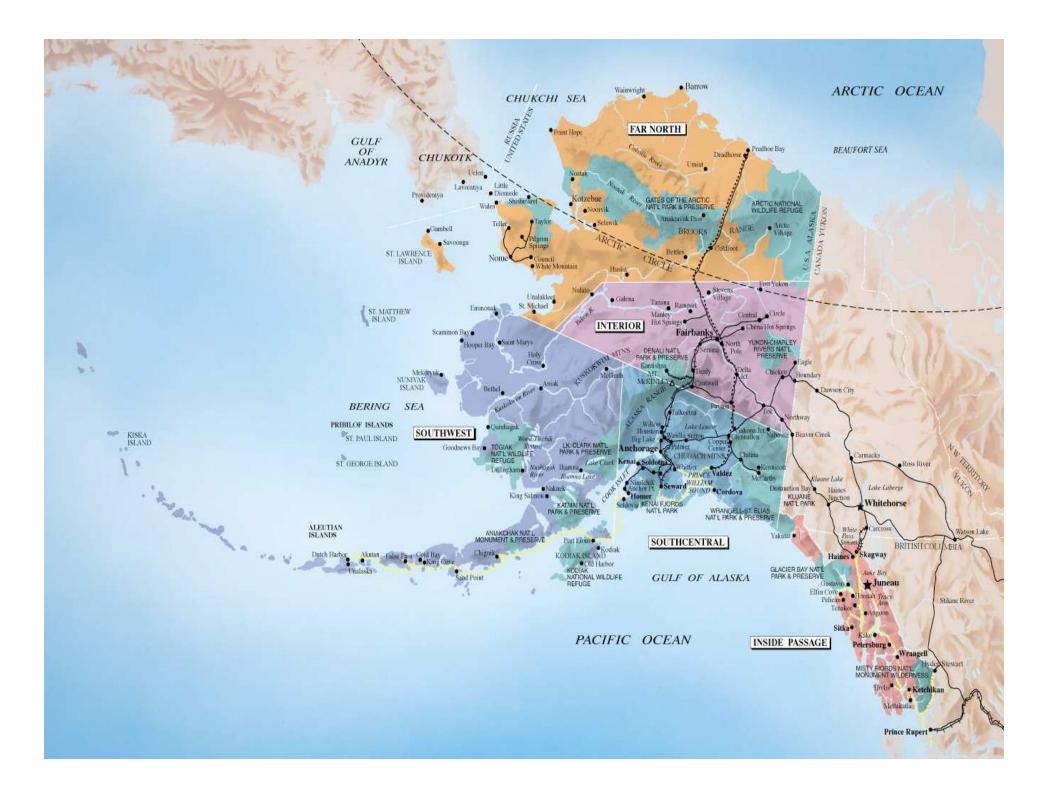
- USA today
- · All energy
- 17,000 billion liters
  - "Withdrawn"
  - "Consumed"
  - Include all NG "fracking" ?
- If all via GH2 + NH3 feedstock:
  - Dissociated, disintegrated:  $H_2O \rightarrow H_2 + O_2$
  - 900 billion liters



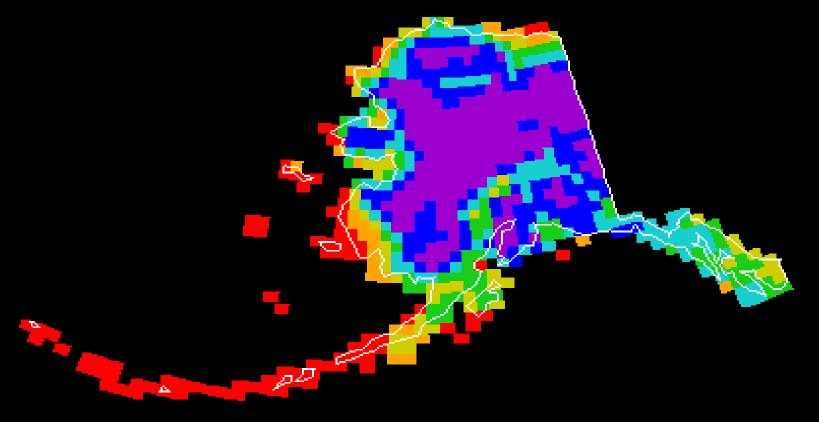




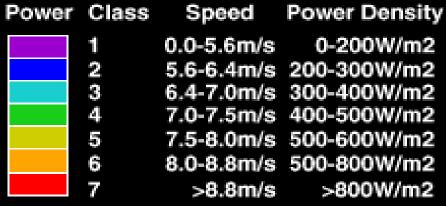


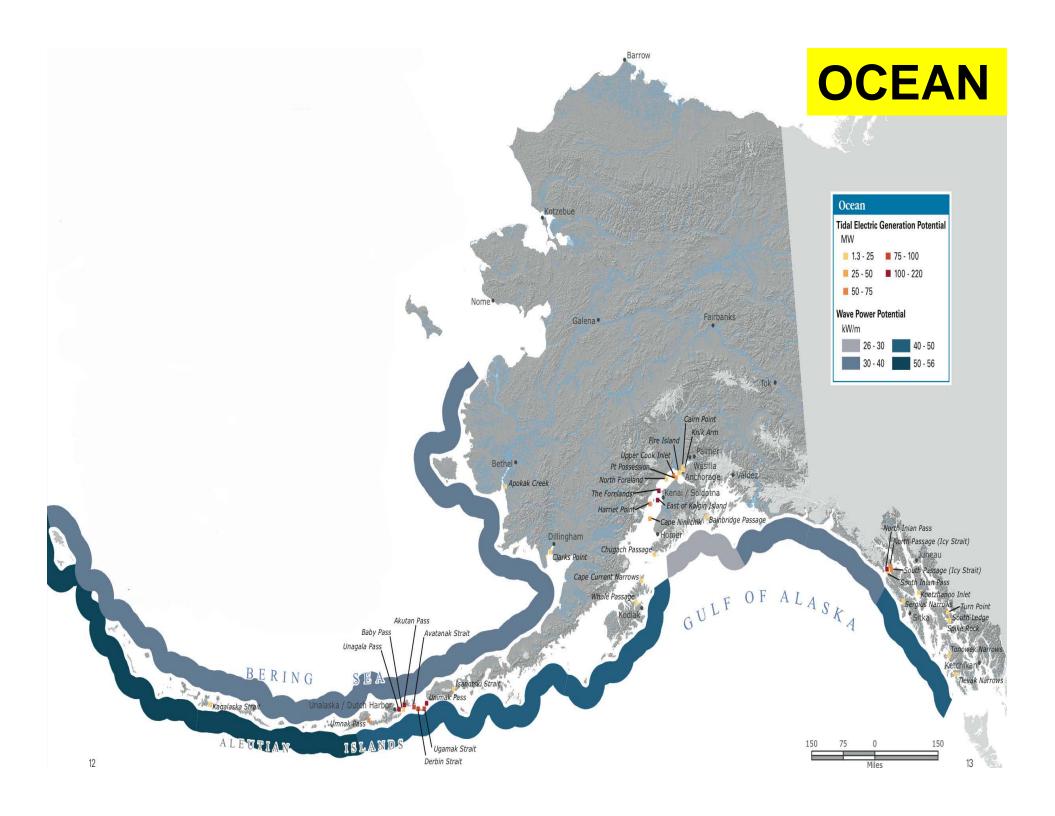


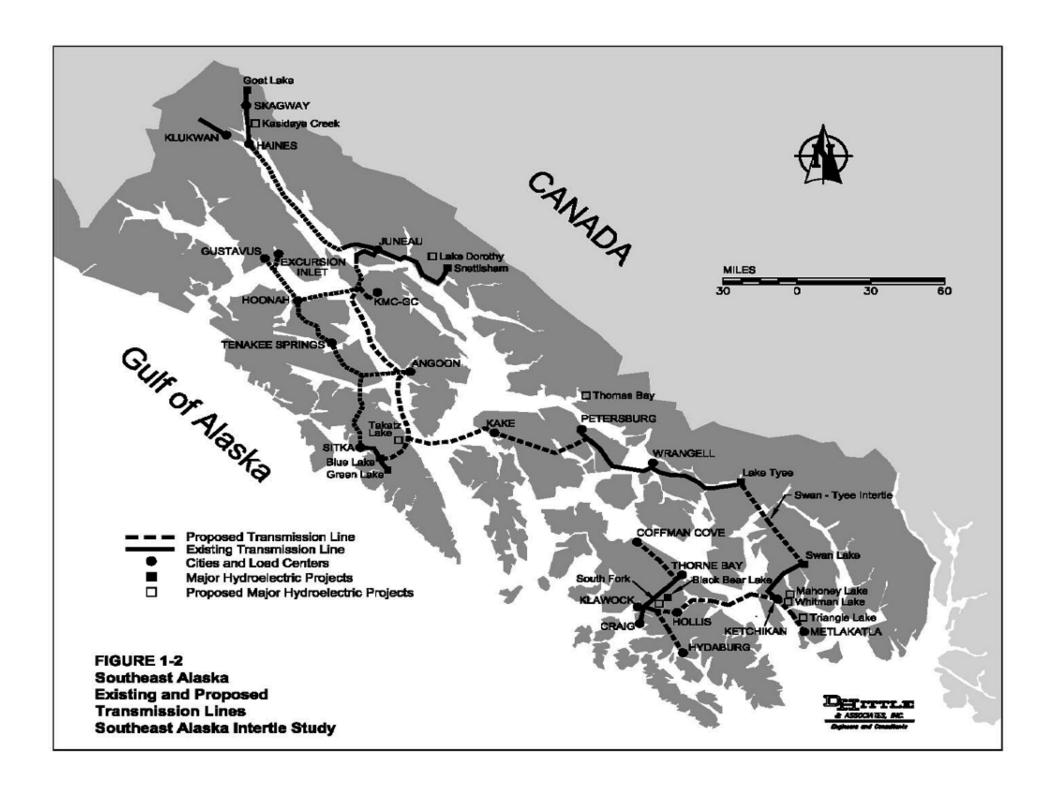


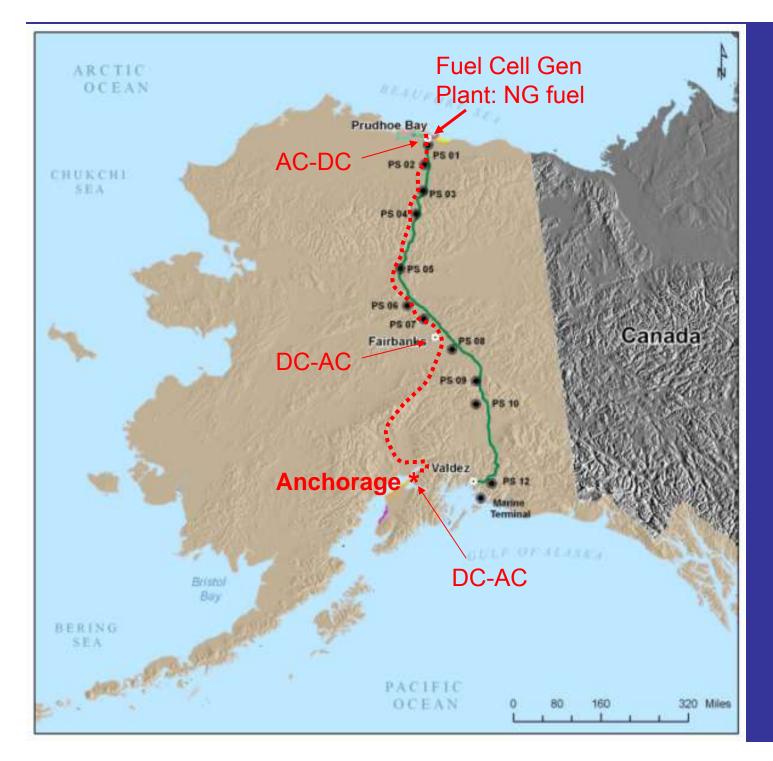












AC-DC
DC-AC
Converter
Stations

Superconducting (SC) electric line would leave TAPS at Fairbanks, follow Alaska Railroad to Anchorage

### 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

## 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?

#### Project Fundamentals

- 1. Does SSAS system "work"?
- 2. Competitive with EHB?
- 3. Useful in Alaska?

#### 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

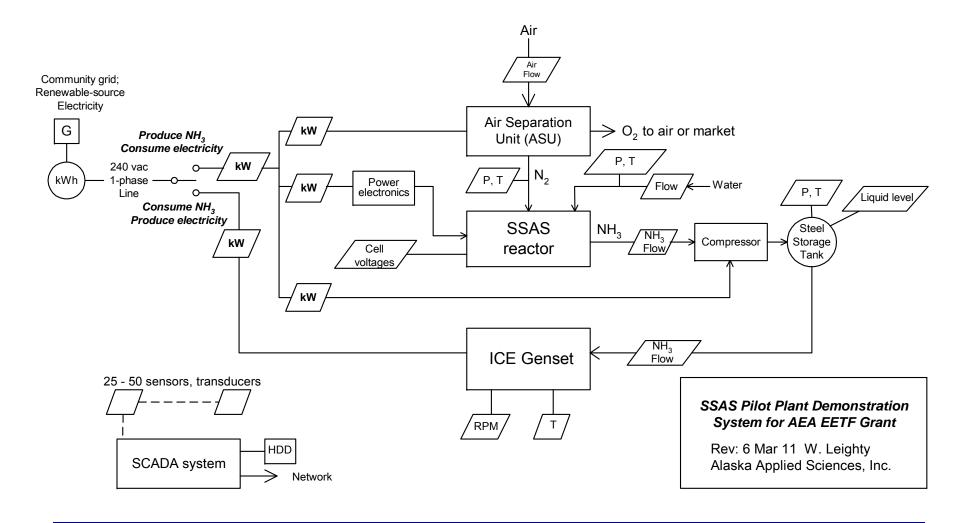
- 1. Test PCC tubes; accept
- 2. Build and test multi-tube reactor
- 3. Build and test BOS
- 4. Instrument with SCADA, remote read at UAF
- 5. Add regeneration: NH3 → electricity to grid
- 6. Package in insulated CONEX
- 7. Acceptance test
- 8. Transport to Juneau, AK for demo
- 9. Demo at other AK sites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

#### Project 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

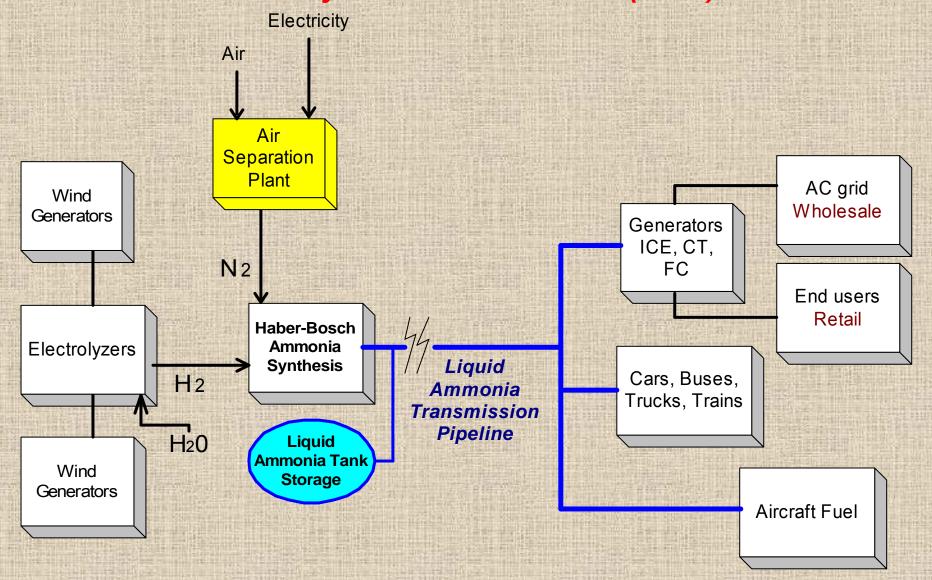
- 4. SSAS unproven: needs proof-of-concept, small pilot plant
- 5. Design and build pilot plant:
  - a. Complete
  - b. SCADA instrumented
  - c. Containerized & transportable
  - d. Upgradeable
- 6. Success:
  - a. Great value to AK, beyond
  - b. Next steps to commercial
  - c. SA AK "RE Cluster Industry"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



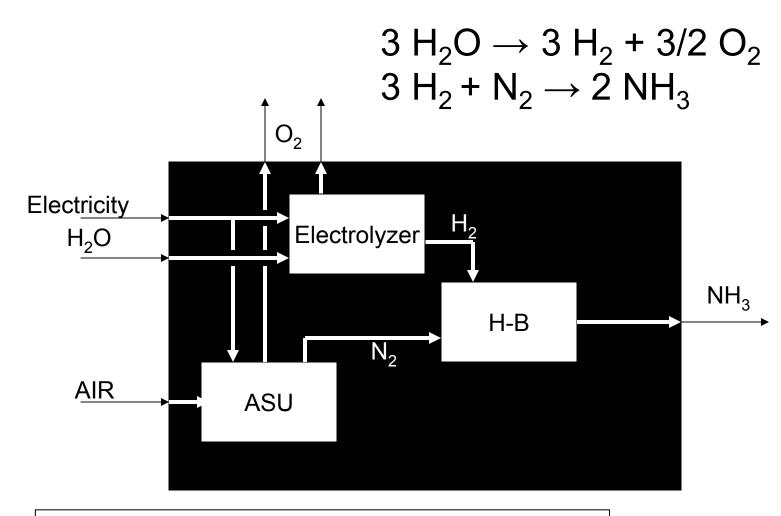
#### PROJECT: Complete RE - NH<sub>3</sub> SSAS Storage System

- > NH3 synthesis from RE electricity, water, air (N<sub>2</sub>)
- > Liquid NH<sub>3</sub> tank storage
- > Regeneration + grid feedback
- > SCADA instrumentation -> UAF ACEP

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

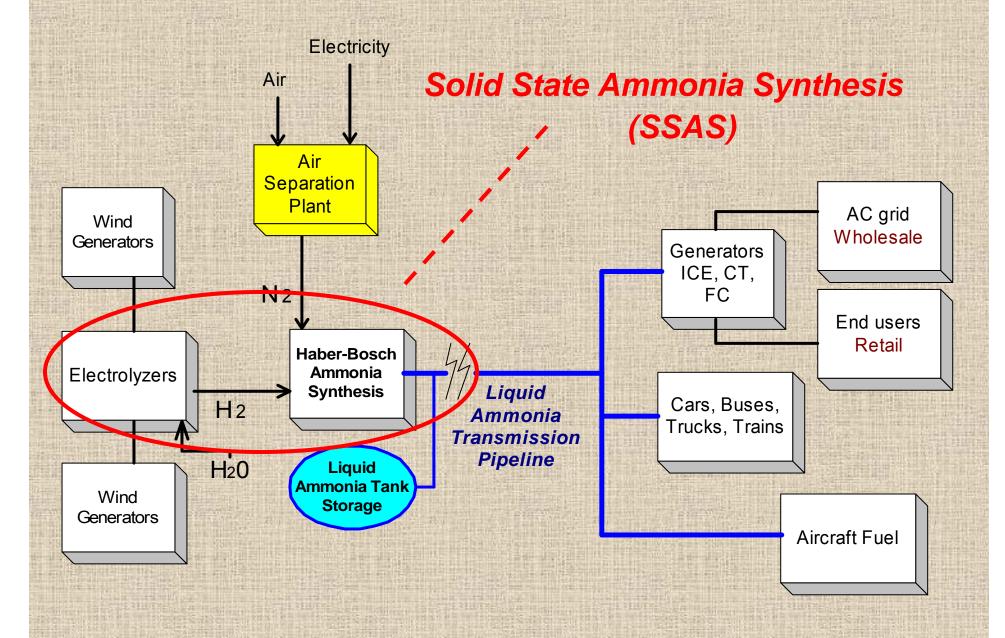


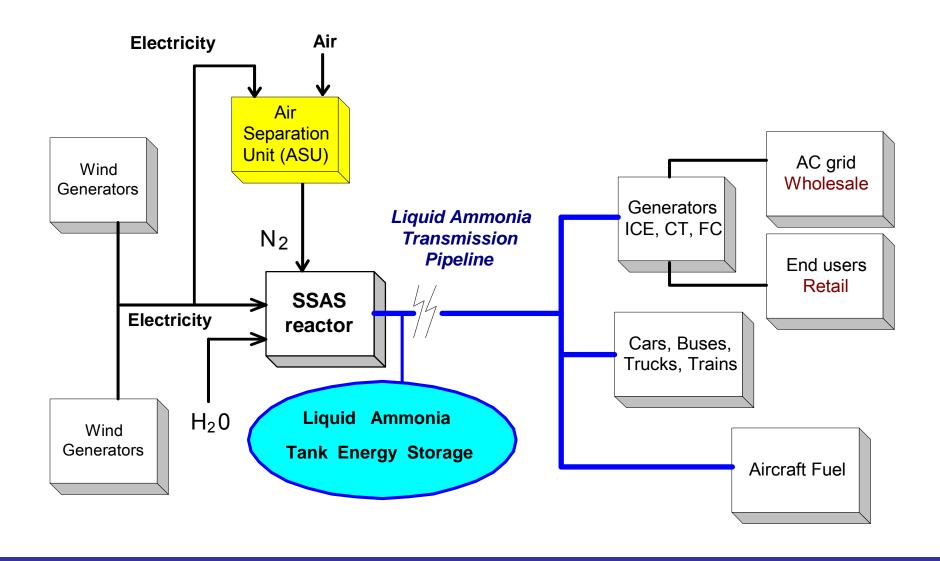
# Inside the Black Box: HB Plus Electrolysis



Energy consumption ~12,000 kWh per ton NH<sub>3</sub>

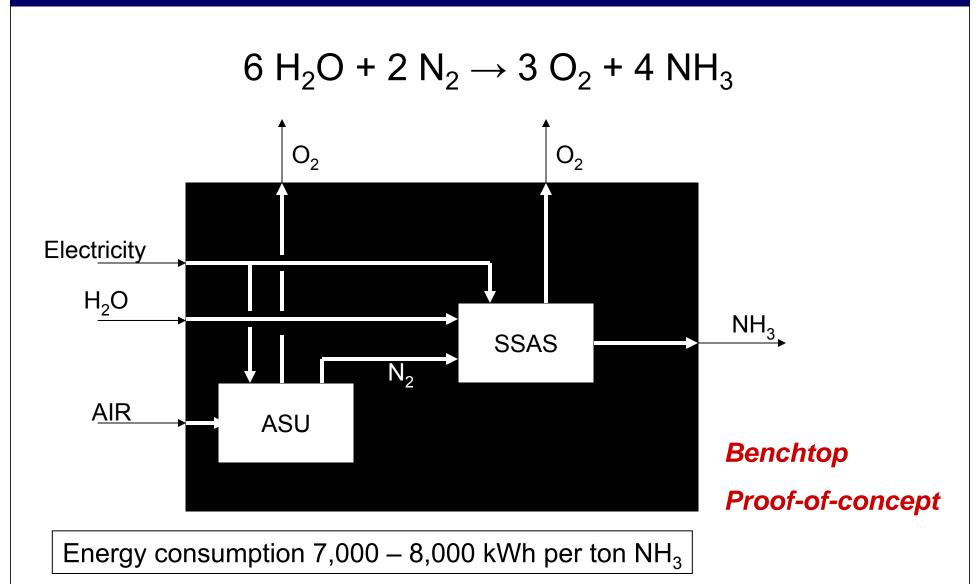
#### RE Ammonia Transmission + Storage Scenario



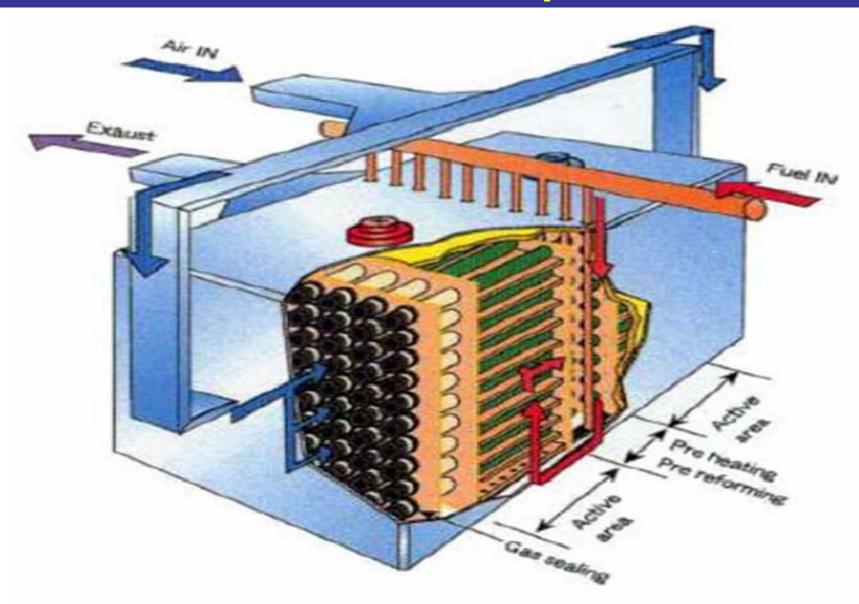


Solid State Ammonia Synthesis (SSAS)

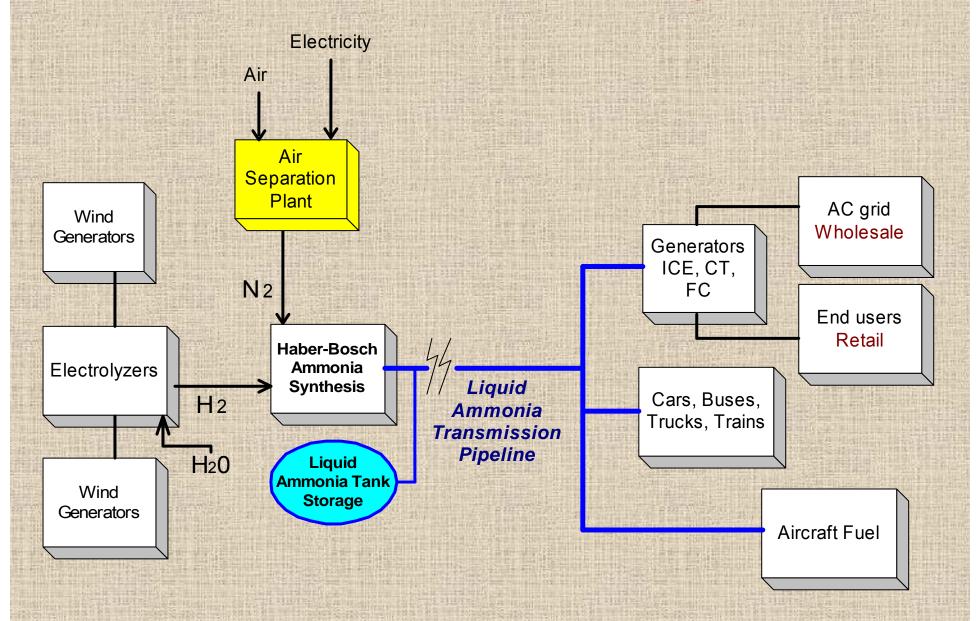
# Inside the Black Box: Solid State Ammonia Synthesis



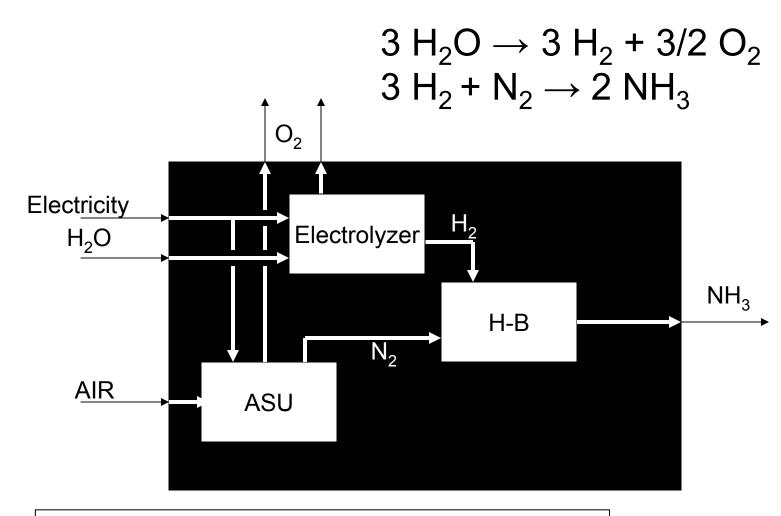
# Solid State Ammonia Synthesis (SSAS) NHThree LLC patent



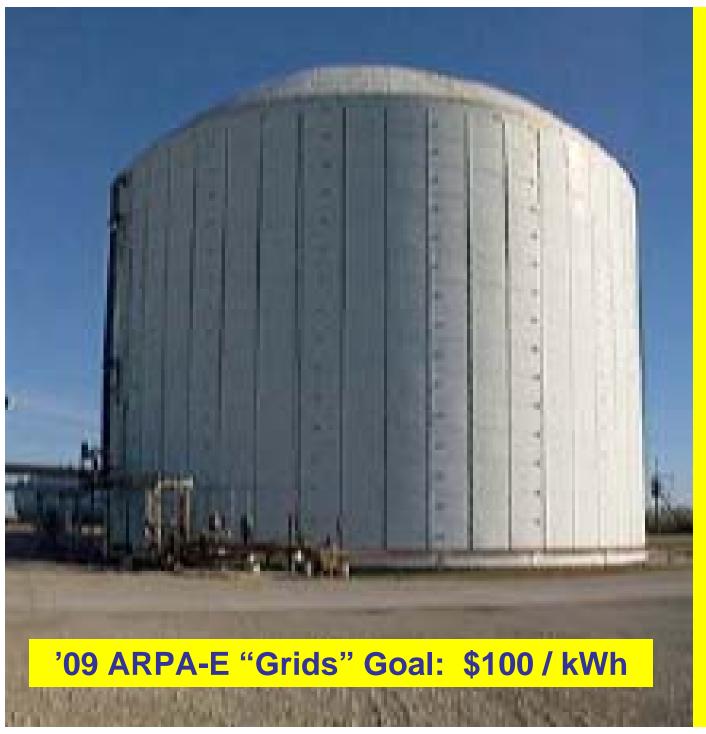
#### RE Ammonia Transmission + Storage Scenario



# Inside the Black Box: HB Plus Electrolysis



Energy consumption ~12,000 kWh per ton NH<sub>3</sub>



"Atmospheric"
Liquid
Ammonia
Storage Tank
(corn belt)

30,000 Tons 190 GWh

\$ 15M turnkey

\$ 80 / MWh

\$ 0.08 / kWh

-33 C

1 Atm

## Why SSAS?

- Electrolysis + Haber-Bosch too costly
  - From RE electricity
  - Capital components at low capacity factor (CF)
  - Energy conversion losses
- Proton conducting ceramics (PCC) now
- Solid oxide fuel cell (SOFC) success
- Need stranded RE transmission
- Need RE storage

#### 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

#### 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

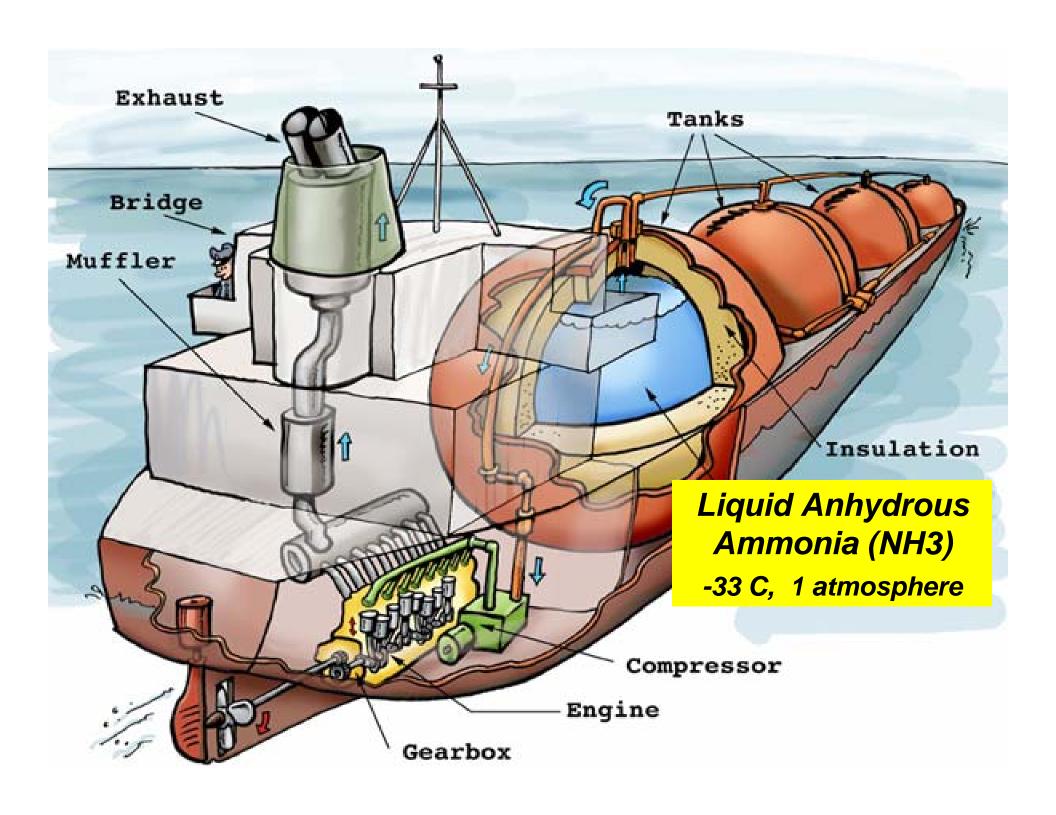
#### Next steps?

#### 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
- 5. Incubator, test sites, commercial rollout

Scales: Village → Susitna Hydro → Global export



#### **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

#### **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

## State of the Art; Competition

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

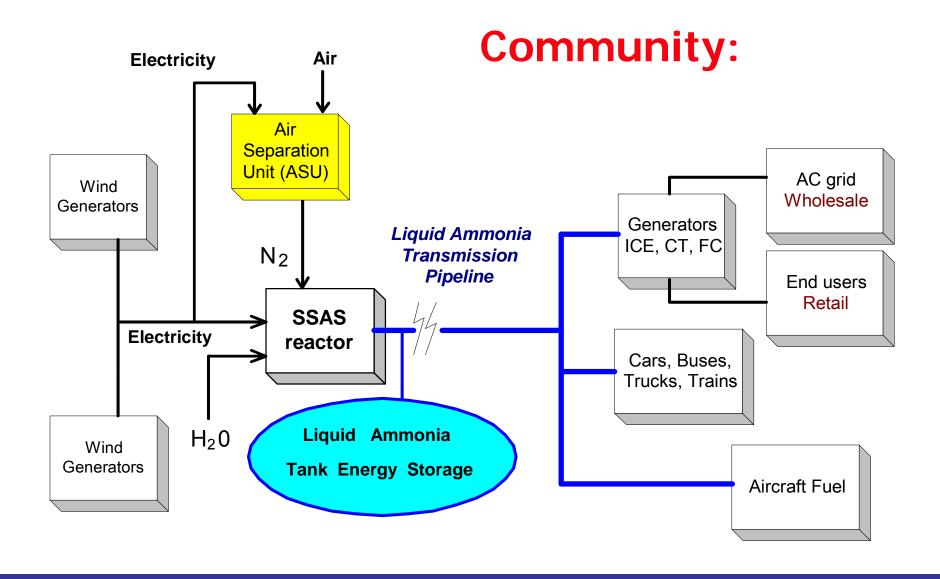
#### EHB vs SSAS prelim estimates

#### EHB:

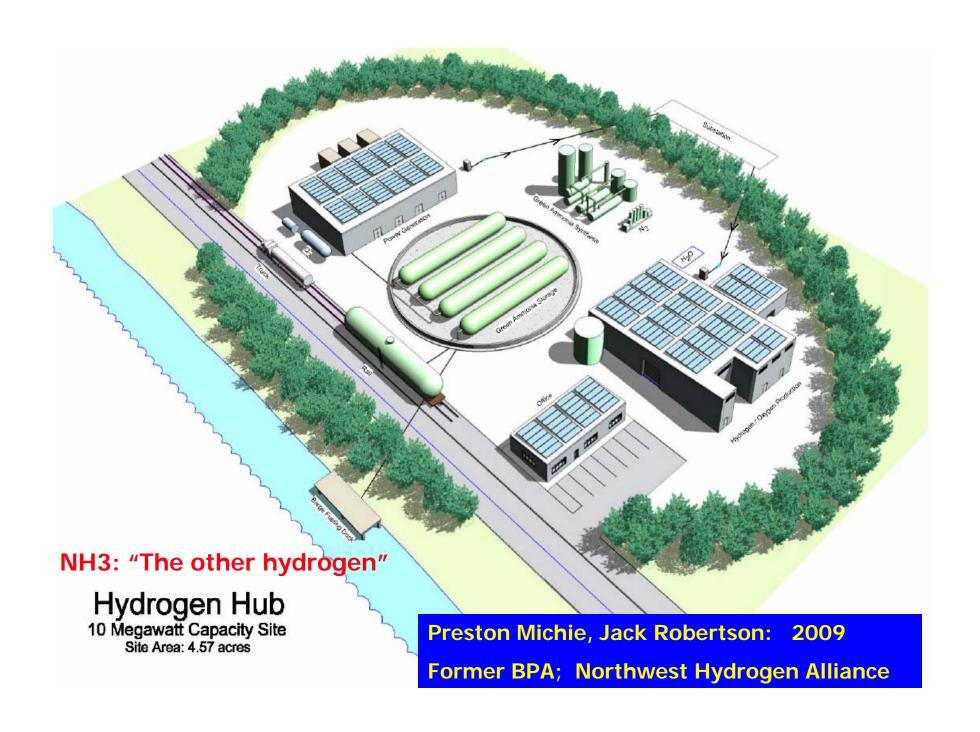
11-12 kWh / kg \$1,000 / kWe input capital cost

#### SSAS:

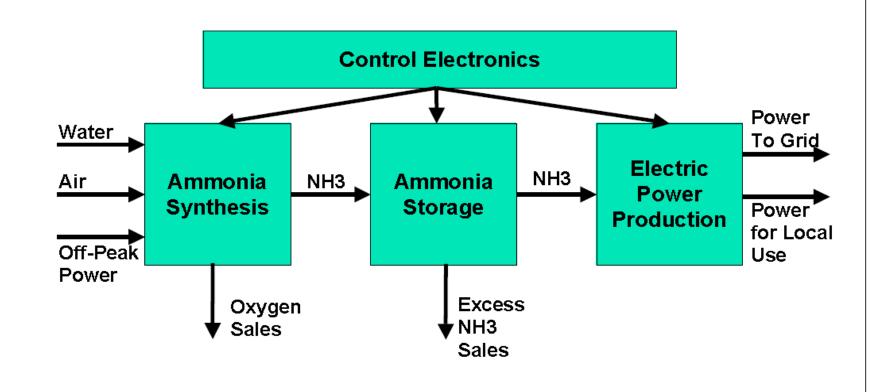
7-8 kWh / kg \$500 / kWe input capital cost \$200K / Mt / day capital cost



Solid State Ammonia Synthesis (SSAS)

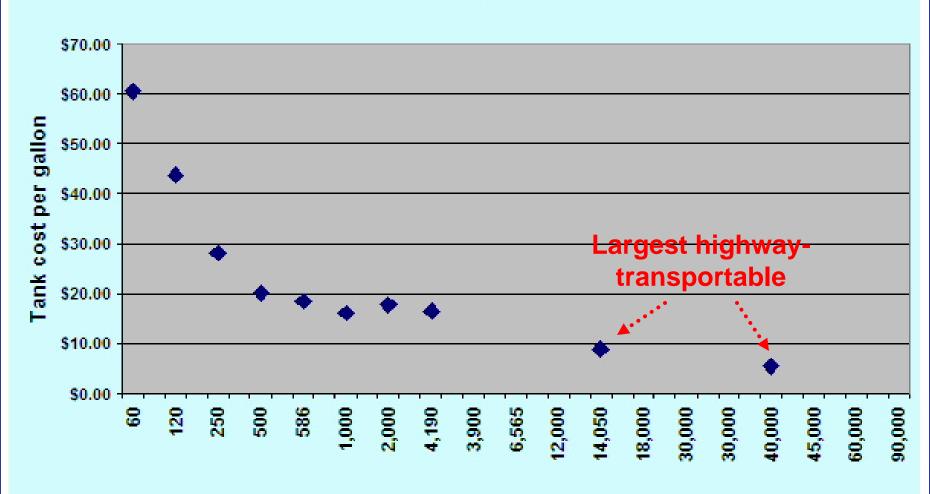


#### **Hydrogen Hub Concept**



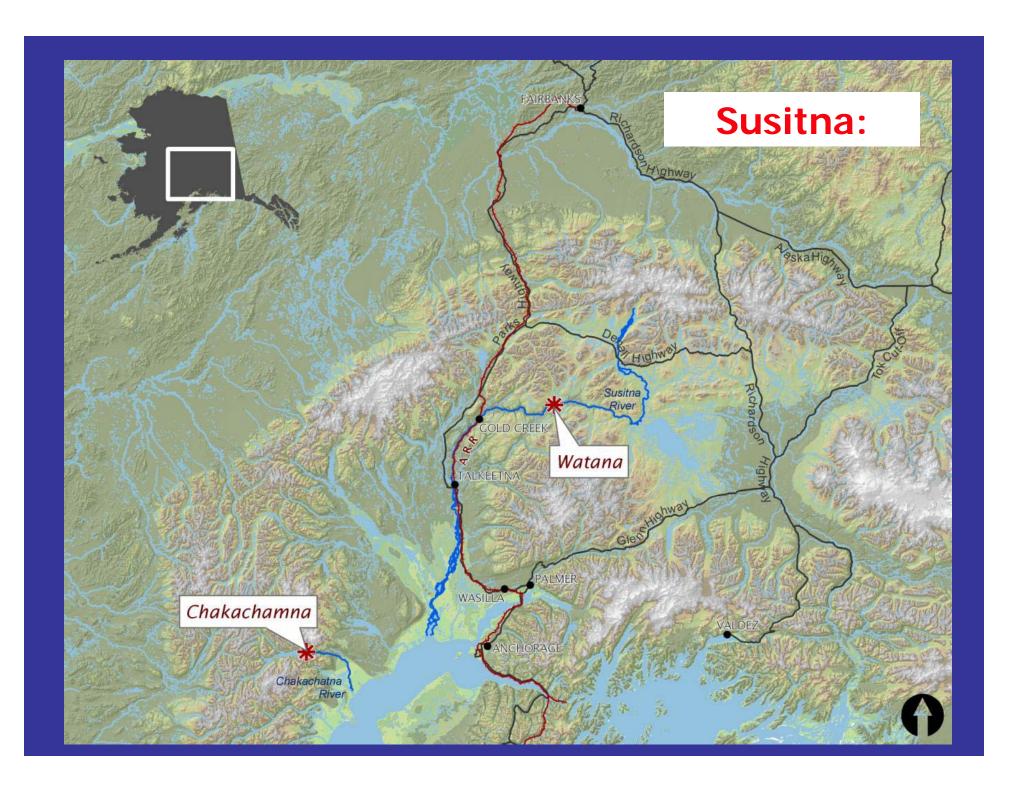
#### Liquid Ammonia Tank Storage

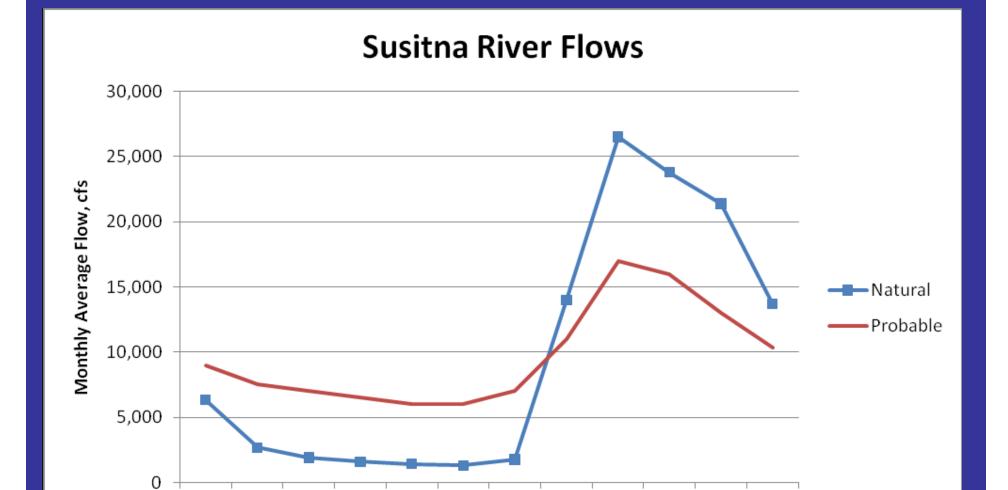




Tank capacity, gallons







Jul Aug Sep

Oct Nov Dec Jan Feb Mar Apr May Jun

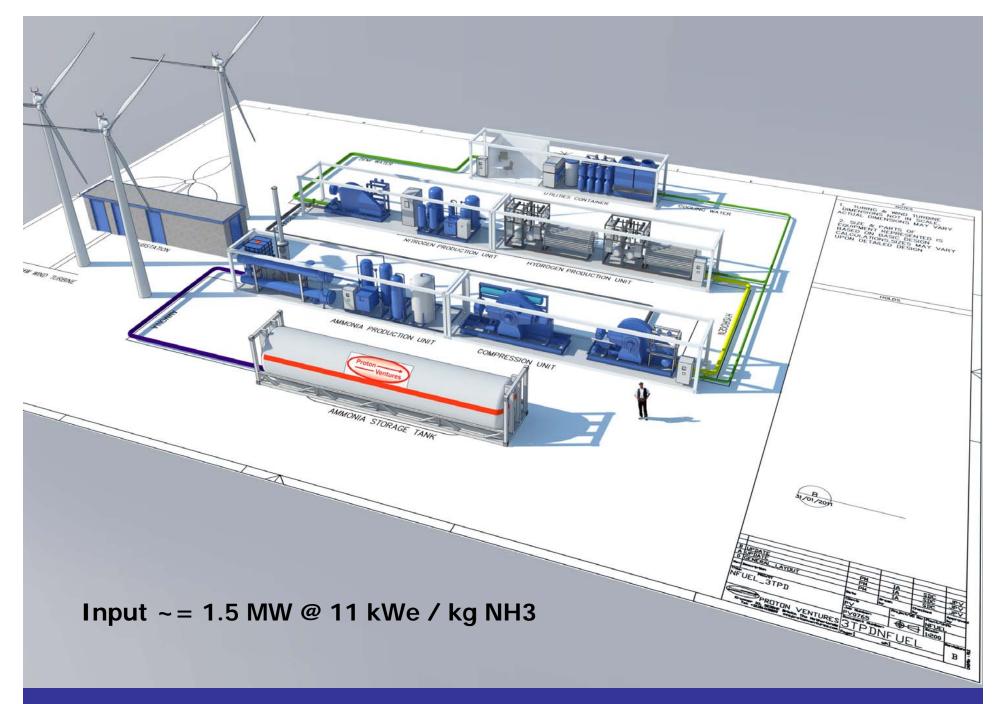
# Military: Land + sea fuel

- USCG, Navy ships
- Land vehicles: road, rail
- Recip engines modify: multifuel, Sturman
- Mini + micro app's



# State of the Art; Competition

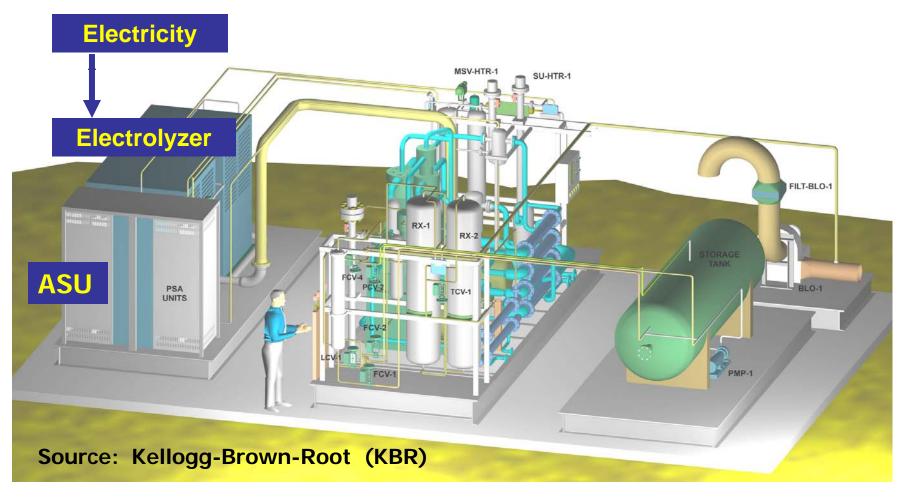
- Electrolysis + "Haber-Bosch" = EHB
  - Proton Ventures
  - Freedom Fertilizer
  - NH3 United, TX + Canada NH3
- Other "SSAS" suppliers
- Do not deploy novel, complex systems in Alaska villages: EHB too risky?



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



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



### 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

#### Markets: Supply, Demand, Price

- Supply Push
- Demand Pull
- Alaska incubator, rollout
- Price
  - Competition
  - Substitutes
  - Volume
  - Condition changes

