

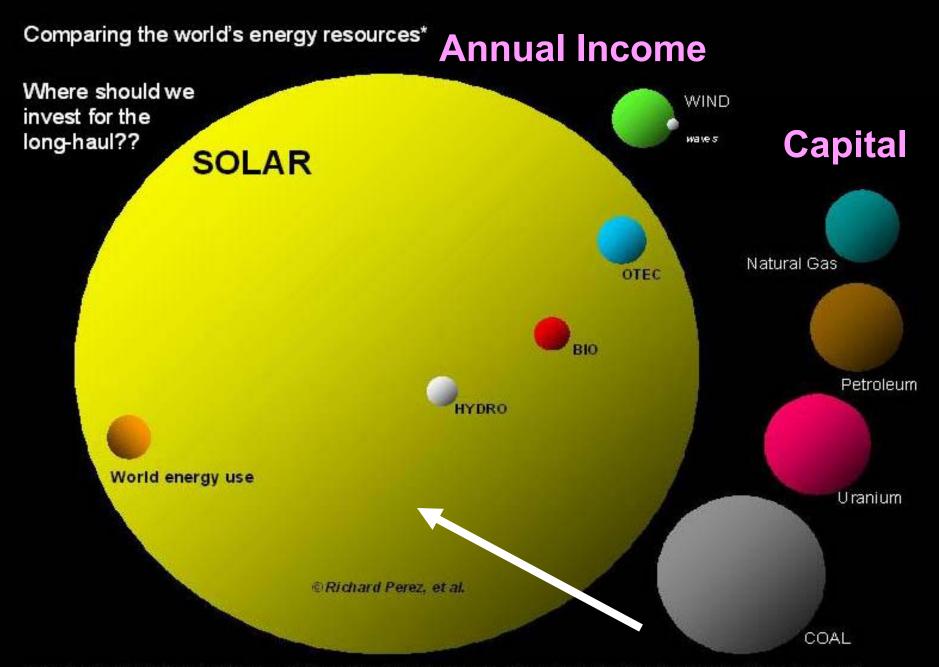
Humanity's Goal

A global, sustainable, benign, equitable, energy economy

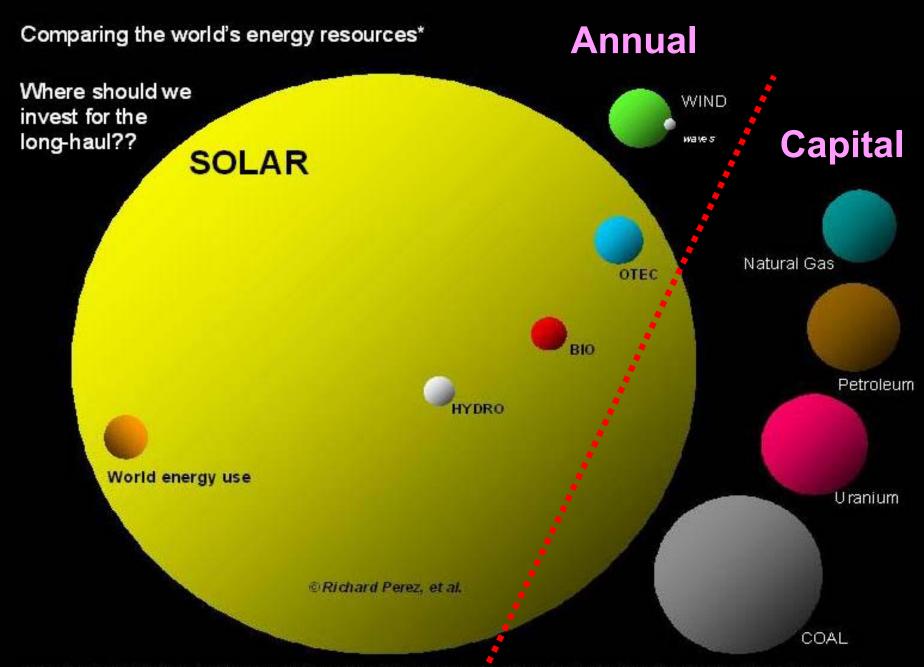
MUST Run the World on Renewables – plus Nuclear?

- Climate Change
- Demand growth
- Water for energy
- War
- Depletion of Oil and Gas
- Only 200 years of Coal left
- Only Source of Income:
 - Sunshine
 - Tides
 - Meteor dust
- Spend our capital ?





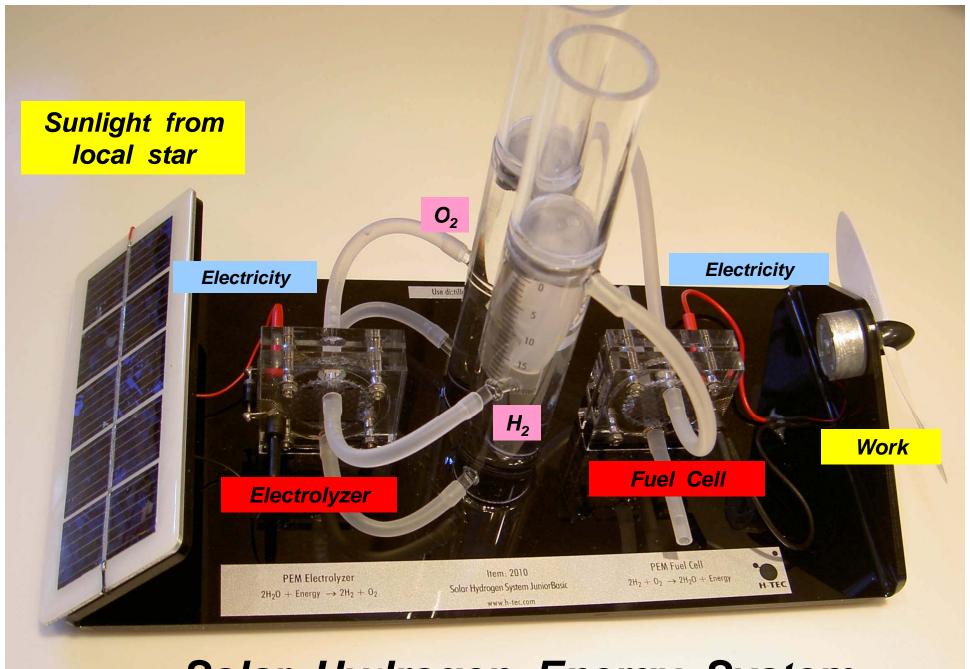
^{*}yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. Word energy use is annual.



*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.

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 renewable energy systems
 - ALL energy: Hermann Scheer



Solar Hydrogen Energy System

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
 - Pipelines
 - GH2 salt caverns
 - NH3 tanks

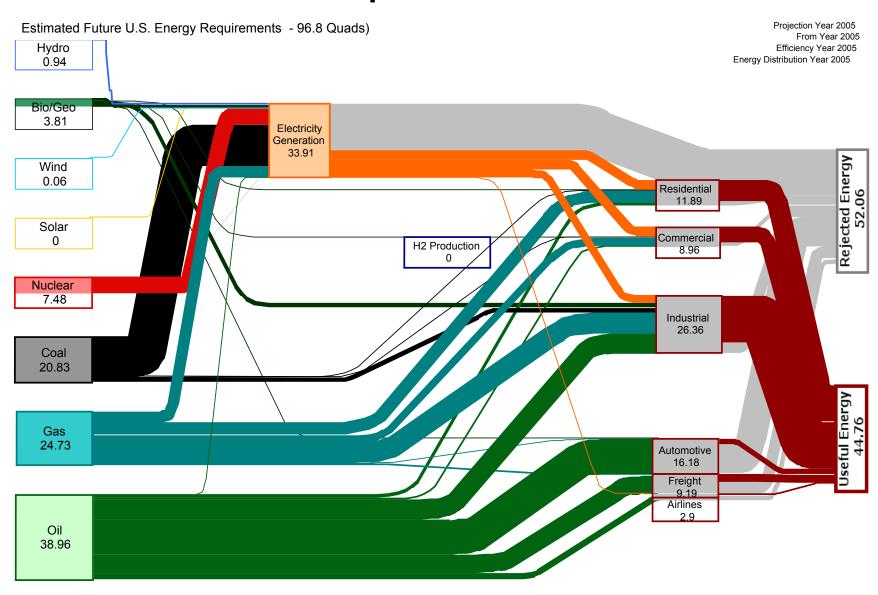
Hydrogen and Ammonia Fuels

- Delivering fuels: distribution
- ICE, CT, Fuel cell
- CHP on-site
- Utility substation wholesale
- Transportation
 - Rail
 - Truck
 - Personal
- Emissions: H₂O, N₂

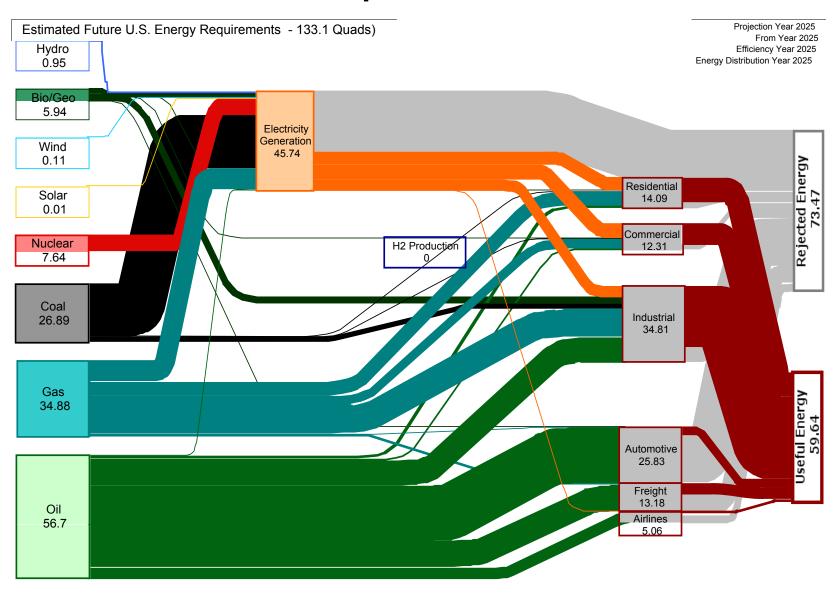
Annual Fresh Water for Energy

- USA today
- All energy = 100 Quads = 10^20 J
- 17,000 billion liters
 - "Withdrawn"
 - "Consumed"
 - Include all NG + oil "fracking" ?
- If all via GH2 + NH3 feedstock:
 - Dissociated, disintegrated: $H_2O \rightarrow H_2 + O_2$
 - 7,000 billion liters H2O
 - System efficiency vis-à-vis today's ?

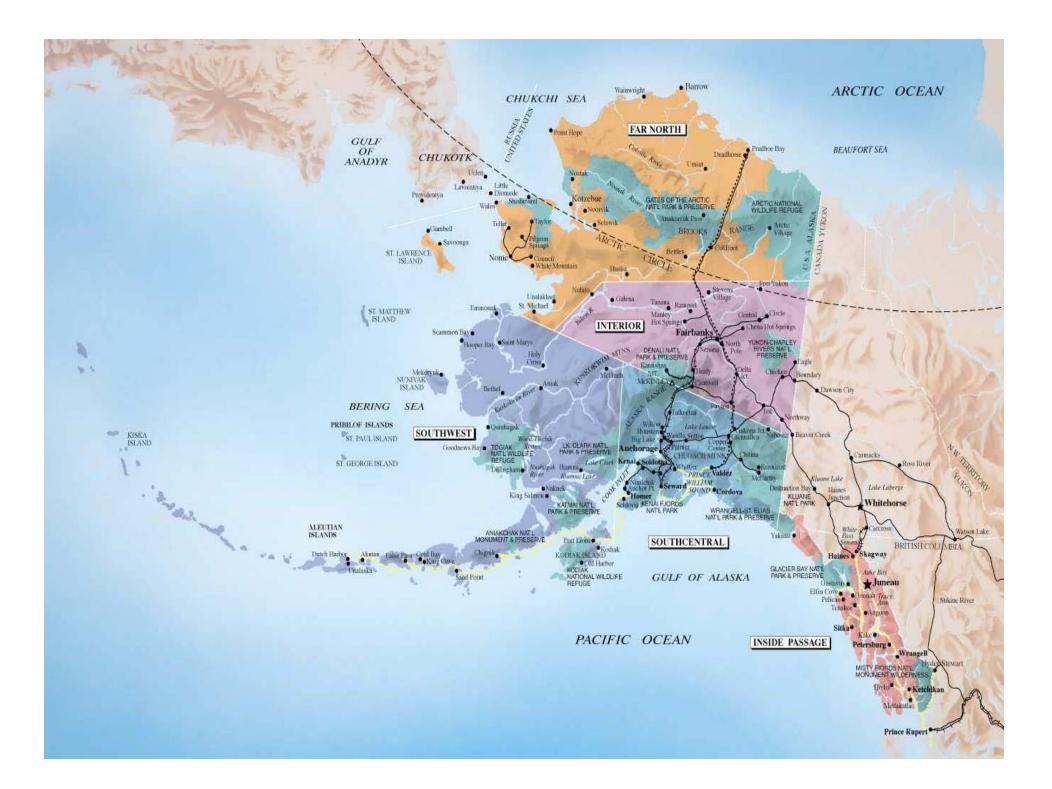
DOE-EIA: 2005 estimated US annual energy: ~ 100 quads = 100 TWh



EIA estimated 2025 annual energy: ~ 130 quads = 130 TWh







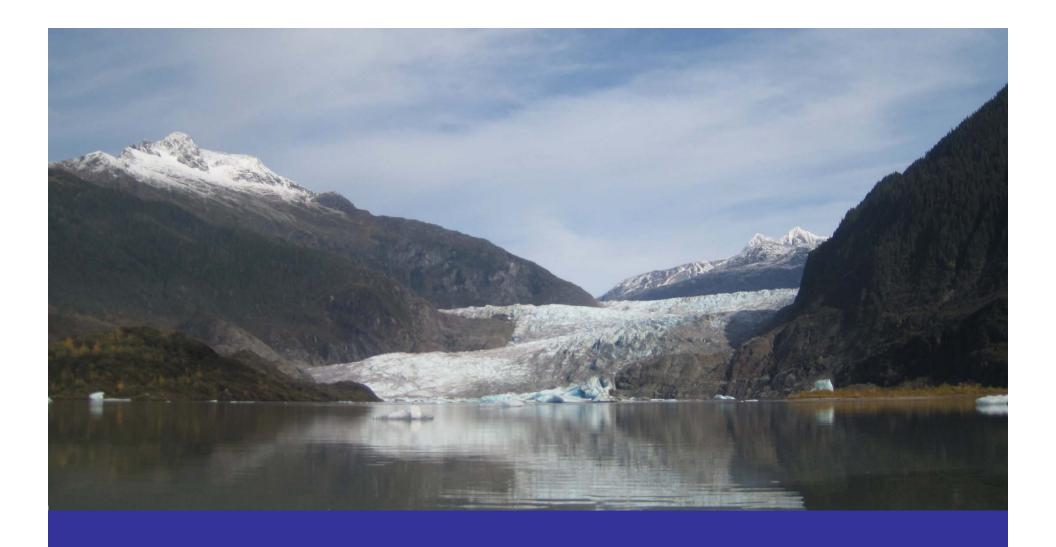


Mendenhall Glacier, Juneau, AK

June '71



Mendenhall Glacier, Juneau, AK 10 October 10



Mendenhall Glacier, Juneau, AK 10 October 10

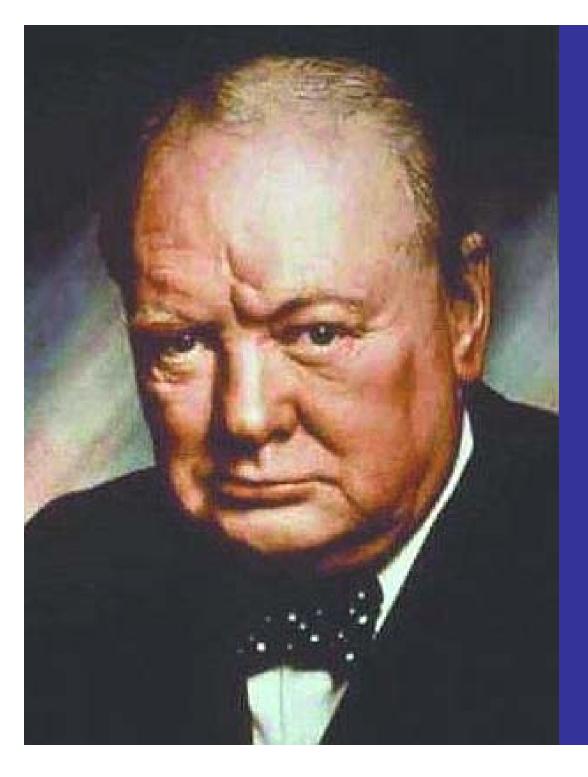
Rapid climate change



Spruce bark beetle kill, Alaska



Shishmaref, Alaska Winter storms coastal erosion



"Americans can be counted on to always do the right thing –

but only after they have tried everything else "

Winston Churchill

The dog caught the car.

Dan Reicher

Trouble with Renewables

- Diffuse, dispersed: gathering cost
- Richest are remote: "stranded"
 - High intensity
 - Large geographic extent
- Time-varying output:
 - "Intermittent"
 - "Firming" integration + storage required
- Distributed AND centralized

Trouble with Renewables: Big Three

- 1. Transmission and gathering
- 2. Storage: Annual-scale firming
- 3. Integration
 - Extant energy systems
 - Electricity grid
 - Fuels: CHP, transportation

Trouble with Renewables: Electricity Transmission

- Grid nearly full: who pays?
- Integration
 - Continental energy system
 - Quality
 - Time-varying
- Costly "firming" storage: CAES, VRB, pump hydro
- Low capacity factor (CF) or curtailment
- Overhead vulnerable: God or man
- Underground: only HVDC, 6x cost
- FERC no interstate jurisdiction
- Wide ROW
- NIMBY: delay + cost, site + ROW



"Transmission"

- Electrofuels
- Renewable-source electricity
- Underground pipelines
- Carbon-free fuels: hydrogen, ammonia
- Low-cost storage:
 - \$ 0.10 0.20 / kWh capital
- CHP, transport, industrial
- GW scale

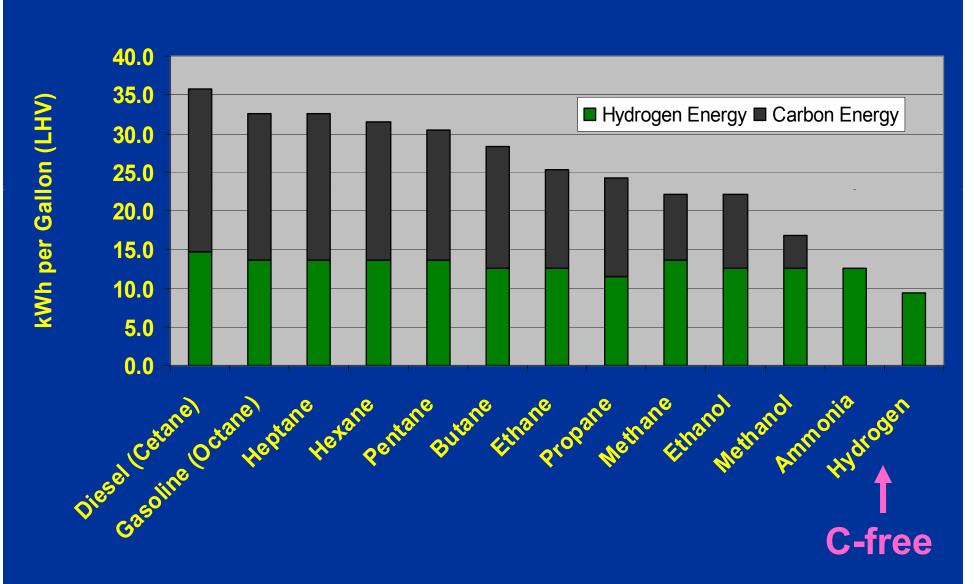
Hydrogen and Ammonia Fuels

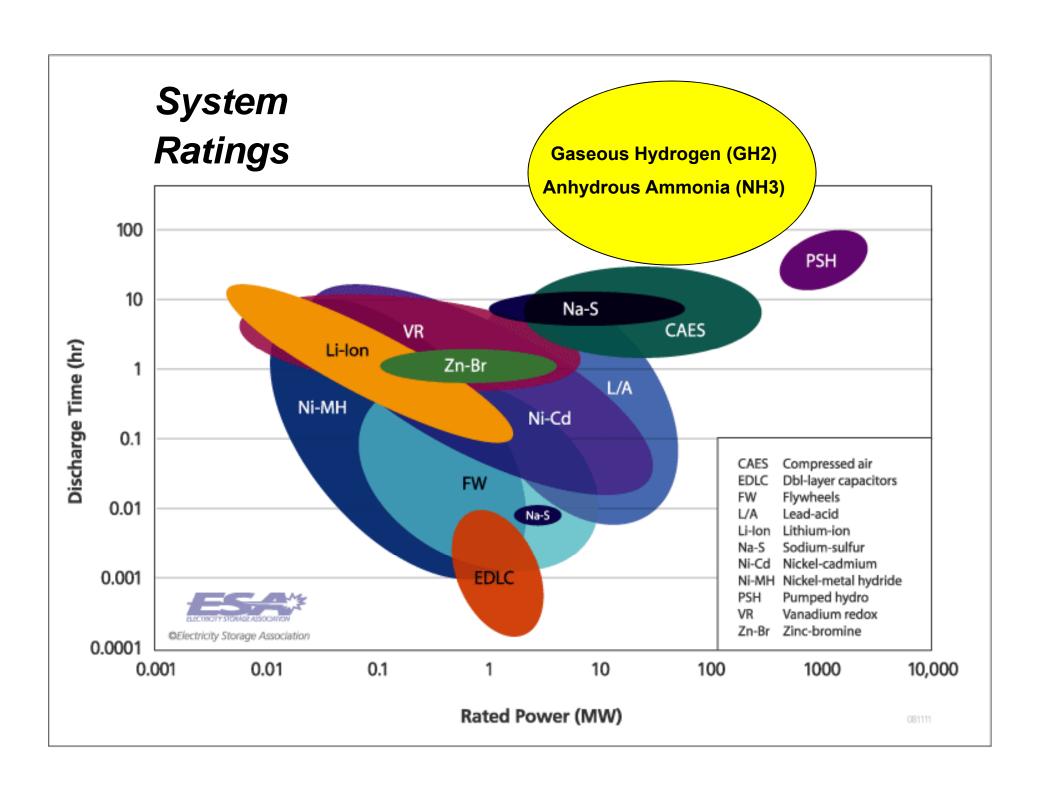
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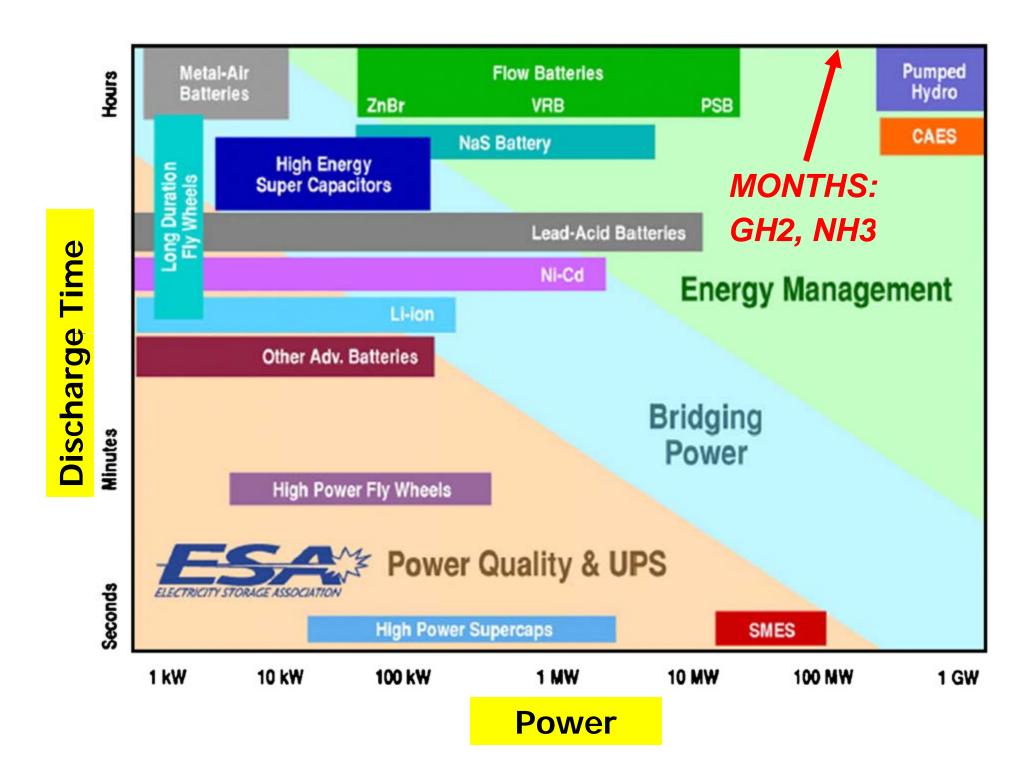
Hydrogen and Ammonia Fuels

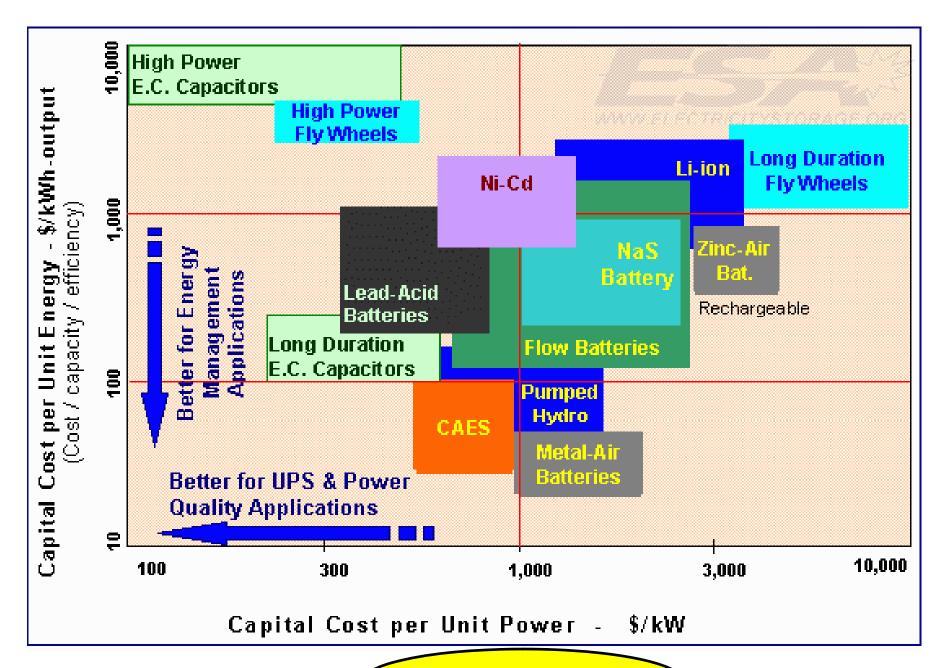
- Delivering fuels: distribution
- ICE, CT, Fuel cell
- CHP on-site
- Utility substation wholesale
- Transportation
 - Rail
 - Truck
 - Personal
- Emissions: H₂O, N₂

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

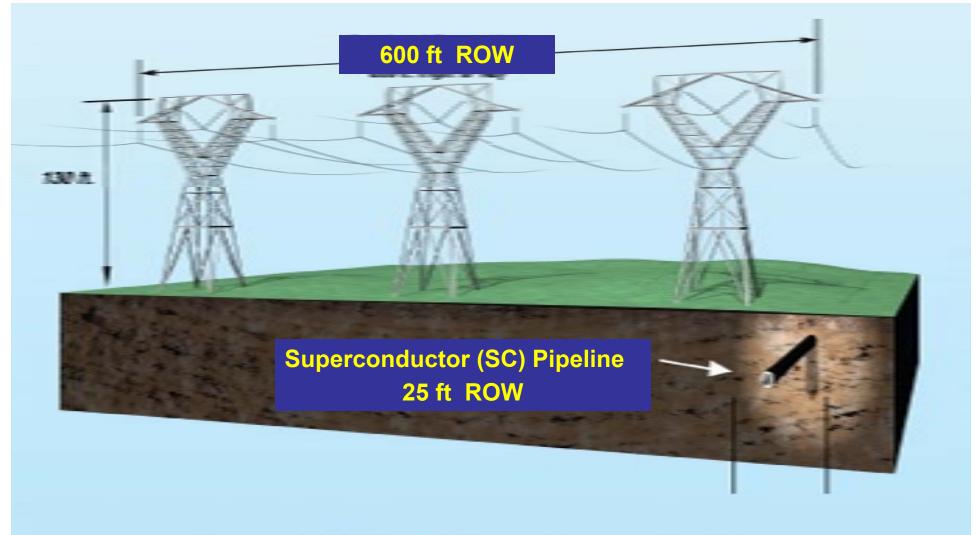








GH2 and NH3



Out of Sight, Out of Harm's Way

10,000 MW alternatives: HVAC vs HVDC superconductor



Exporting From 12 Windiest Great Plains States

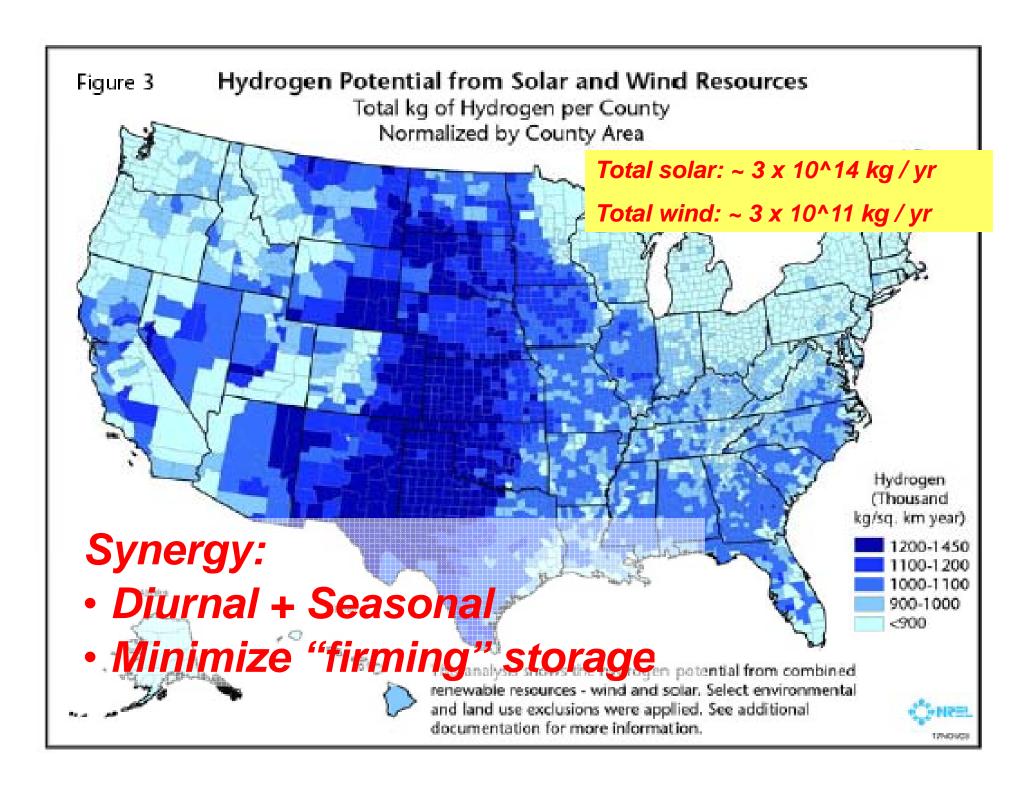
Number of GH2 pipelines or HVDC electric lines necessary to export total wind resource

Capacity at 500 miles length

Capacity Factor (CF) = 30%

						3 GW	
	Annual	Nameplate	Nameplate	6 GW	\$ Billion	500 KV	\$ Billion
	Energy	Installed	Installed	36" GH2	Total	HVDC	Total
	Production	Capacity	Capacity	Hydrogen	Capital	Electric	Capital
State	(TWh)	(MW)	(GW)	Pipelines	Cost	Lines	Cost
Texas	6,528	1,901,530	1,902	317		634	
Kansas	3,647	952,371	952	159		317	
Nebraska	3,540	917,999	918	153		306	
South Dakota	3,412	882,412	882	147		294	
Montana	3,229	944,004	944	157		315	
North Dakota	2,984	770,196	770	128		257	
Iowa	2,026	570,714	571	95		190	
Wyoming	1,944	552,073	552	92		184	
Oklahoma	1,789	516,822	517	86		172	
Minnesota	1,679	489,271	489	82		163	
New Mexico	1,645	492,083	492	82		164	
Colorado	1,288	387,220	387	65		129	
TOTALS	33,711	9,376,694	9,377	1,563	\$1,500	3,126	\$2,000

Wind energy source: Archer, Jacobson 2003



Major Electricity Transmission Studies

•	EWITS-NREL	225 - 330	GW
•	WWSIS-NREL	30	GW
•	Brattle Group	24	GW
•	SEIA-AWEA	300	GW
•	JCSP	745	GW
•	AEP-AWEA	350	GW
•	Frontier + Transwest	115	GW
•	ICFI Wyoming	12	GW

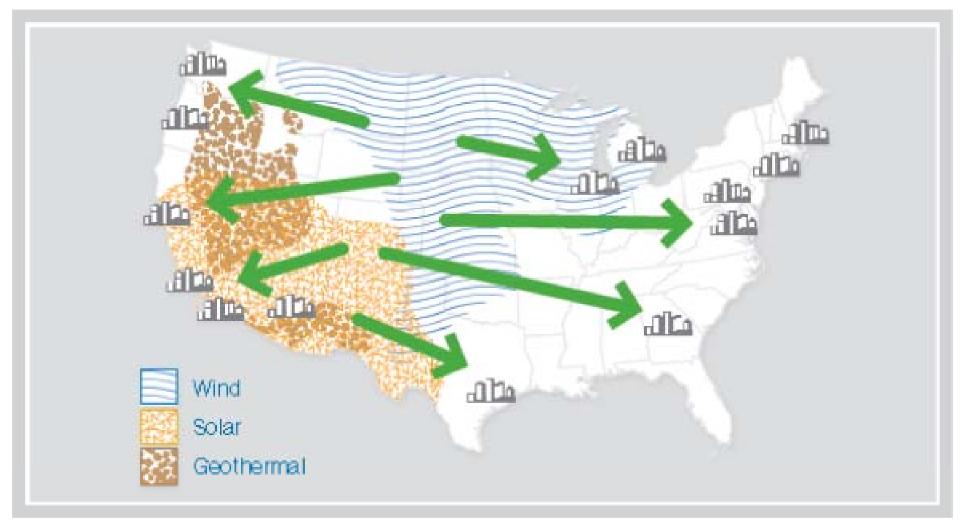
Total ~ 1,000 GW

Great Plains Potential: 3,000 GW wind, nameplate

3,000,000 GW solar, nameplate

Total USA energy @ 33% CF: ~ 3,460 GW

@ 5 GW / 765 kv AC or HVDC line: ~ 700 new lines

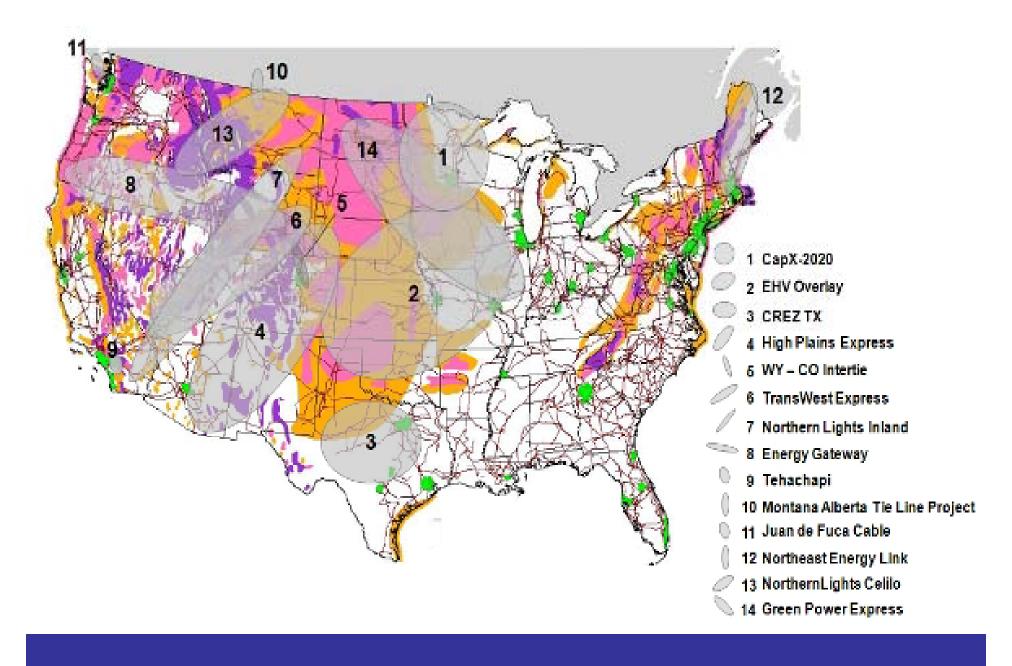


Source: AWEA and SEIA.

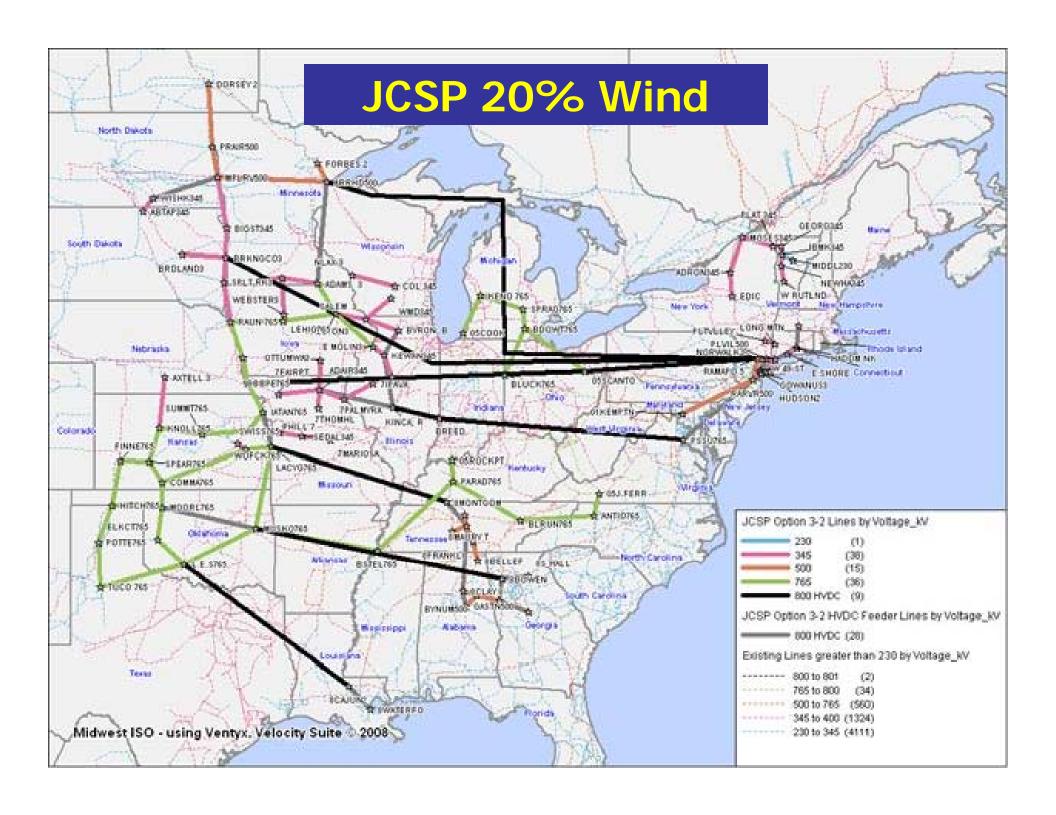
SEIA – AWEA Feb 09

"Green Power Superhighways:

Building a Path to America's Clean Energy Future"



Emerging Energy Research LLC



Mega Project Scenario Legend: **WWSIS** Final Wind MW (Change from In-Area MW) New Transmission MW (GW-miles) 13770 (+11430)+3200 (1600) 2 x 500kV 3600 (2400 Myy) 1000 (300) x 345kV N. 1440 -3150(-5610)(-810)Total Wind MW: 24040 (801 sites) [\$48.1B] +5000 (900) Change from in-area MW: 2 x 345kV -5940 (-197 sites) (-\$11.88) Total Solar MW: 5700 MW (-100 MW) [-\$0.4 B] 1890 4350 (-9330)Total Additional Transmission: (+1560) + 6900 GW-miles [+\$11 B] **Total Change in Capital Cost:**

- \$1.2B

Frontier Line

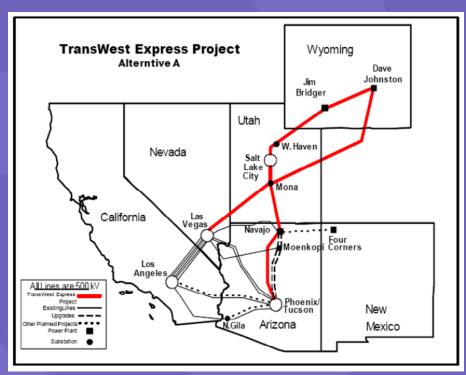


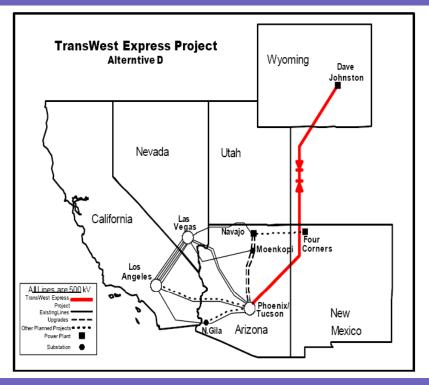
Example pathway by California Energy Commission, *Wyoming-California Corridor Transmission Expansion Study*, Global Energy Decisions, June 2006, CEC-700-2006-008.

- Proposed transmission corridor to interconnect Wyoming, Utah, Nevada, California and possibly other states
- MOU signed on April 4, 2005

TransWest Express

Several alternatives proposed, including:





Statement of Robert Smith on behalf of Arizona Public Service Company and the TransWest Express Project before the House Subcommittee on Water and Power and the House Subcommittee on Forests and Forest Health, June 27, 2006.

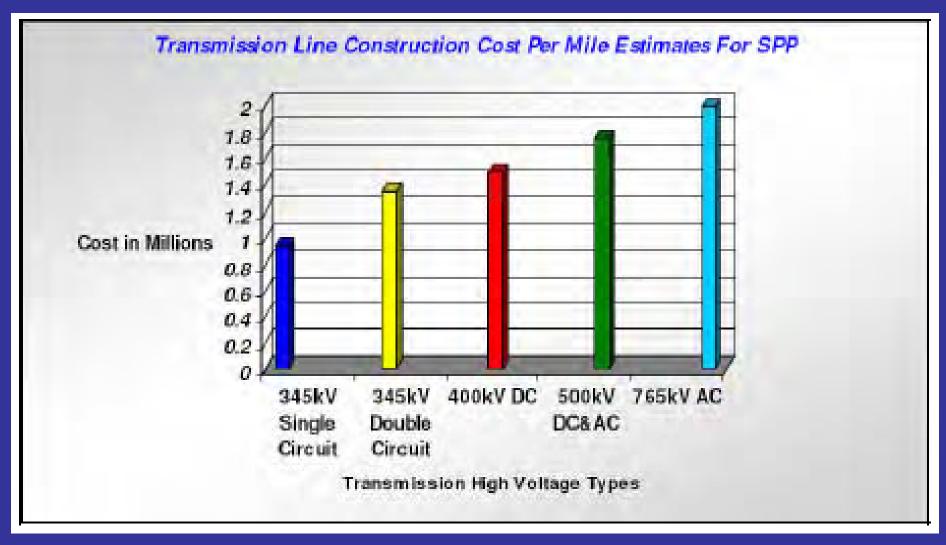


(Sources: Edison Foundation¹², AEP¹³)

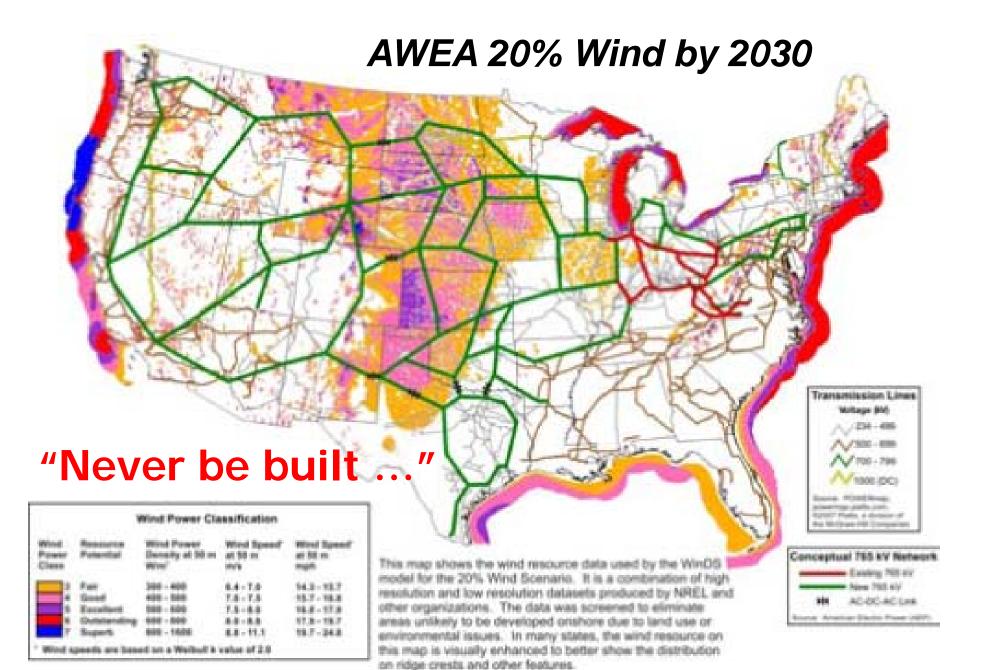
SEIA – AWEA Feb 09

"Green Power Superhighways:

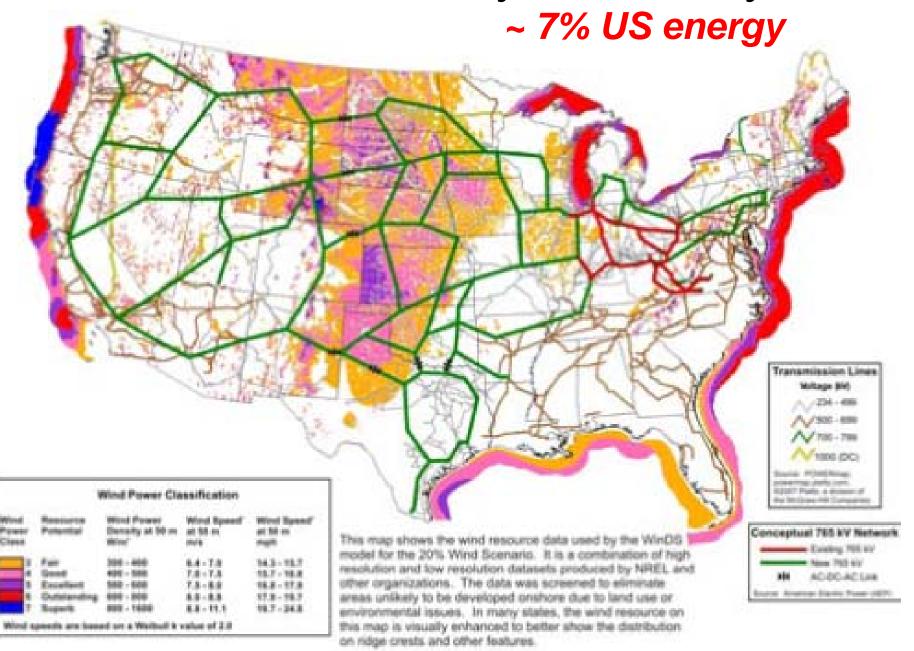
Building a Path to America's Clean Energy Future"



Transmission Line Construction Cost
\$ million per Mile
Southwest Power Pool '07

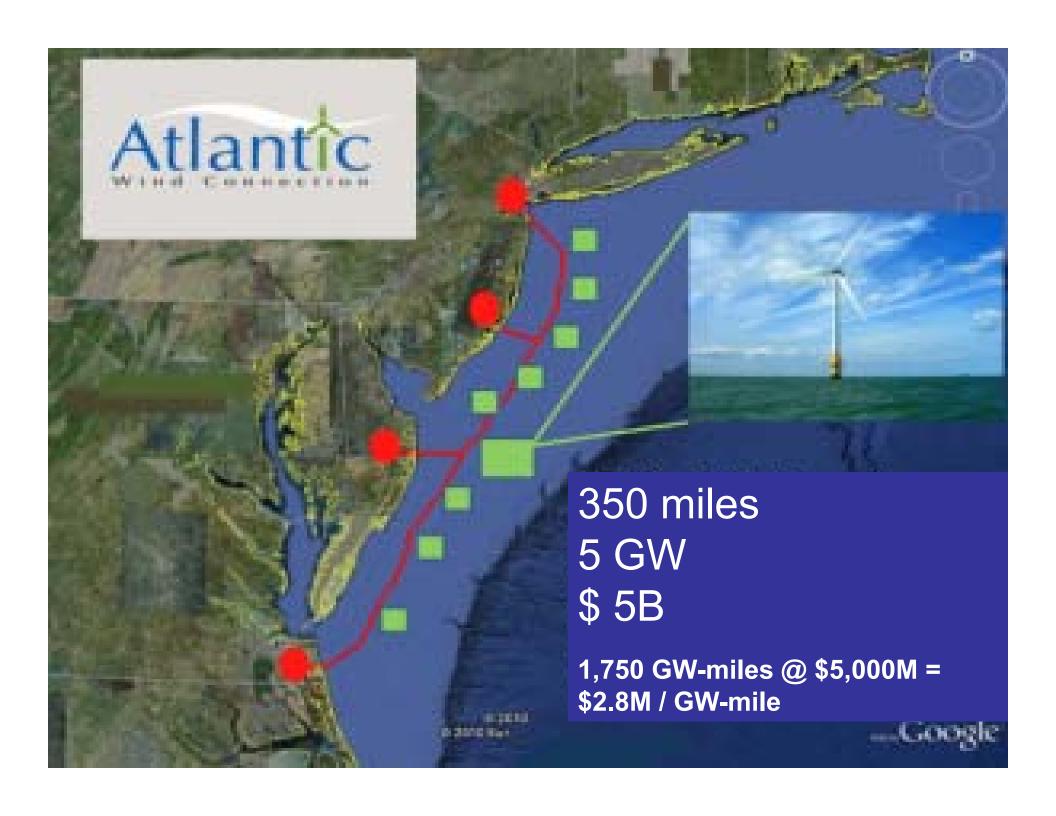


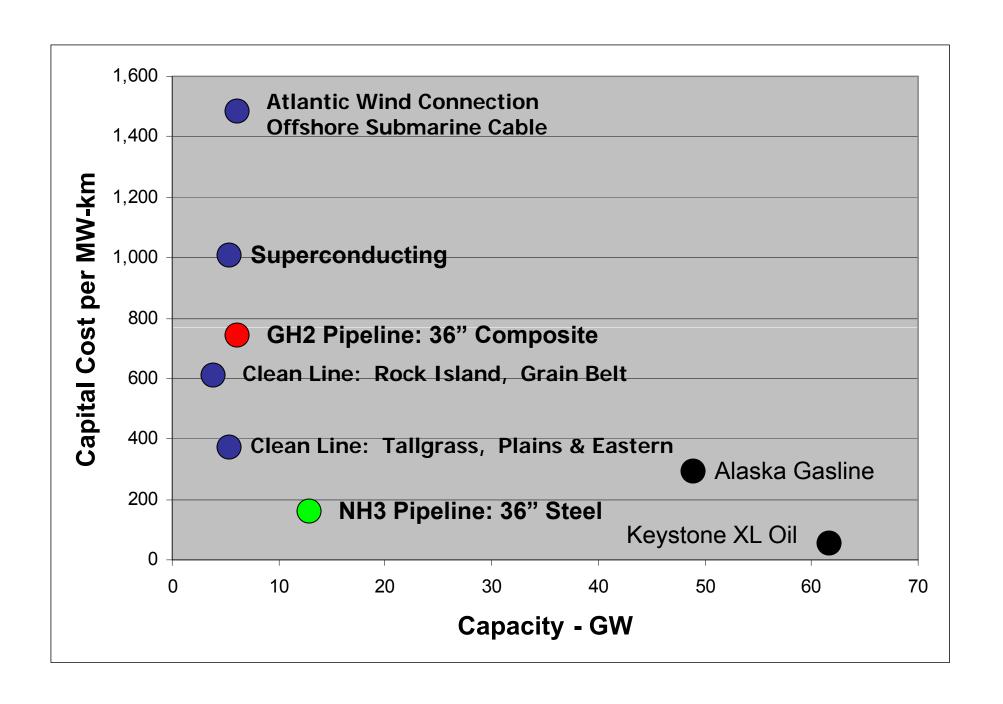
AWEA: 20% Electricity from Wind by 2030



Electricity Capital Cost per GW-mile

		KV	Capacity 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



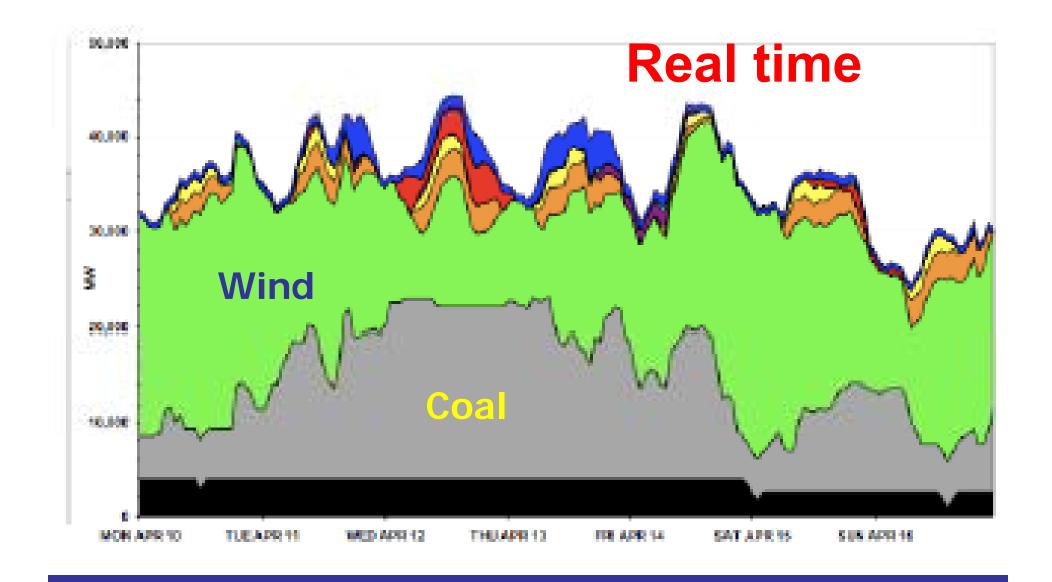


"Firm" Energy Essential

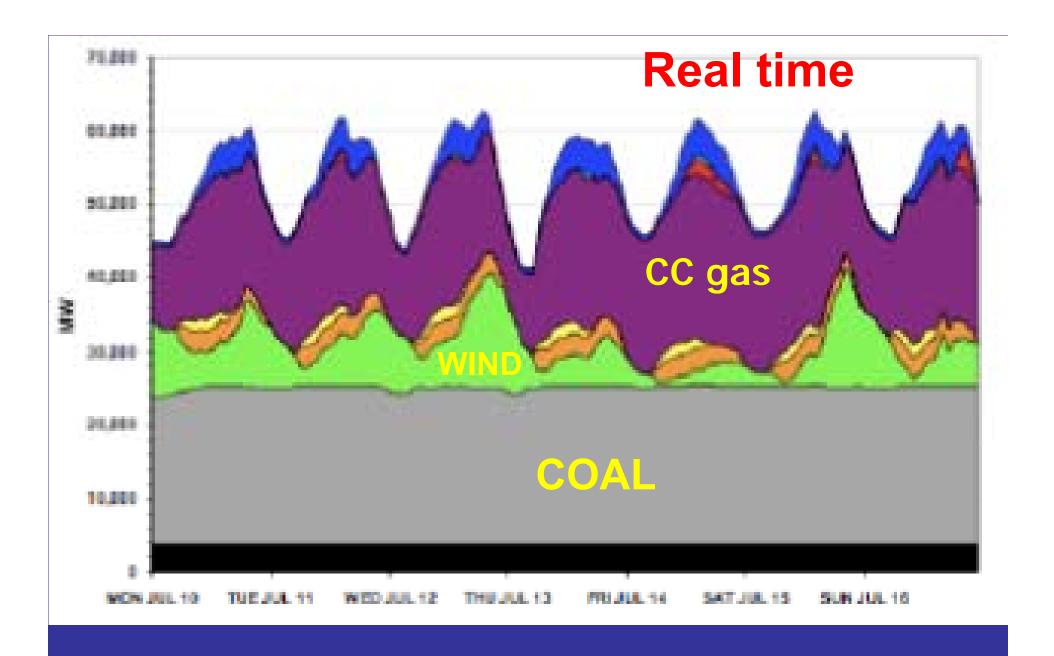
- Every hour, every year
- Dispatchable
- Strategically: indigenous, secure
- Market price: worth more
- Bankable large projects
- Risk avoidance:
 - -Rapid climate change
 - -Economic chaos

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
 - 0&M
- 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



WWSIS: April week: ~30% RE



WWSIS: July week: ~10% RE

Wind seasonality, Great Plains

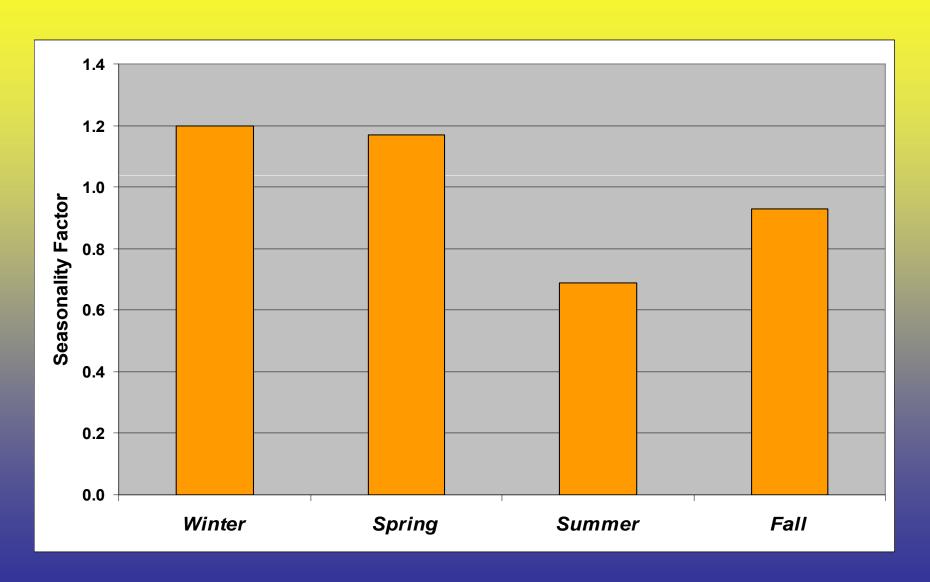
Normalized to 1.0

 Winter 	1.20
 Spring 	1.17
 Summer 	0.69
 Autumn 	0.93

Source: D. Elliott, et al, NREL

Wind Seasonality, Northern Great Plains

Normalized to 1.0 per season

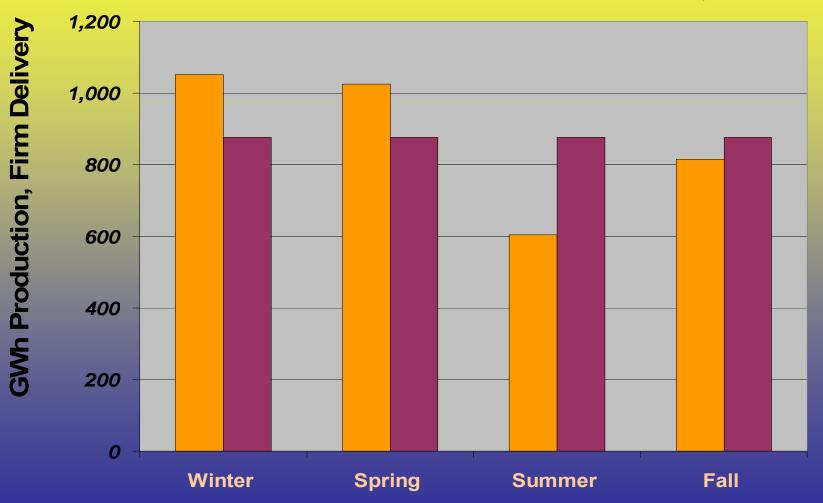


Wind Seasonality, Northern Great Plains

1,000 MW windplant: AEP = 3,500 GWh/yr

"Firm" goal = 875 GWh / season Storage: 320 GWh per 1,000 MW wind

Source: NREL, D. Elliott



320 GWh

Annual firming, 1,000 MW wind

- CAES (compressed air energy storage)
 - O&M: \$46 / MWh typical
 - Iowa: Power = 268 MW

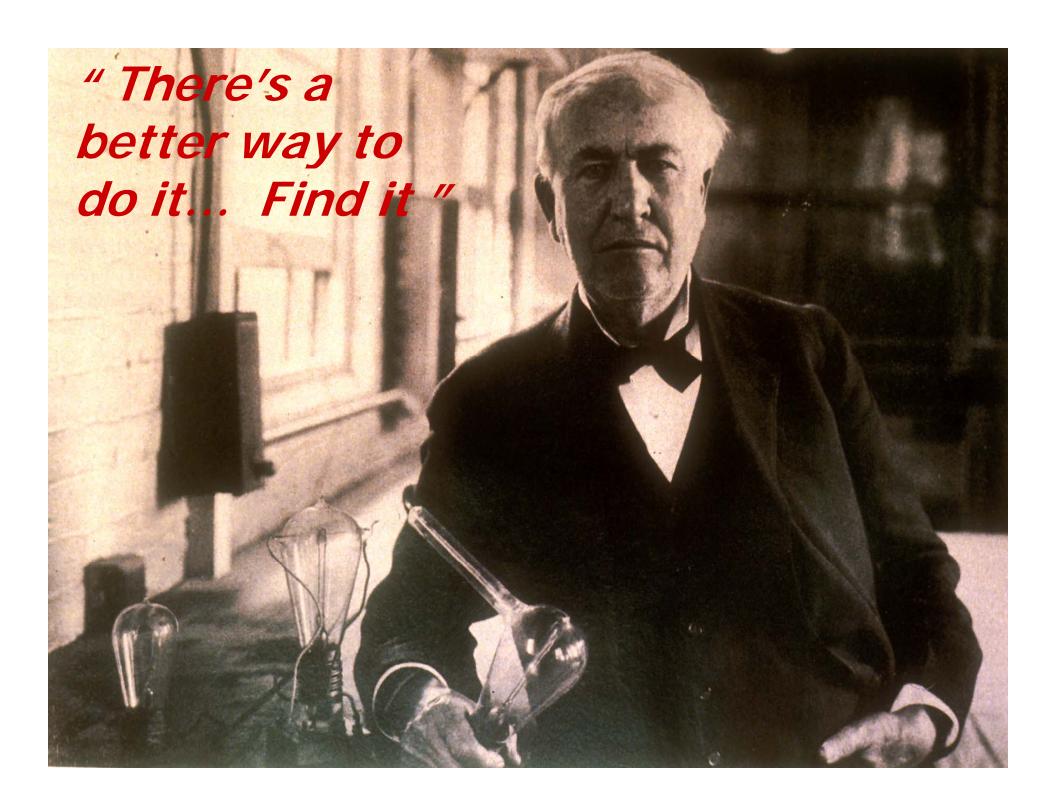
Energy capacity = 5,360 MWh

Capital: 268 MW @\$800 / kW = \$214 M

Storage @ \$40 / kWh = \$13 Billion

Storage @ \$1 / kWh = \$325 Million

- VRB flow battery
 - O&M: 80% efficiency round-trip
 - Capital: \$500 / kWh = \$160 Billion

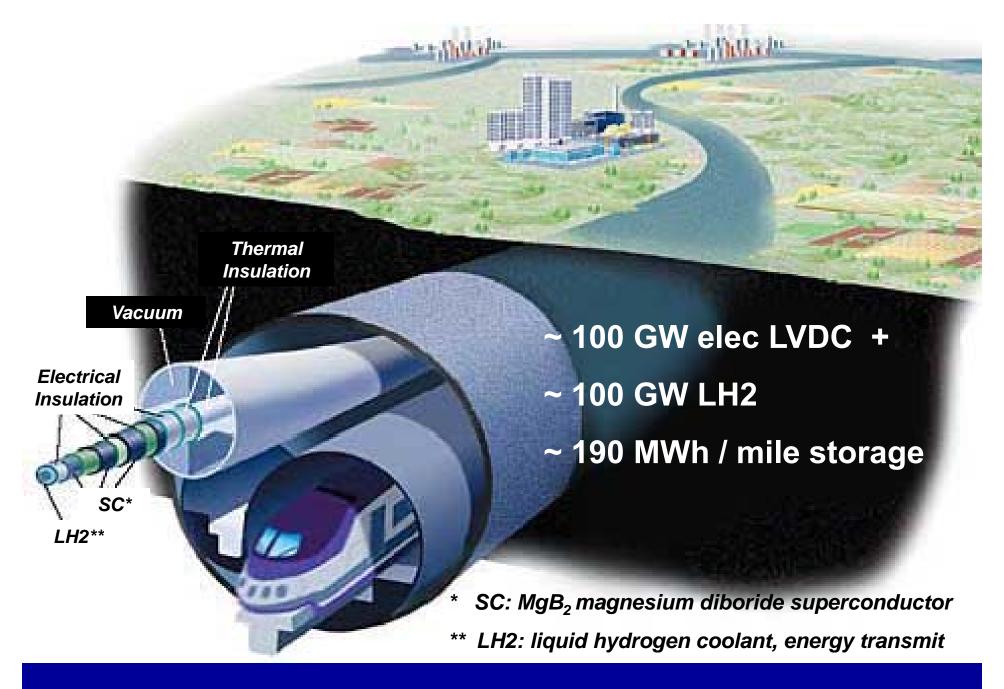


Why Hydrogen, Ammonia?

- Transmission via underground pipeline
 - Easier to site, permit
 - Lower NIMBY
 - Protected: acts of God and man
 - FERC interstate jurisdiction
 - High capacity: 5 10 GW
 - Lower capital cost / GW mile
- Affordable storage:
 - Annual-scale firming
 - Dispatchable fuel supply
- Zero-carbon fuels: RE
- Nascent markets: transport fuel, other
- Integration
 - Continental energy system
 - Elec grid quality
 - Elec grid generation O+M: fatigue, wear, efficiency

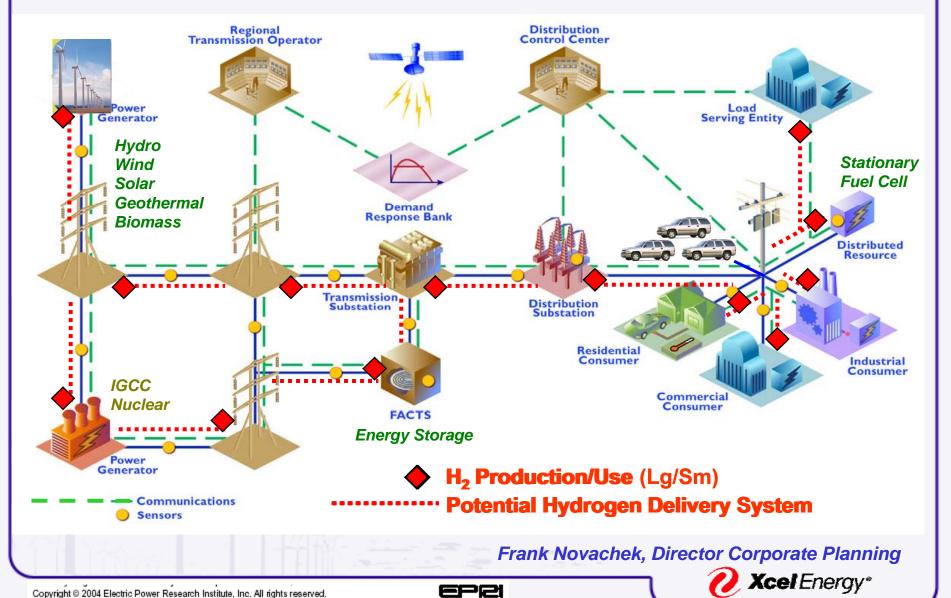
Annual Fresh Water for Energy

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



Continental Supergrid – EPRI concept "Energy Pipeline"

Energy System of the Future



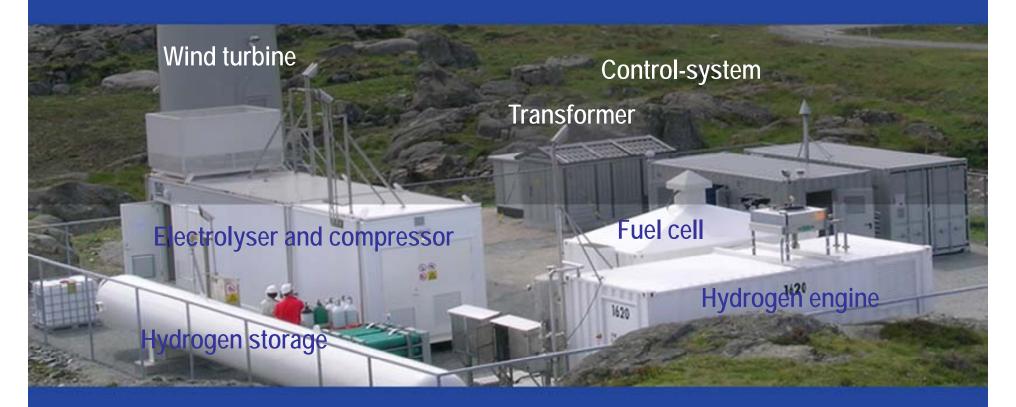
Utsira Island, Norway



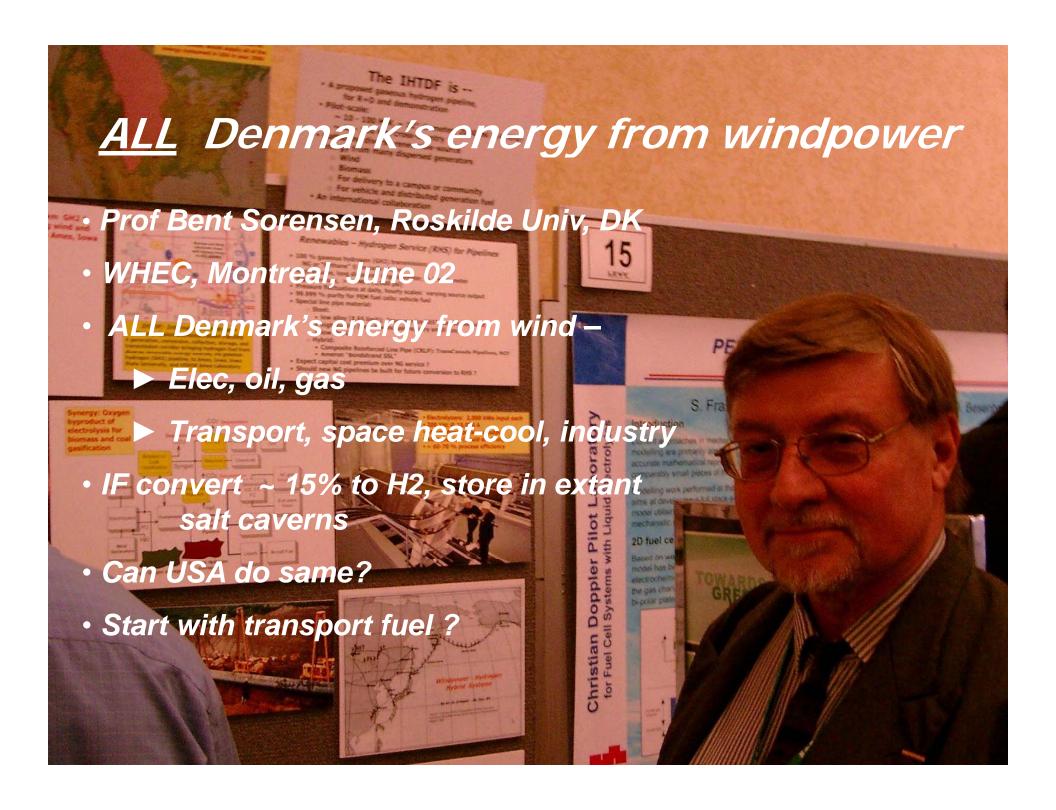


The wind - hydrogen plant at Utsira

A vision becoming reality

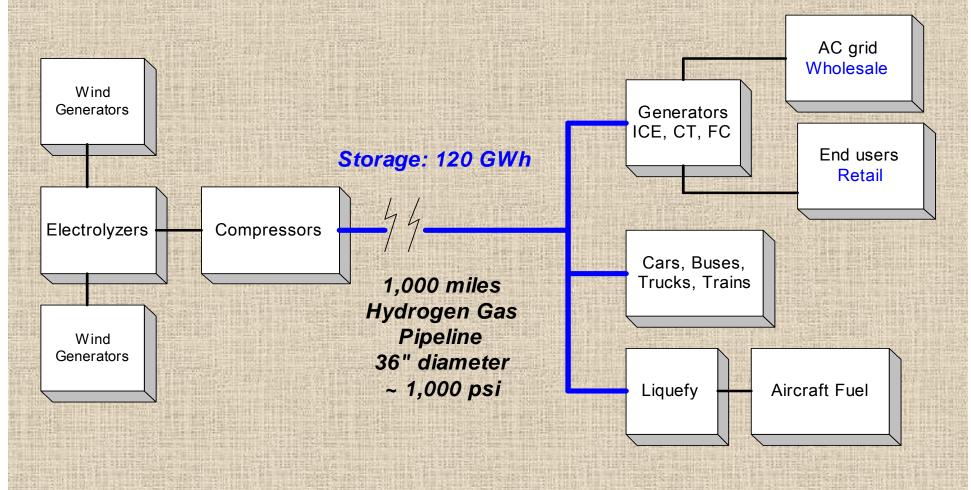




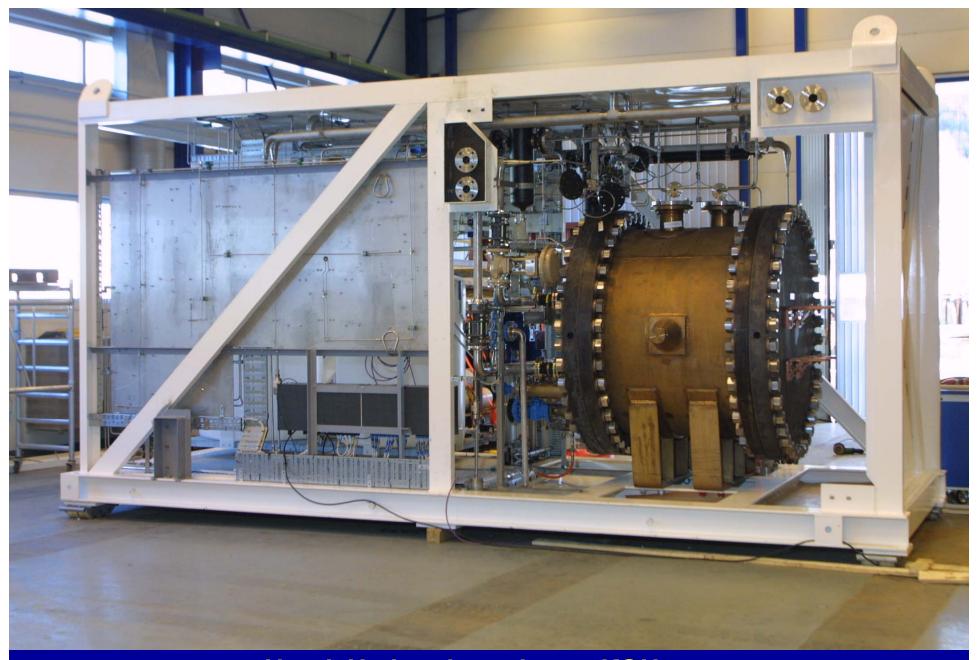


Hydrogen Transmission Scenario

- Low-pressure electrolyzers
- · "Pack" pipeline: ~ 120 GWh

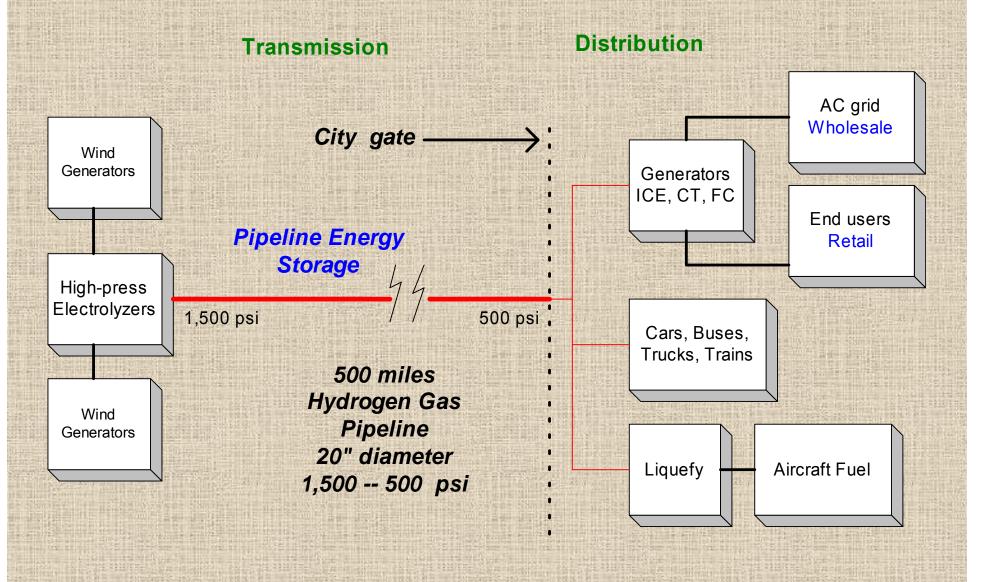


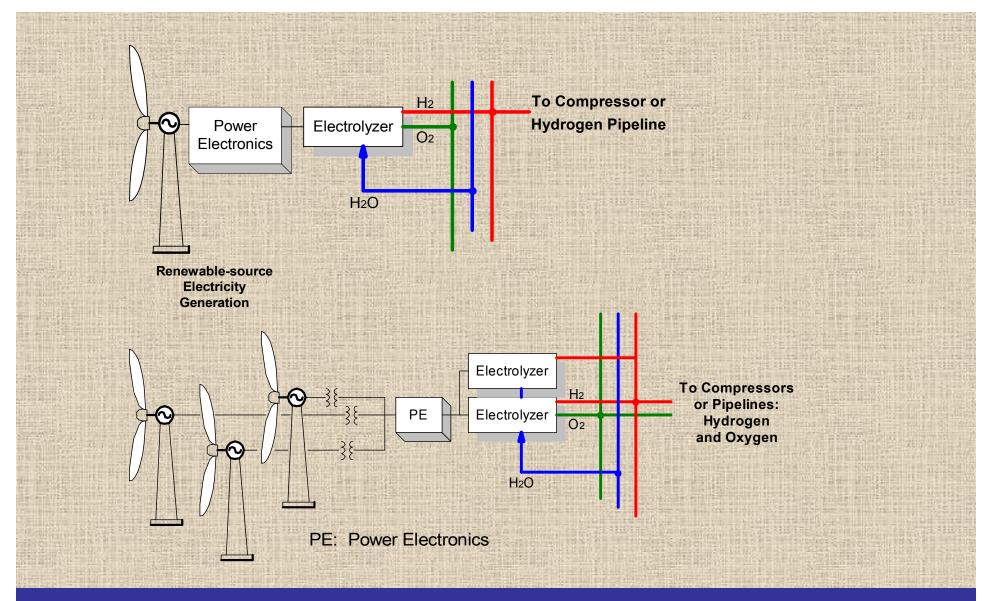




Norsk Hydro electrolyzer, KOH type 560 kW input, 130 Nm3 / hour at 450 psi (30 bar)

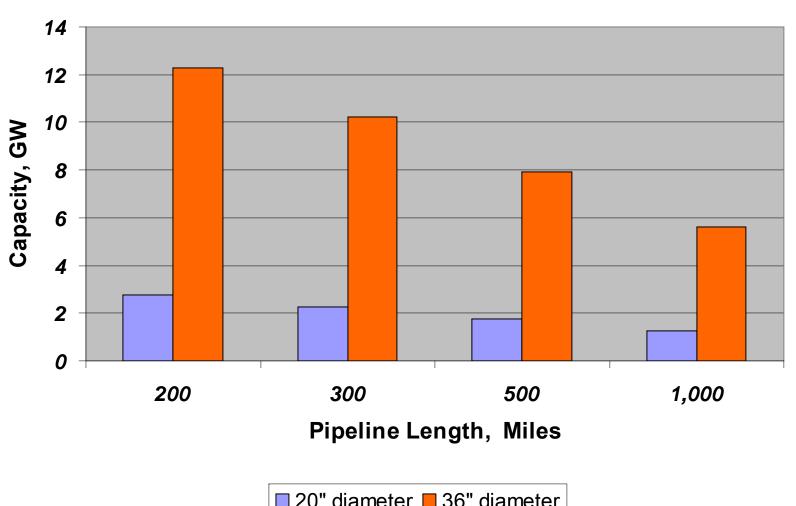
Compressorless system: No geologic storage



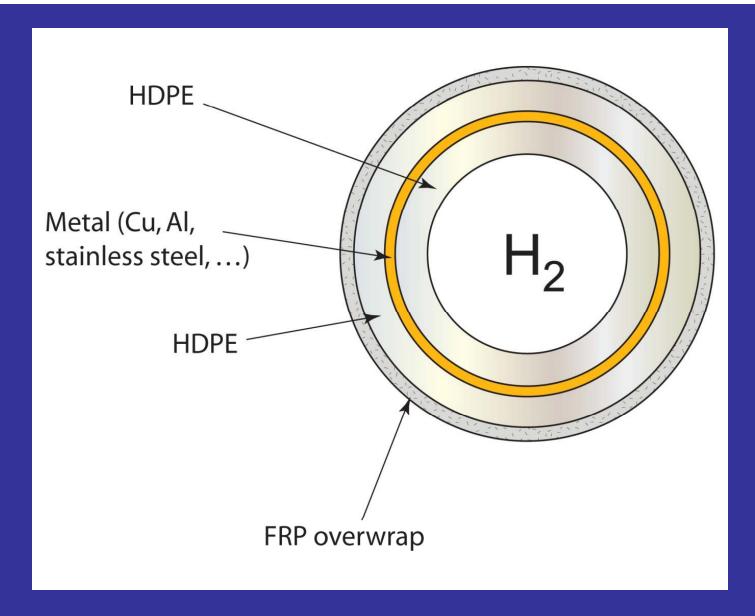


Topology Options: H₂ and O₂ Production and Gathering from Renewable Energy Generation

Compressorless 20", 36" GH2 Pipeline Capacity 1,500 psi IN / 500 psi OUT



■ 20" diameter ■ 36" diameter



Polymer-metal linepipe avoids hydrogen embrittlement

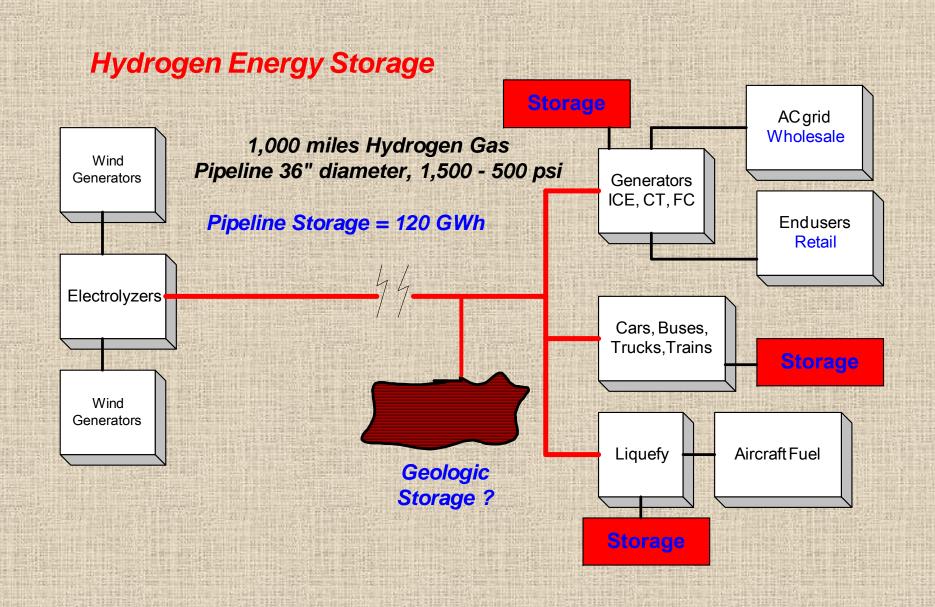


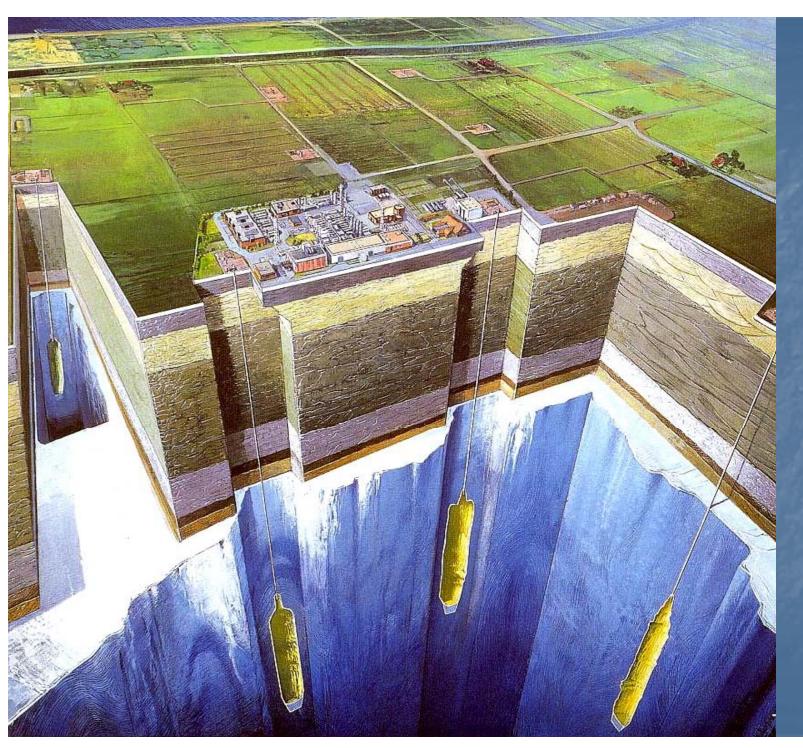
Gaseous Hydrogen (GH2)

36" diam, 800 km No compression

8,000 MW

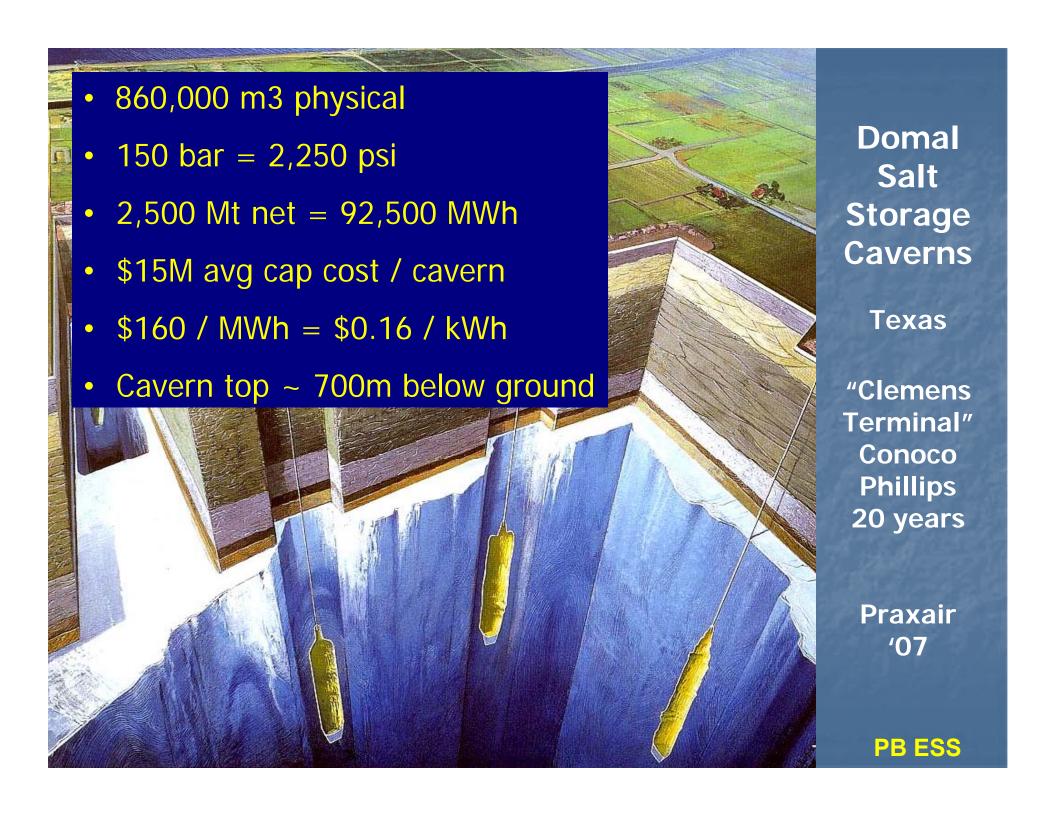
CRLP™ is a trademark of NCF Industries, Inc.





Domal Salt Storage Caverns

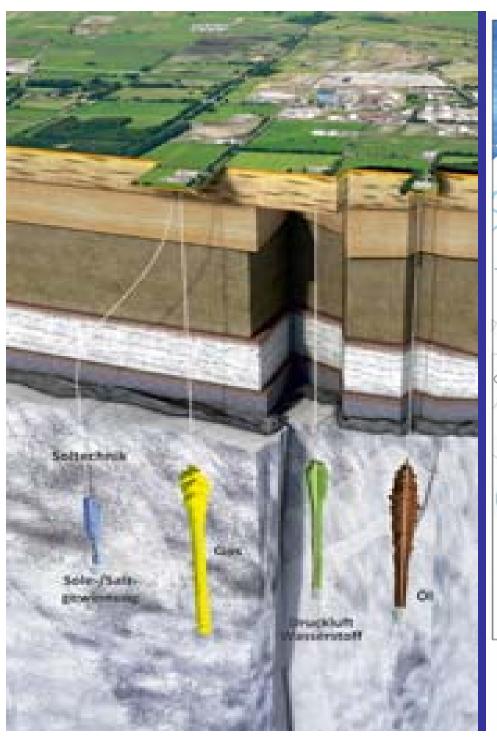
PB ESS



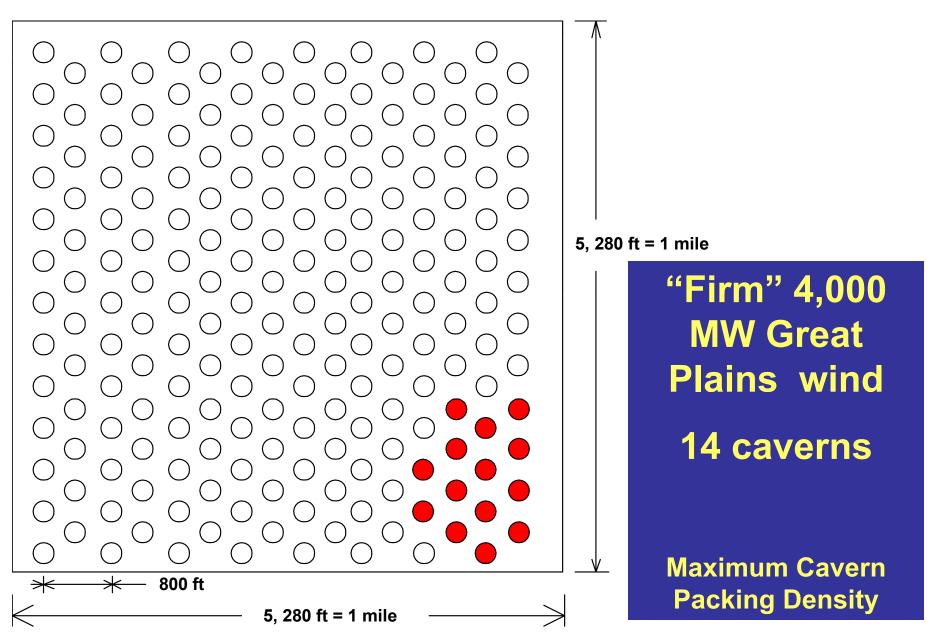


Renewable-source GH2 geologic storage potential.

Candidate formations for manmade, solution-mined, salt caverns





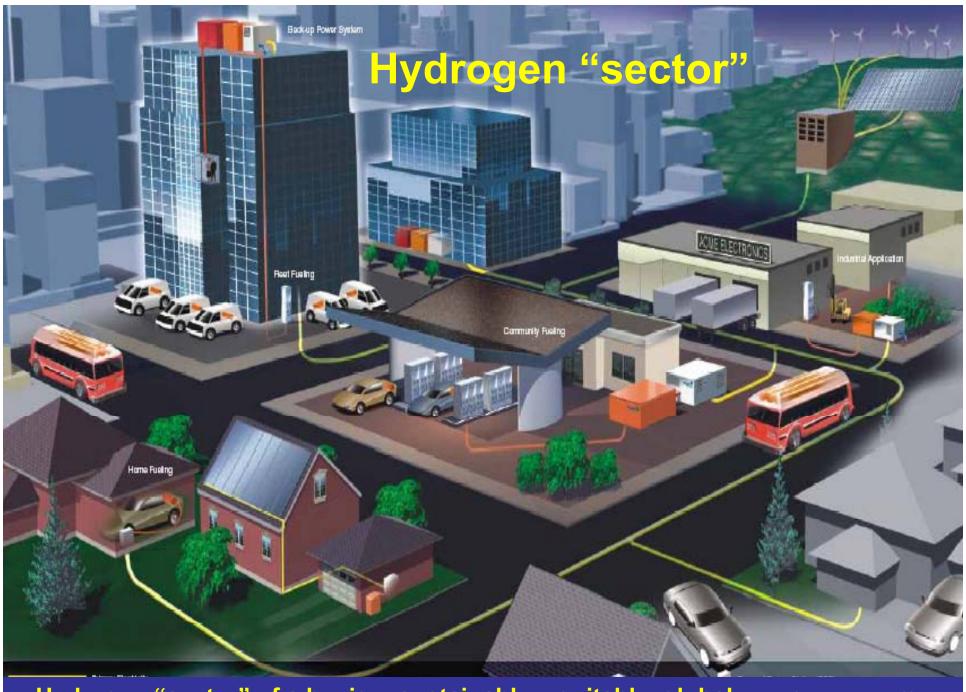


 $(8 \times 13) = 104 + (8 \times 12) = 96$ Total = 200 caverns per square mile Each cavern is 200 ft diam, with minimum 200 ft web separation.

Optimistic: Total Installed Capital Cost 1,000 mile Pipeline "Firming" GH2 cavern storage

Windplant size 1,000 MW [million]
Wind generators \$ 1,000
Electrolyzers 500
Pipeline, 20" 1,100
storage caverns [4]
Caverns @ \$10M ea 40
Cushion gas @ \$5M ea 20
TOTAL \$ 2,660

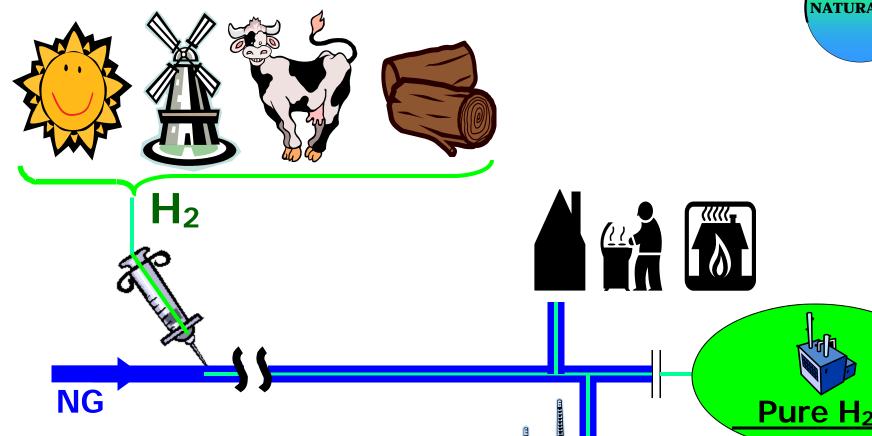
Cavern storage: ~ 3 % of total capital cost



Hydrogen "sector" of a benign, sustainable, equitable, global energy economy

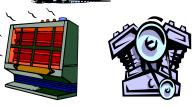
The NATURALHY approach: EC, R+D

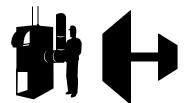




NATURALHY:

- Breaks "chicken-egg" dilemma
- Bridge to sustainable future
- Power To Gas







Carmakers Commit to Hydrogen Fuel Cell Cars?

- 9 Sept 09 "Letter of Understanding"
- Carmakers:

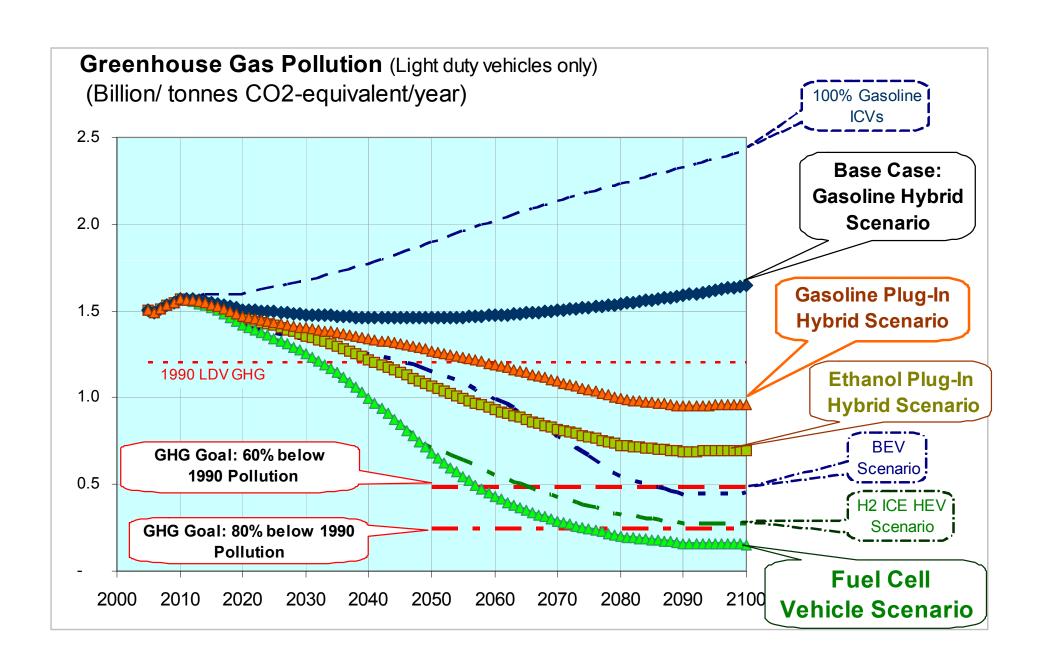
Daimler Ford

GM/Opel Honda

Hyundai/Kia Renault

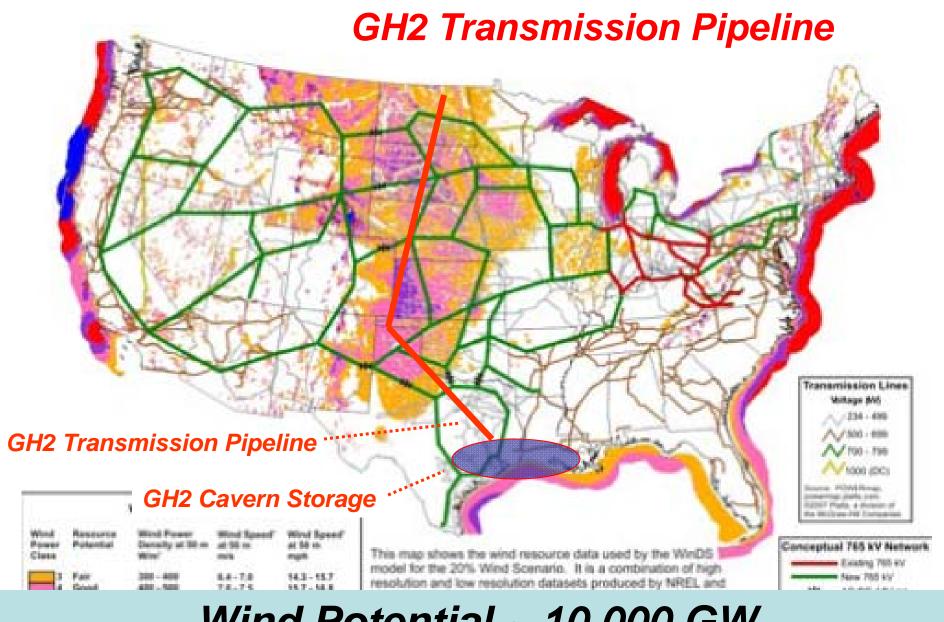
Nissan Toyota

- Serial production ~ 2015: "... quite significant number" of electric vehicles powered by fuel cells
- Vague; lobbying for fed FCV funds restore?
- Will need H2 fuel: "... hydrogen infrastructure has to be built up with sufficient density ..."

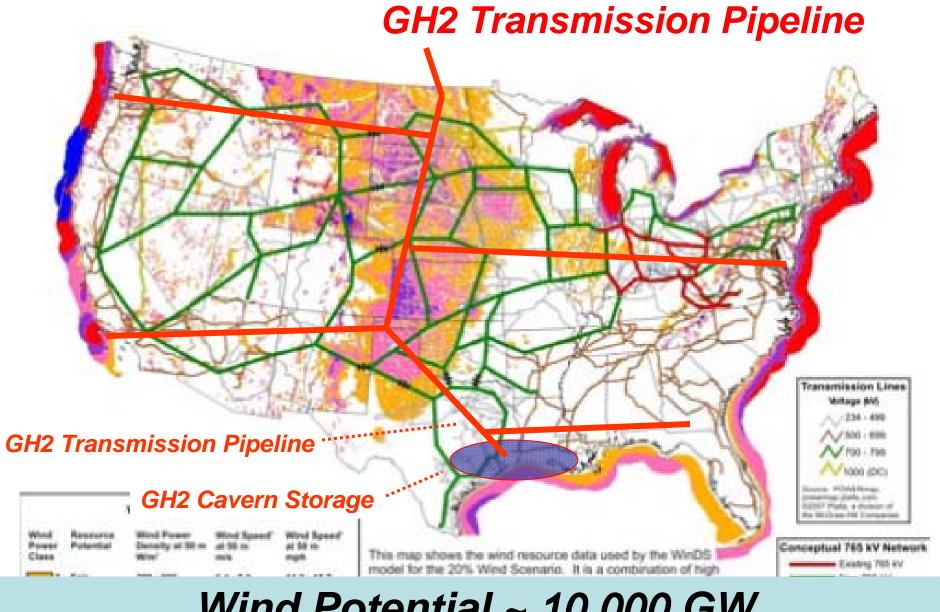


CA: 20% of "cars" hydrogen fueled by 2030

- 20% of 45M vehicles = 9M
- @ 78 mpg = 78 miles / kg H2
- 12,000 miles / year = 150 kg H2 / year
- 1,800 M kg H2 / year = 1.65 MMt H2 fuel
- @ 50 kWh / kg at windplant gate:
 - 82,500 GWh / year
 - @ 40% CF = 23,000 MW nameplate wind
 - Requires 3 GH2 pipelines, 36", 500 miles long
 - PLUS @ 4 caverns / GW = 92 storage caverns,
 to firm the supply at annual scale

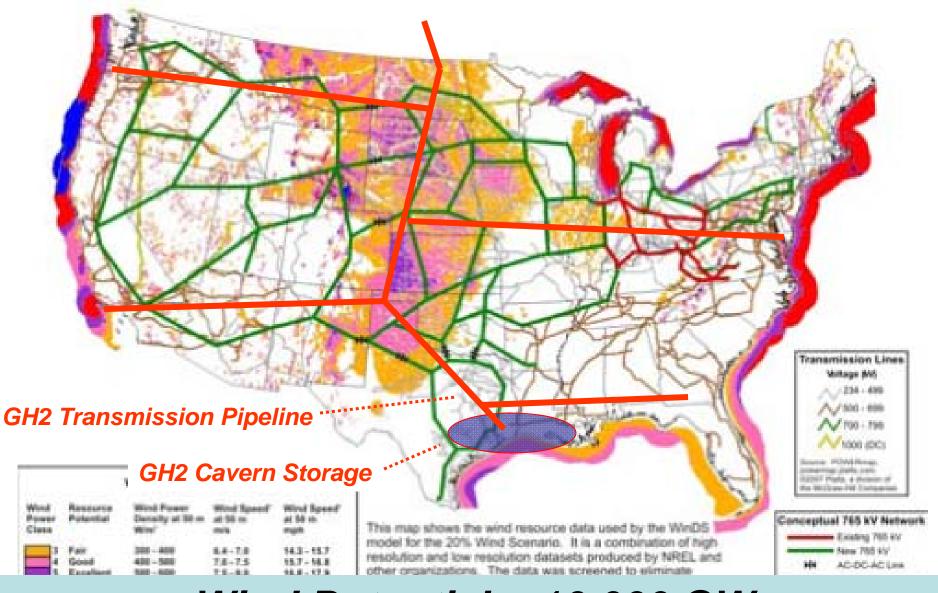


Wind Potential ~ 10,000 GW 12 Great Plains states



Wind Potential ~ 10,000 GW 12 Great Plains states

AWEA 20% Wind Electricity by 2030



Wind Potential ~ 10,000 GW

Capital Cost per GW-mile

Electricity:		Capacity	
	KV	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

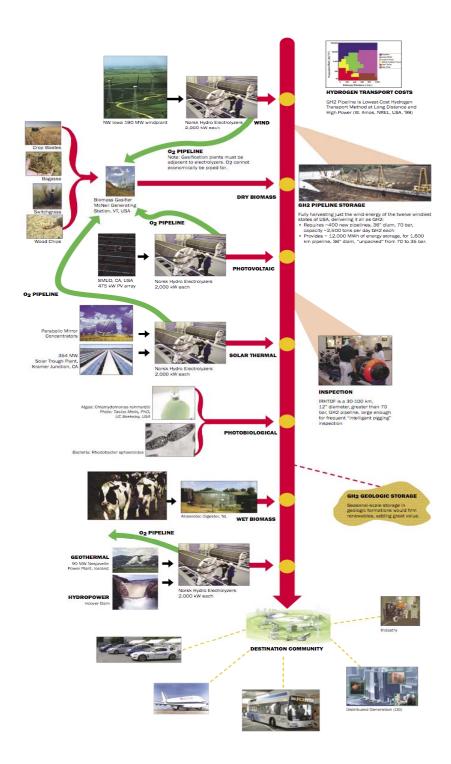
Hydrogen pipeline:

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

(100 bar = 1,500 psi)

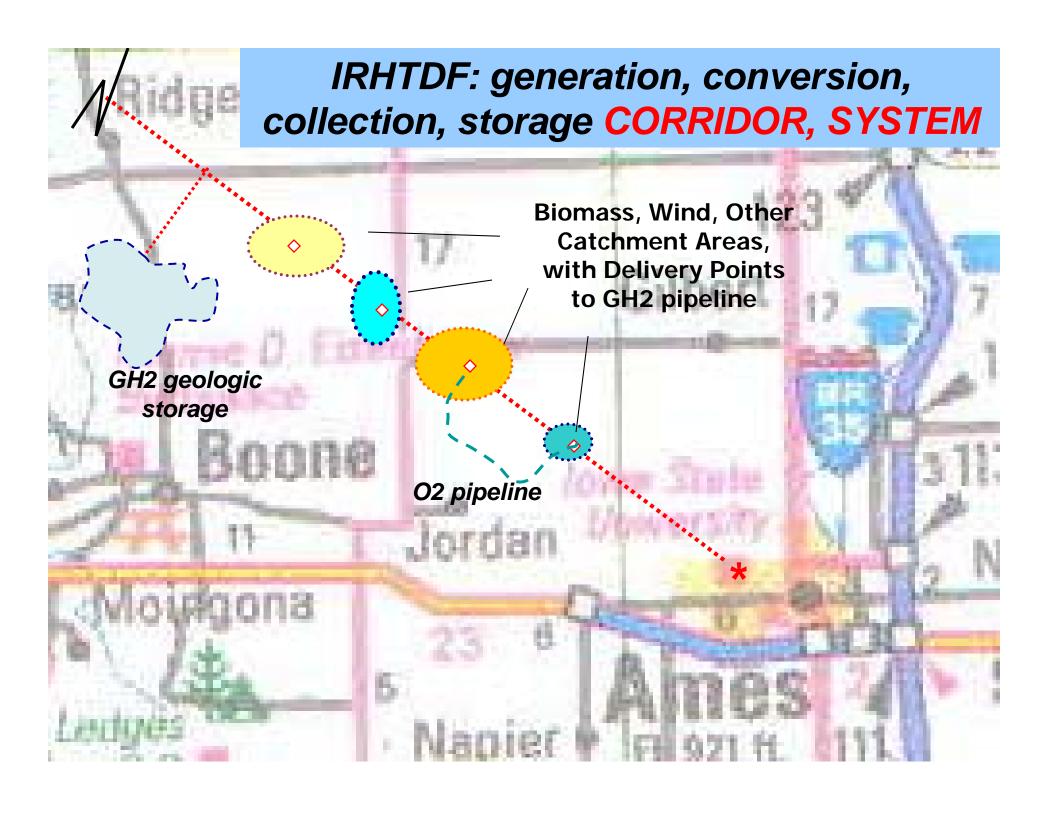
Pilot plant needed

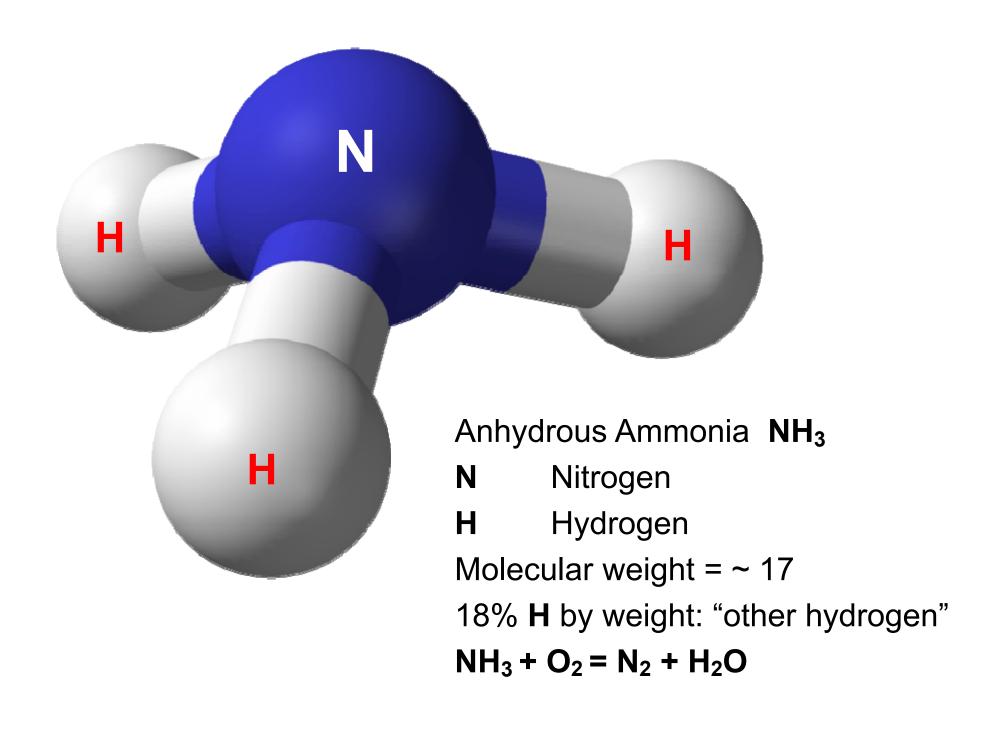
- Every major new industrial process
- Renewables-source systems
- Diverse, large-scale, stranded
- US, Japan, Canada, IPHE → "IRHTDF "



Pilot-scale Hydrogen Pipeline System: Renewables

- Diverse
- Dispersed, diffuse
- Large-scale
- Stranded
 - Remote
 - No transmission





Why Ammonia? Fertilizer and Fuel

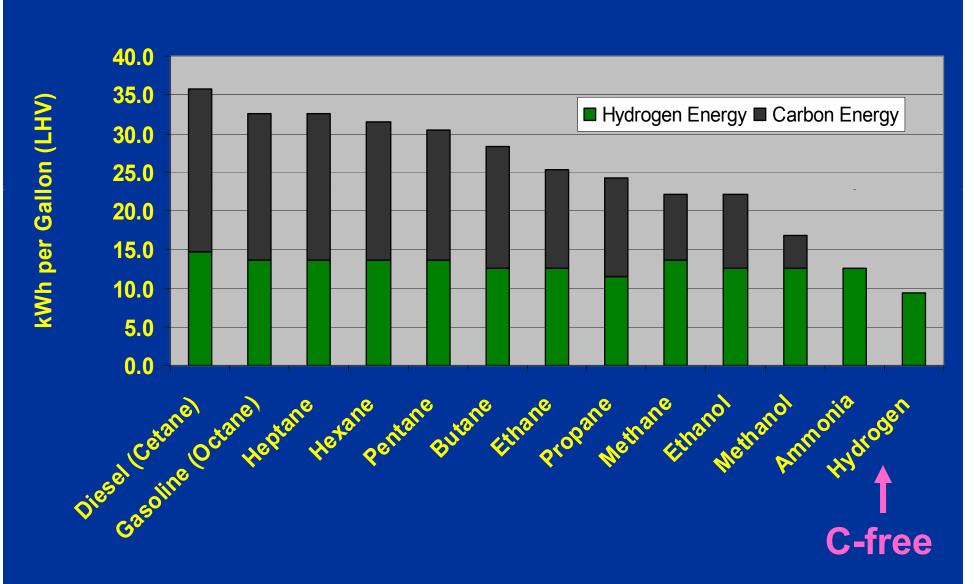
Only liquid fuel embracing:

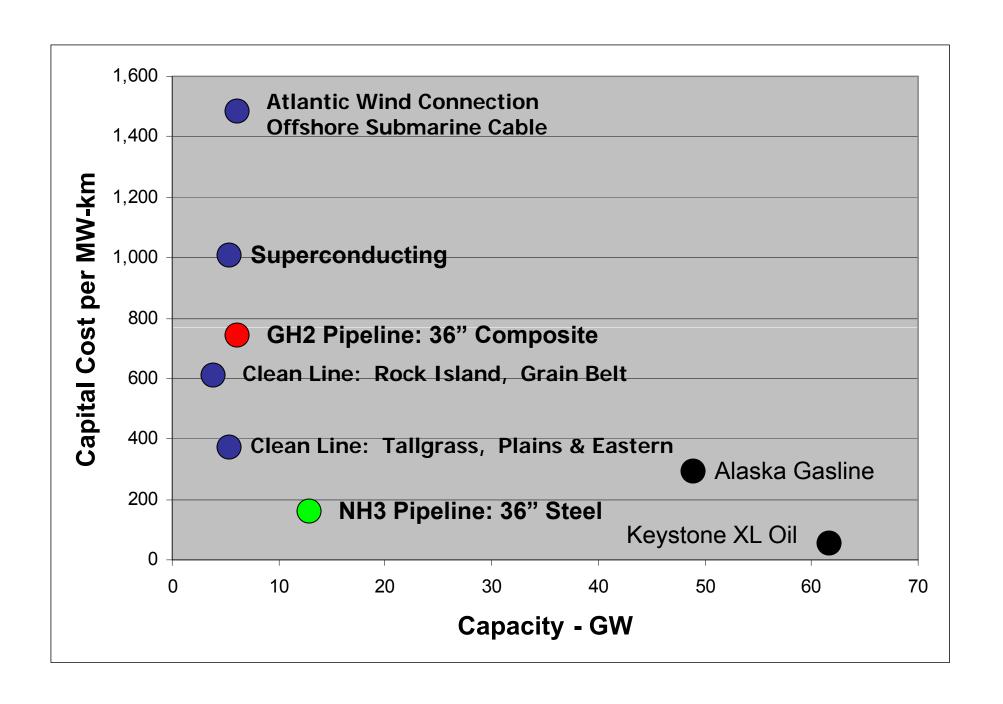
- Carbon-free: clean burn or conversion; no CO₂
 - Excellent hydrogen carrier
 - Easily "cracked" to H₂
- Reasonably high energy density
- Energy cycle inherently pollution free
 - Potentially all RE-source: elec + water + Nitrogen
 - Cost competitive with hydrocarbon fuels?
- Decades of global use,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

Ammonia Fuel Uses

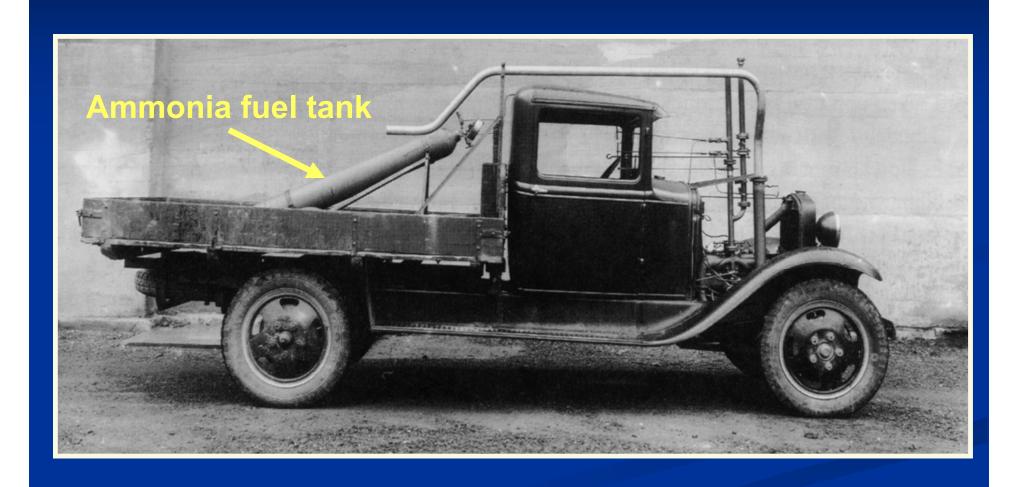
- 1. Internal Combustion Engine (ICE)
 - Diesel: NH₃ gas mixed with intake air
 - Spark-ignition: 70%+ NH₃ plus
 gasoline, ethanol, propane, NG, hydrogen
 - NOx ~ ½ gasoline engines
- 2. Combustion Turbines
- 3. Direct Ammonia Fuel Cells:
 - Combined heat + power (CHP)
 - No NOx
- 4. Reform ("crack")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

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





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

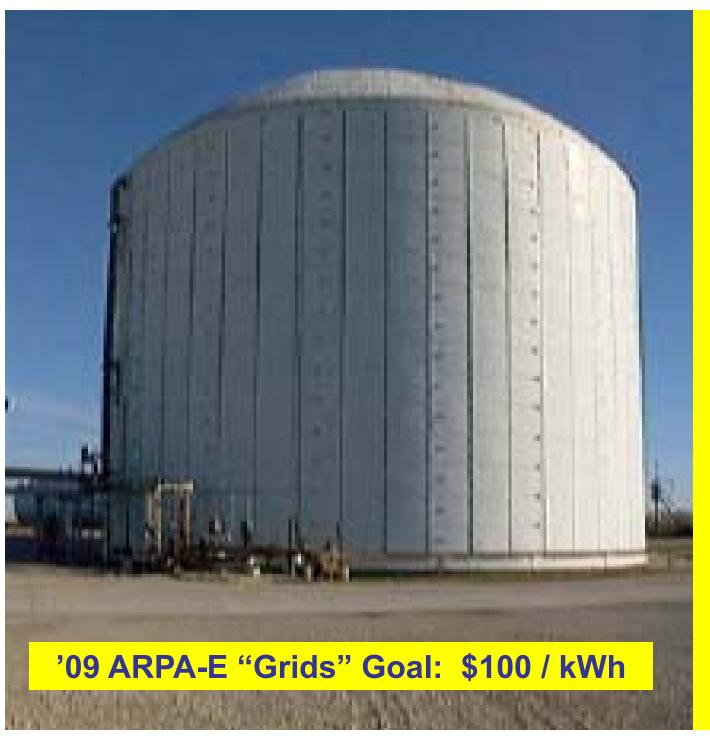
2007

1,000 hours, ICE, 6 cyl, 100 hp 75% ammonia, 25% propane



NH₃ Ag Fertilizer Tanks, Wind Generators, NW Iowa





"Atmospheric"
Liquid
Ammonia
Storage Tank
(corn belt)

30,000 Tons 190 GWh

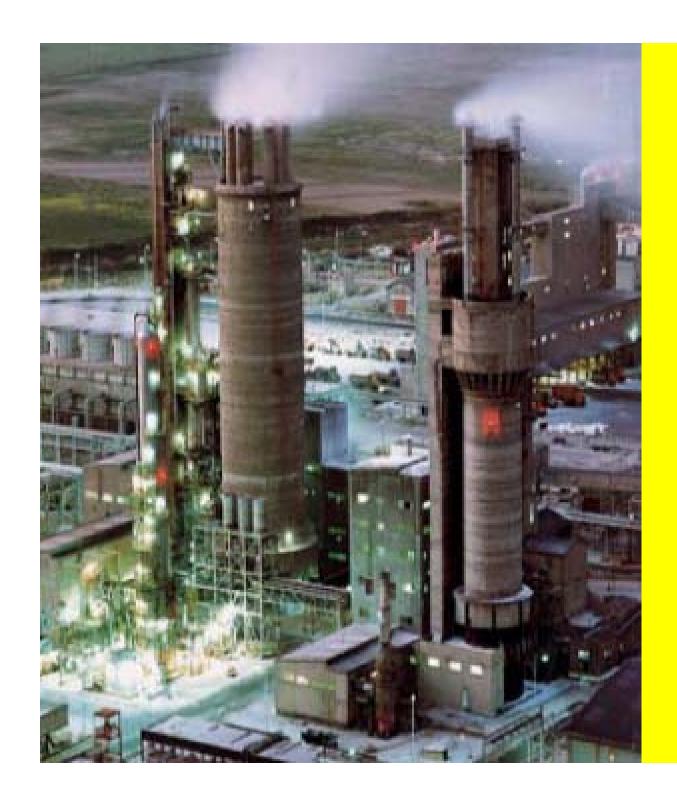
\$ 15M turnkey

\$ 80 / MWh

\$ 0.08 / kWh

-33 C

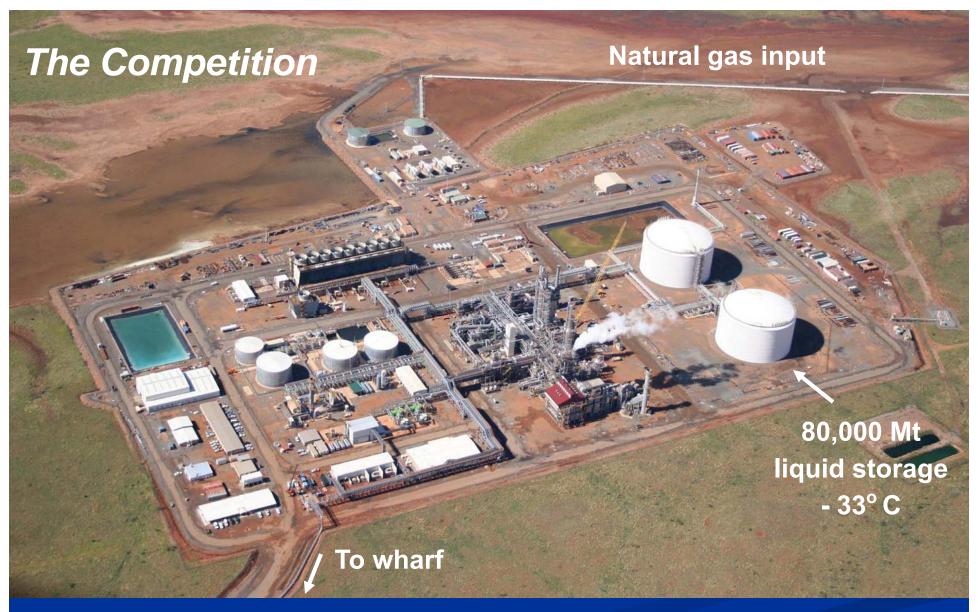
1 Atm



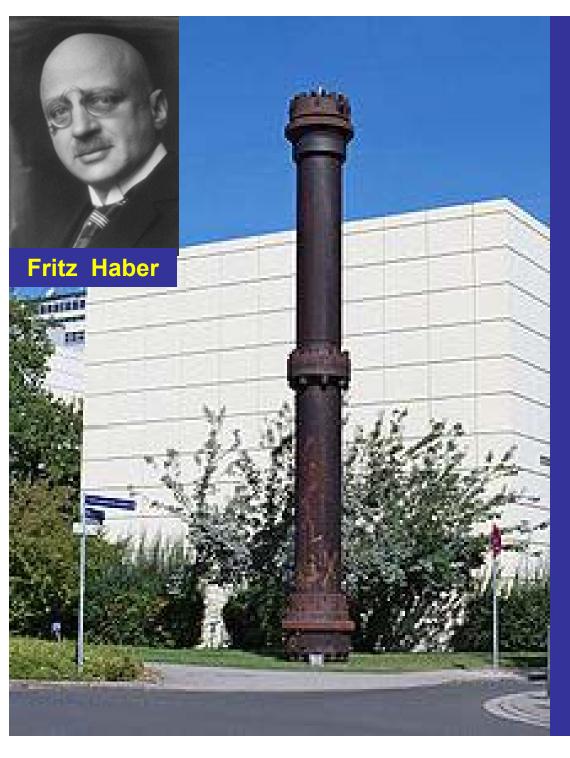
95% Global Ammonia

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



Haber-Bosch Process 1909 – 1913 BASF

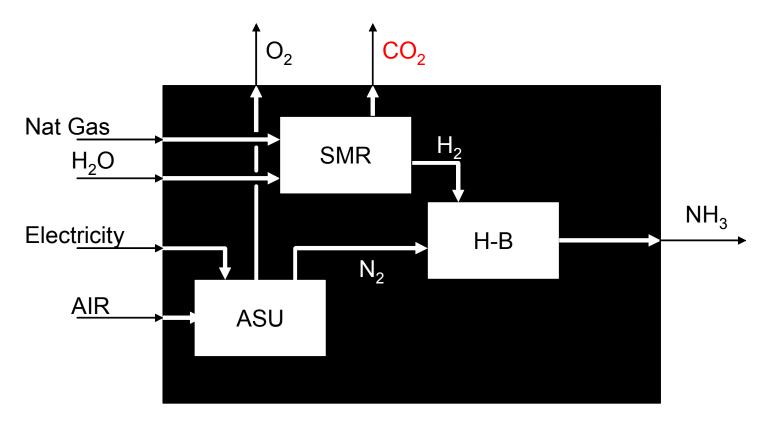
- NH₃ synthesis
- Coal gasification → H2
- WW I explosives
- 40% humanity: N fertilizer

Haber-Bosch Reactor 1921

Ludwigshafen, Germany

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

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

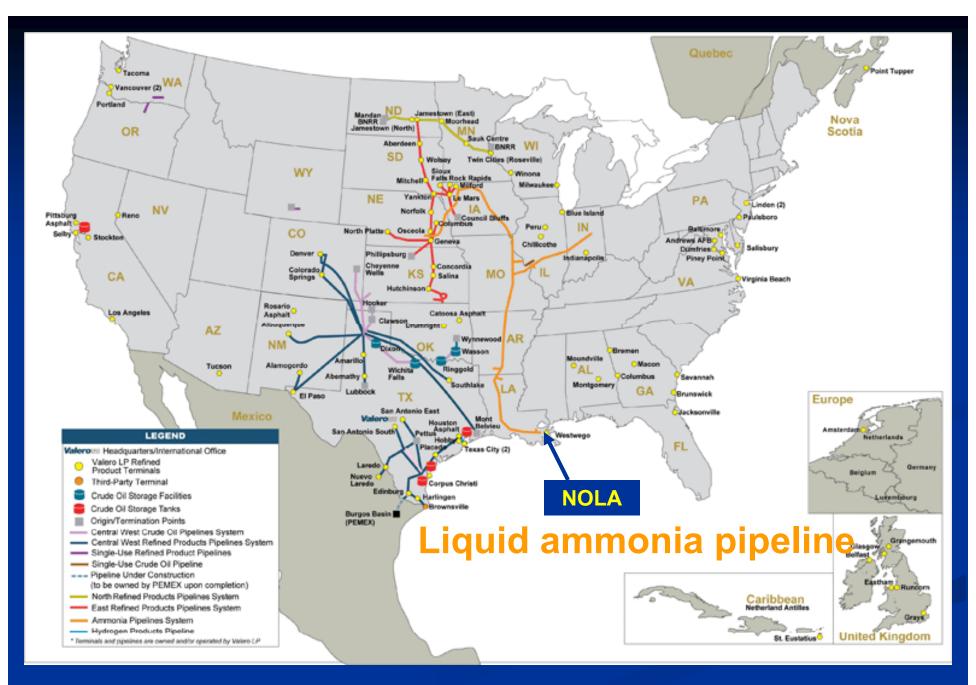


Energy consumption ~33 MMBtu (9,500 kWh) per ton NH_3 Tons CO_2 per ton NH_3 = 1.8

Ammonia Tanker Burrup Peninsula Western Australia







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

E	lectricity :		Capacity	
		<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:

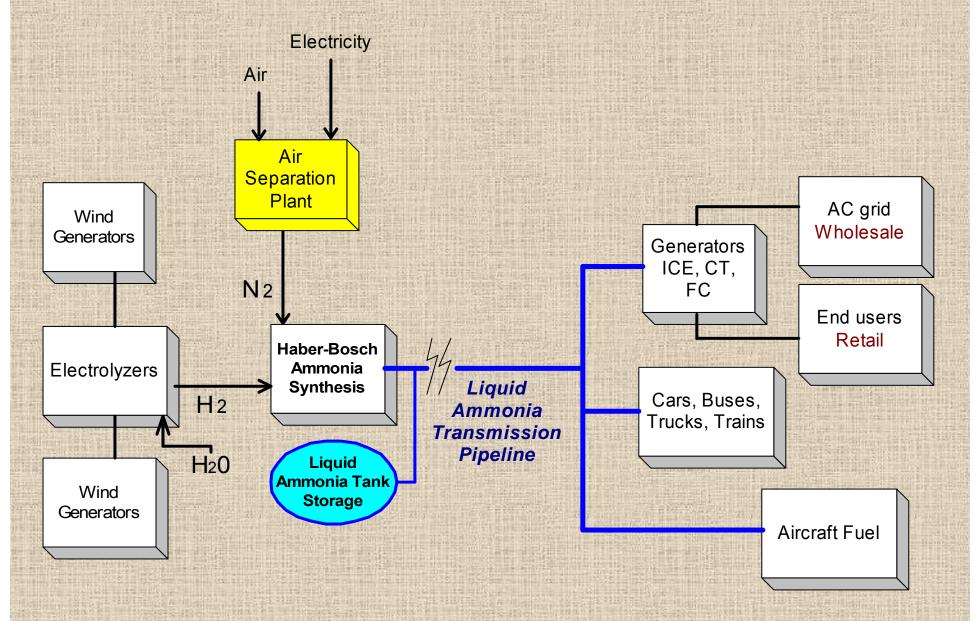
10", liquid, 500 miles, with pumping 0.2

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

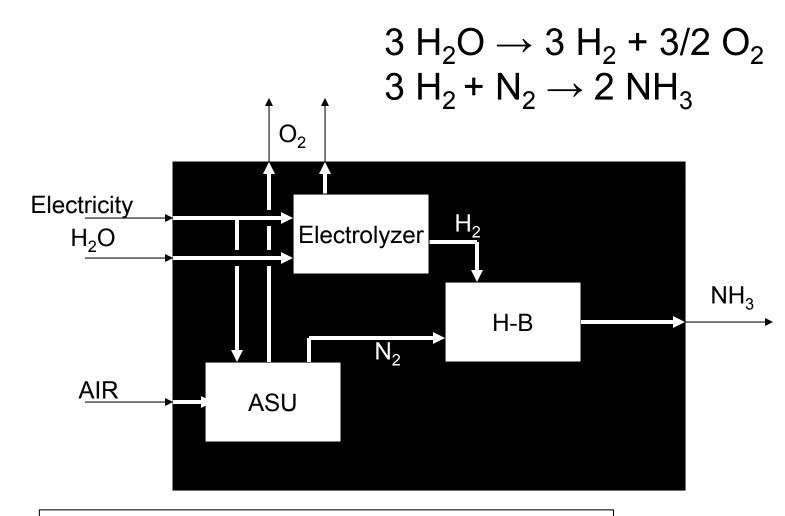


RE Ammonia Transmission + Storage Scenario



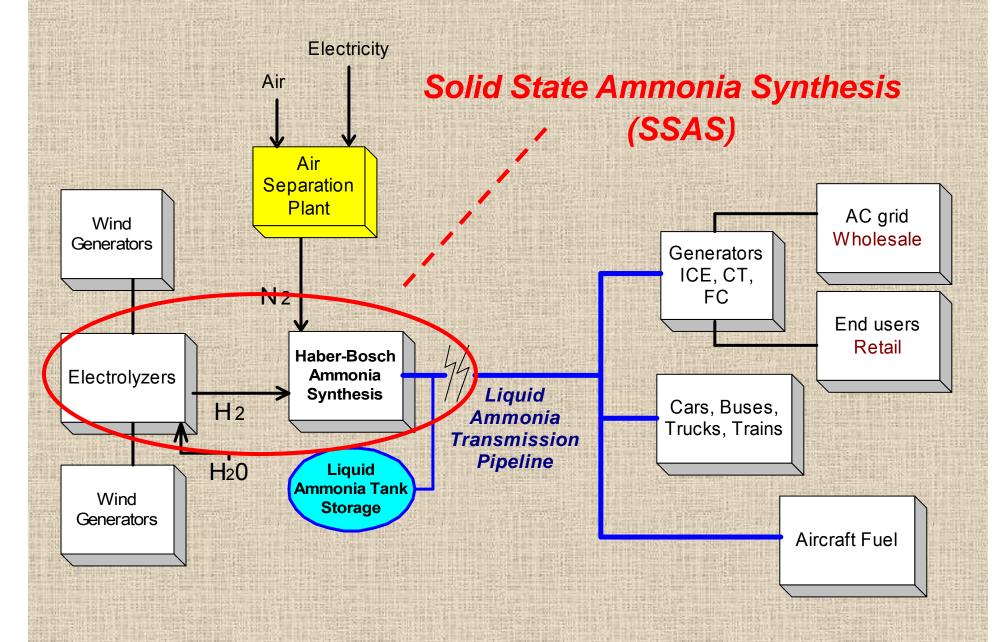


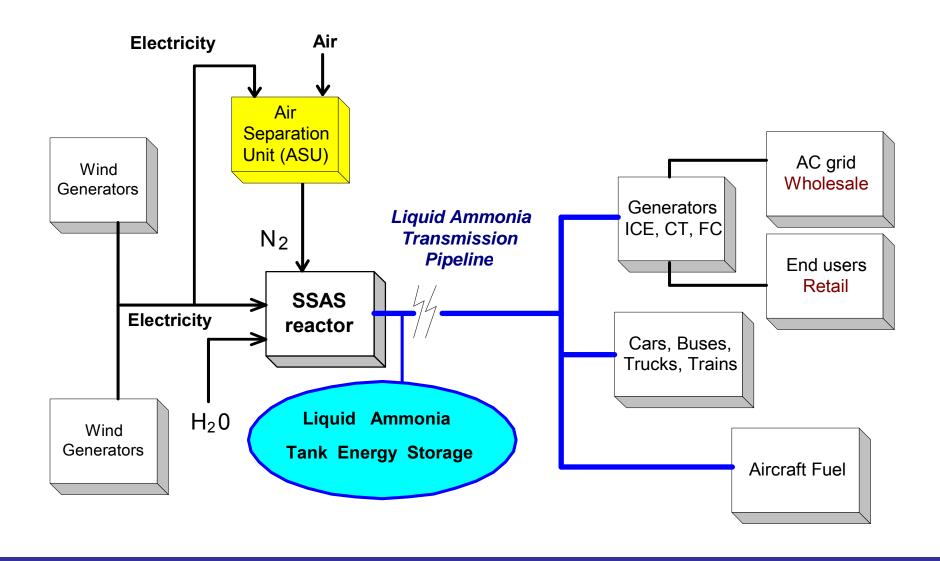
Inside the Black Box: HB Plus Electrolysis



Energy consumption ~12,000 kWh per ton NH₃

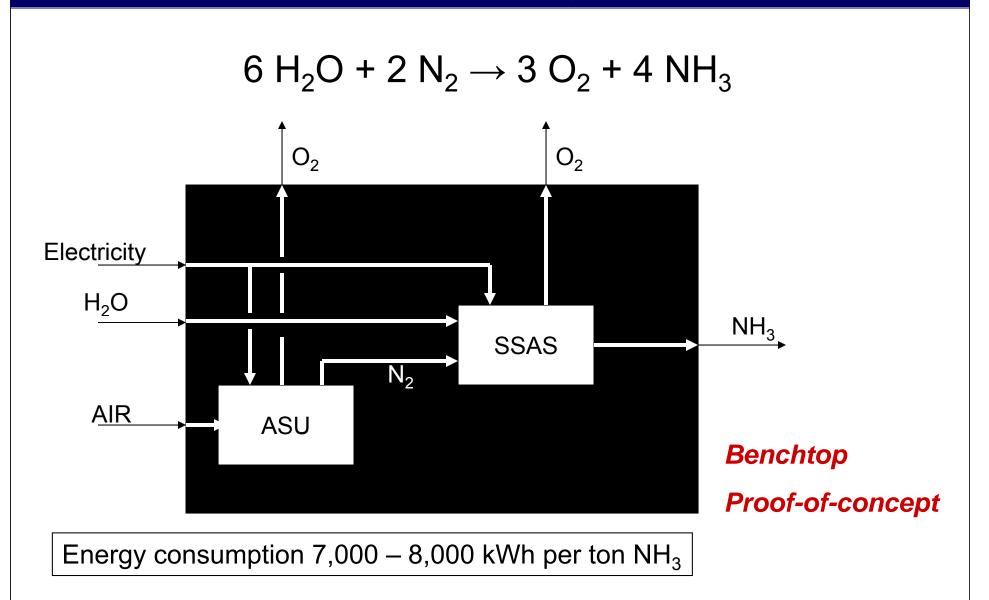
RE Ammonia Transmission + Storage Scenario



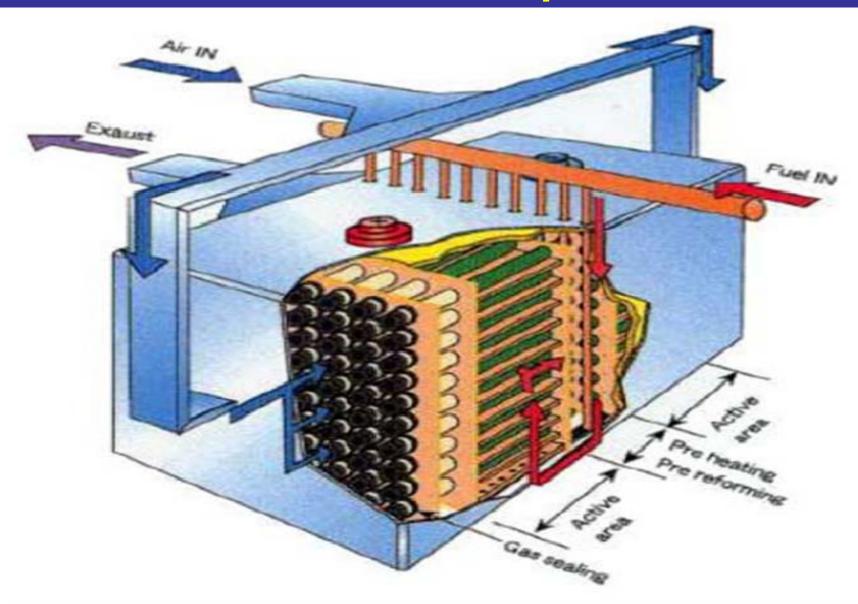


Solid State Ammonia Synthesis (SSAS)

Inside the Black Box: Solid State Ammonia Synthesis



Solid State Ammonia Synthesis (SSAS) NHThree LLC patent



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

Wind - to - Ammonia Potential, NW Iowa



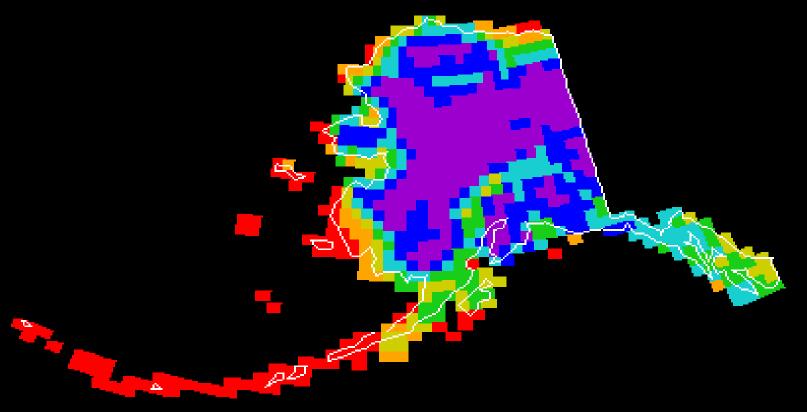
320,000 MWh storage Annual firming 1,000 MW wind

- 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

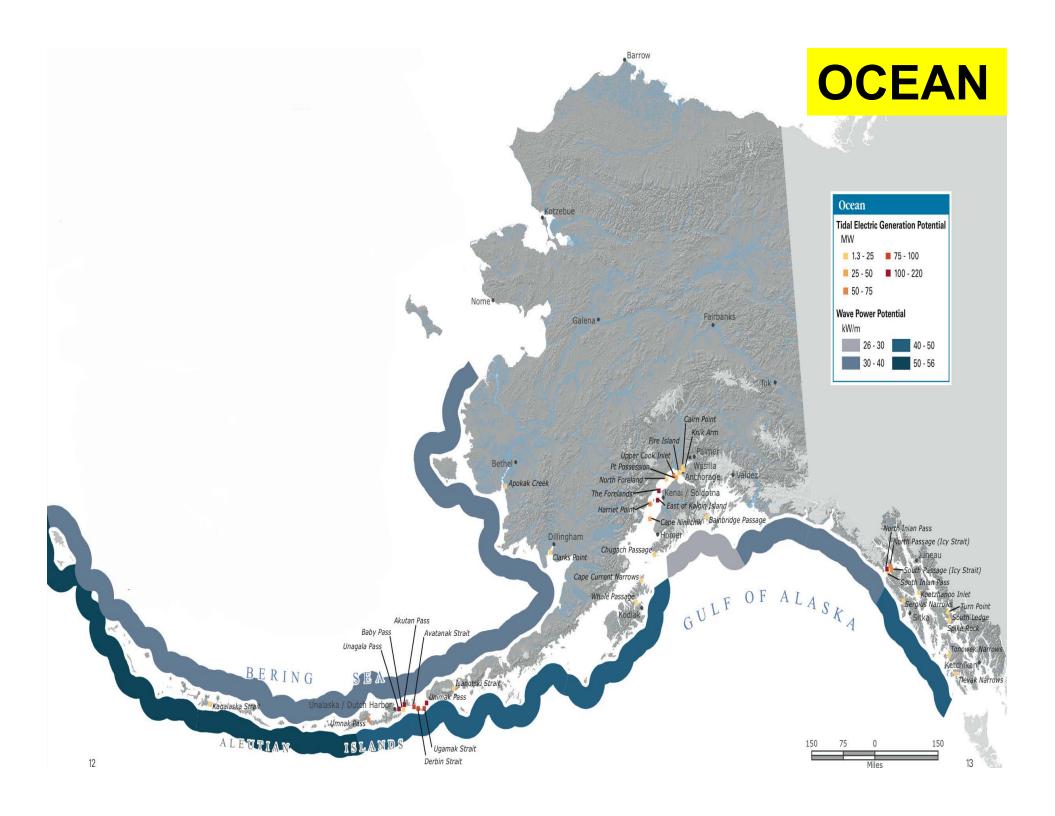
Opportunity: Alaska Applications

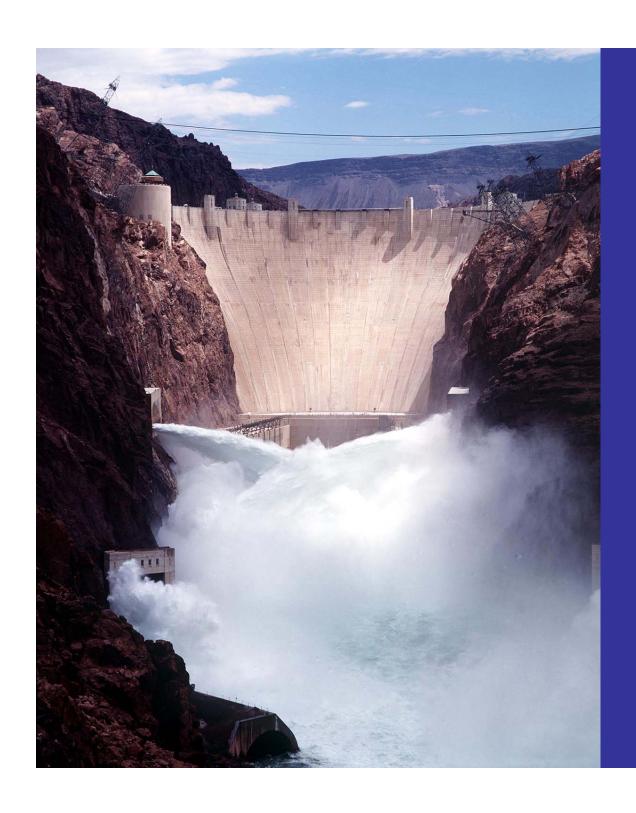
- 1. Village energy "independence": degree
 - a. Internal, external energy economies
 - b. Diverse renewable sources
 - c. Low-cost tank storage
 - d. CHP, transportation fuels
- 2. Firming storage: annual scale
 - a. Susitna hydro
 - b. Other
- 3. Export large, diverse, stranded renewables
 - a. Cryo 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

Wind Power Class

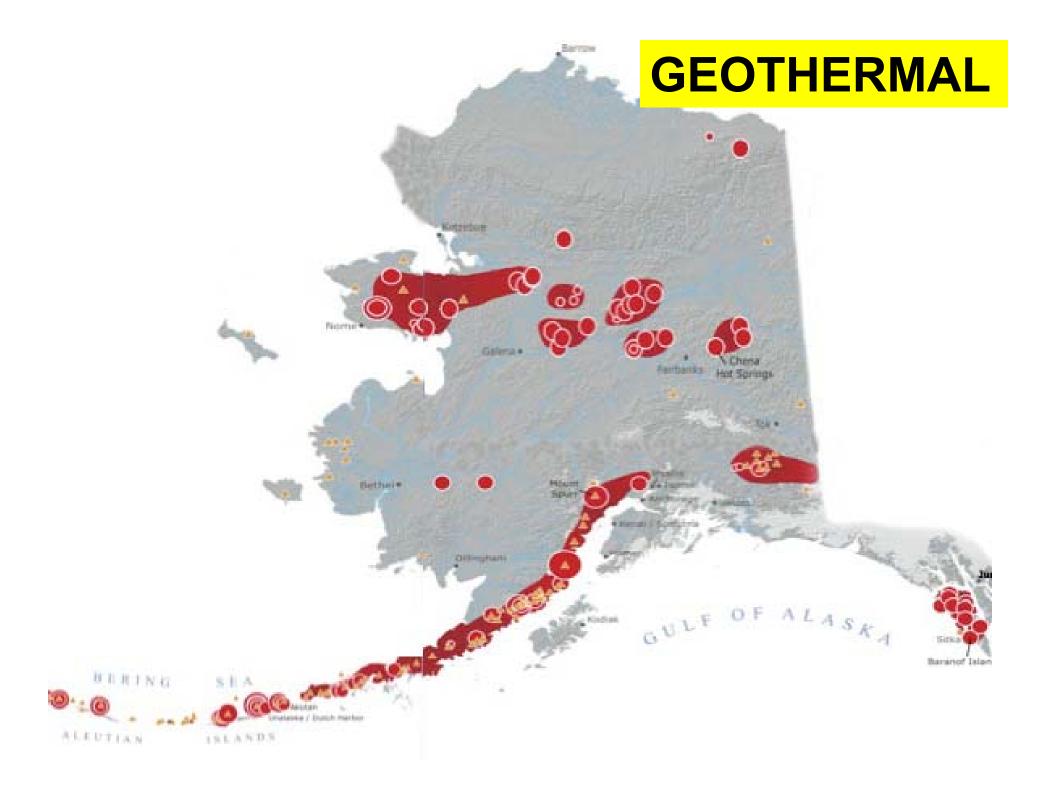


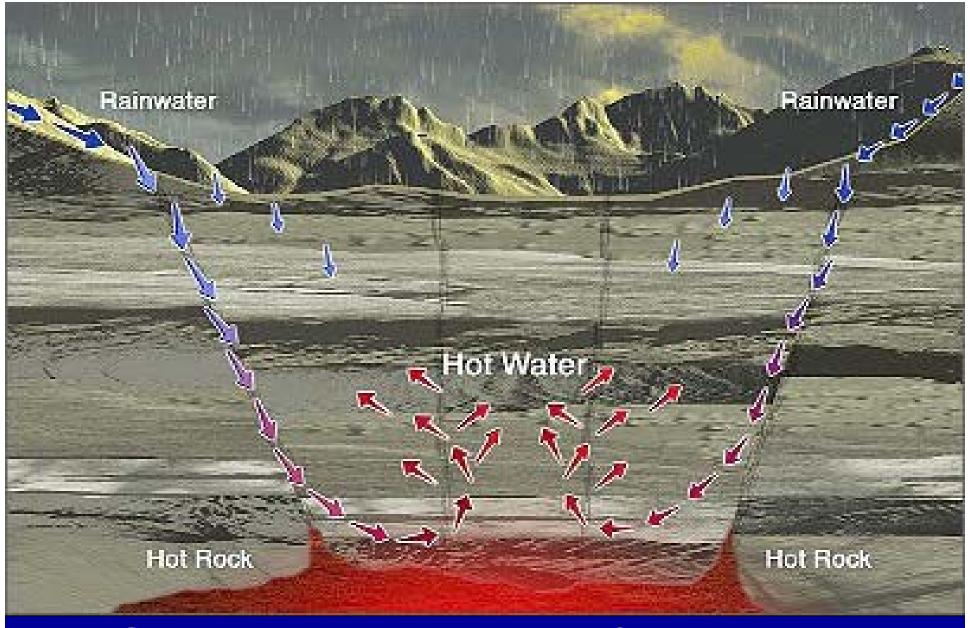
	ahaaa	Power Density
1	0.0-5.6m/s	0-200W/m2
		200-300W/m2
3		300-400W/m2
4	7.0-7.5m/s	400-500W/m2
5	7.5-8.0m/s	500-600W/m2
6	8.0-8.8m/s	500-800W/m2
7	>8.8m/s	>800W/m2



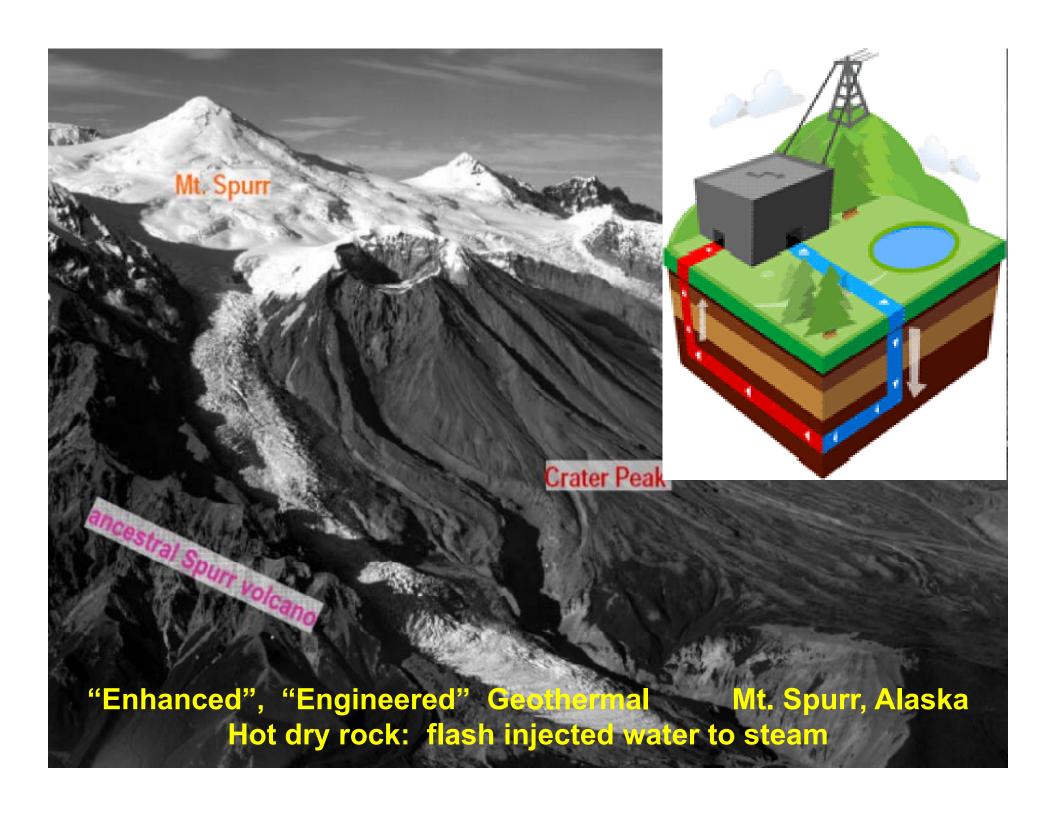


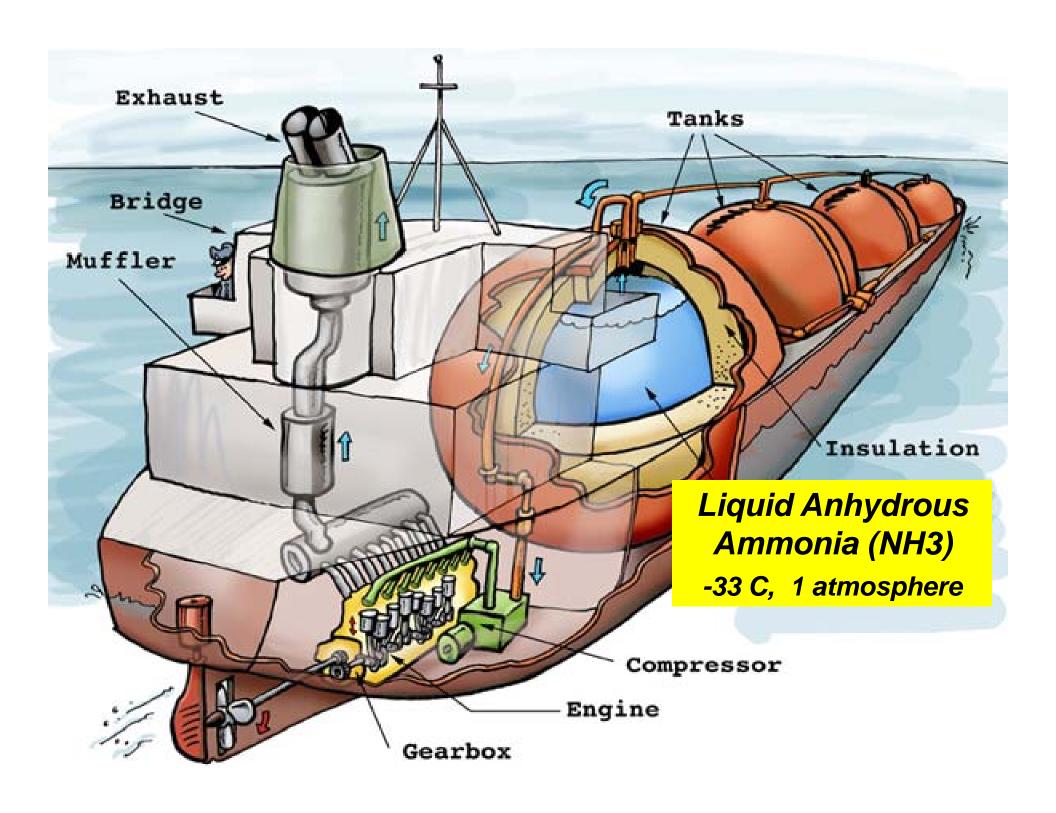
Hydro

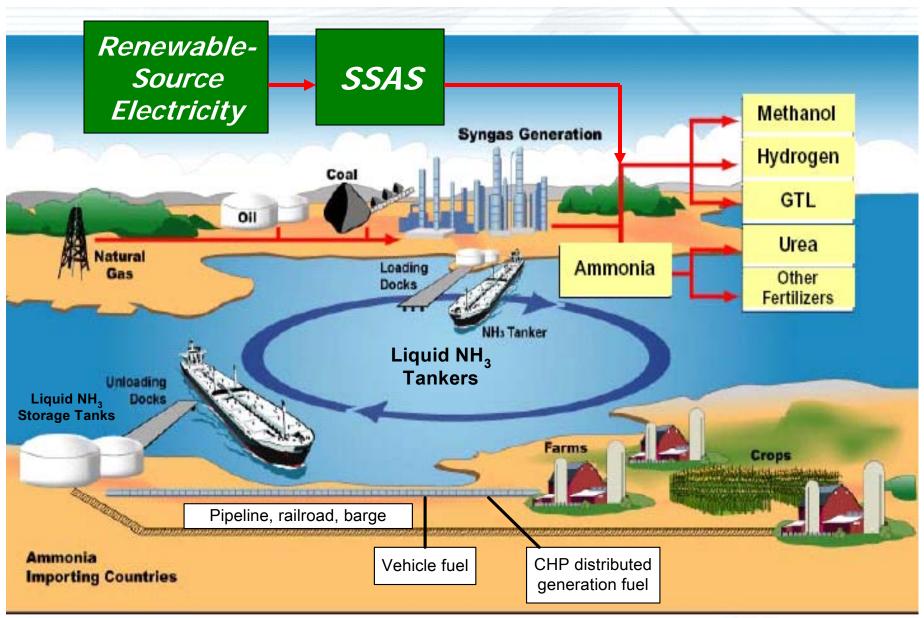




Geothermal: hot water, surface recharge





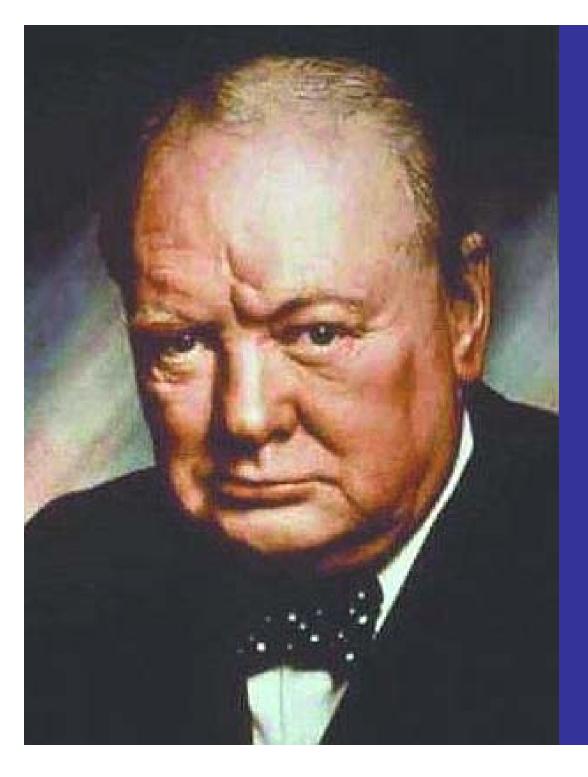


KBR Energy and Chemicals

Alaska Energy Authority Emerging Energy Technology Fund Project Fundamentals

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

SSAS Proof-of-concept pilot plant Two-year project Alaska Applied Sciences, Inc.



"Americans can be counted on to always do the right thing –

but only after they have tried everything else "

Winston Churchill

The dog caught the car.

Dan Reicher

Humanity's Goal

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

CANNOT with only electricity transmission

"Transmission"

- Beyond "Smart Grid", GW scale
- Electrofuels
- Renewable-source electricity
- Underground pipelines
- Carbon-free fuels: hydrogen, ammonia
- Low-cost storage:
 - \$ 0.10 0.20 / kWh capital
- CHP, transport, industrial

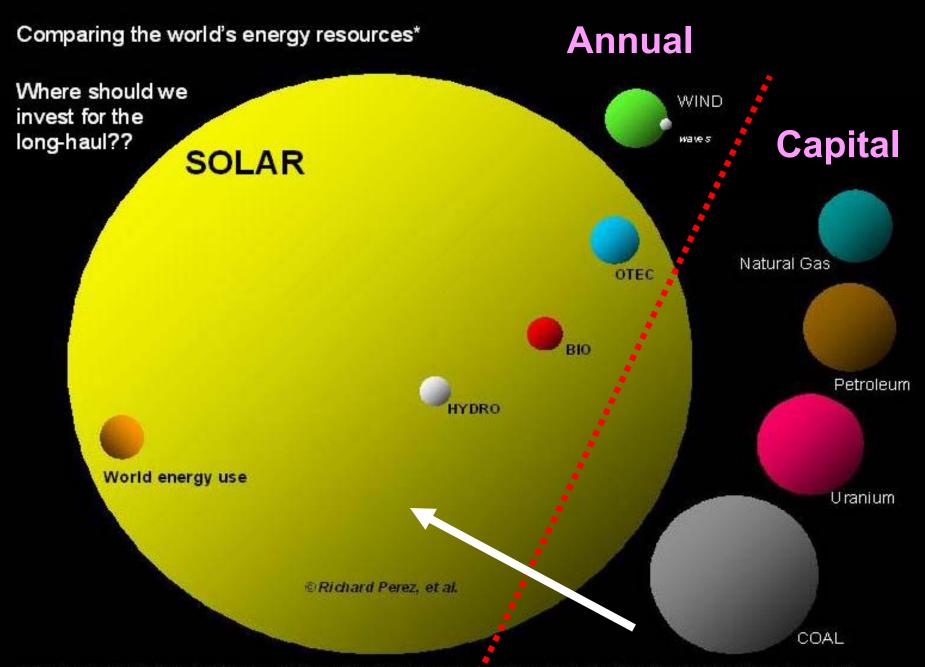
Beyond "Smart Grid"

- 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

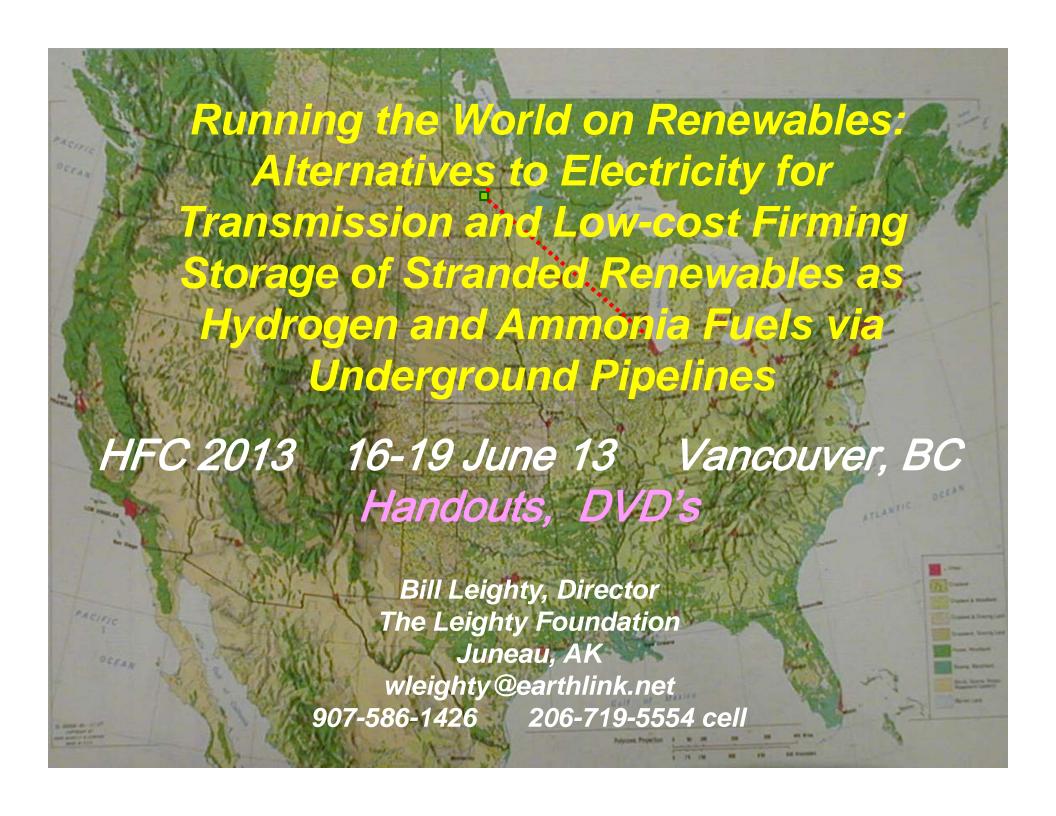
MUST Run the World on Renewables – plus Nuclear?

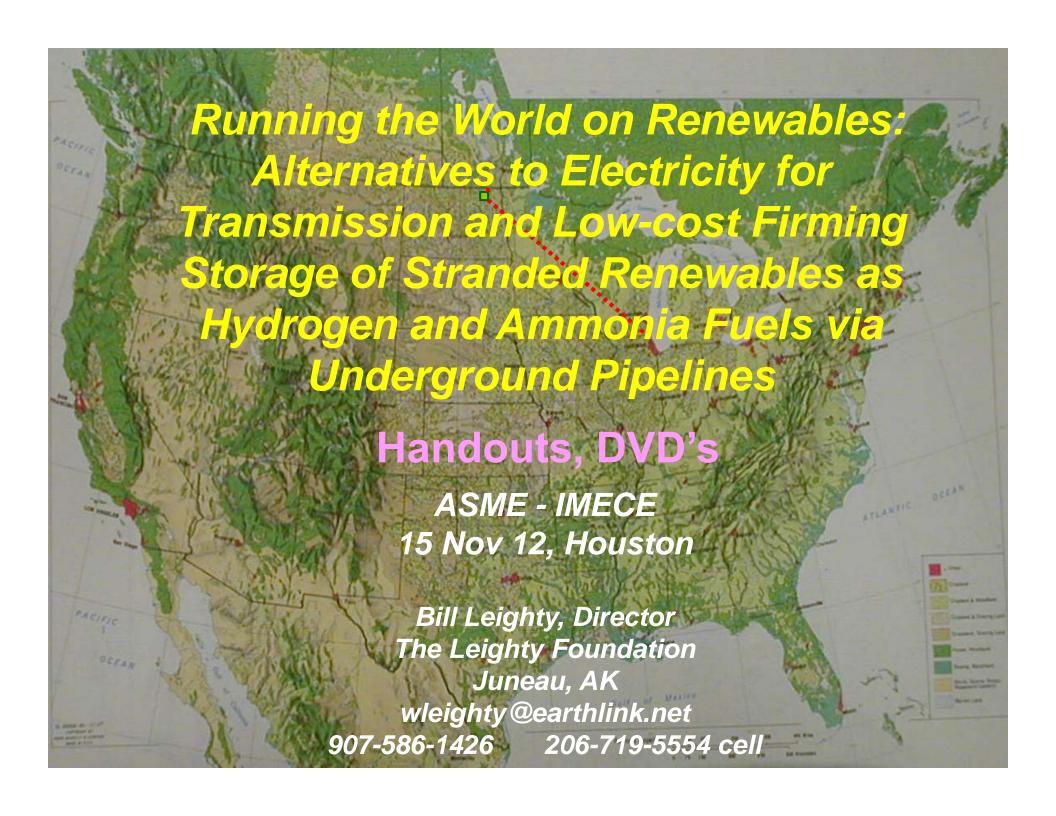
- Global
- Indigenous
- Firm: available
- C-free
- Benign
- Abundant
- Affordable
- Equitable
- Perpetual:
 - solar
 - geothermal
 - tidal

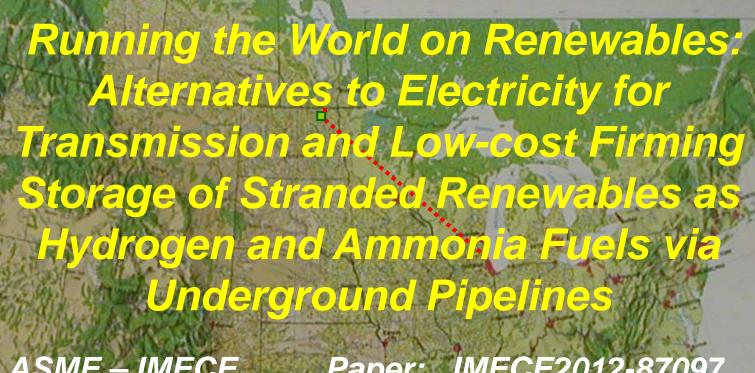




*yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. Word energy use is annual.







Paper: IMECE2012-87097 ASME – IMECE

> American Society of Mechanical Engineers, International Mechanical Engineering Congress and Exposition

ATLANTIC OCEAN

15 Nov 12, Houston

Bill Leighty, Director The Leighty Foundation Juneau, AK wleighty@earthlink.net 907-586-1426 206-719-5554 cell End 15 Nov 12 presentation; 22 minutes videorecorded live.

The following slides are supplemental.

Pipeline & Gas Journal

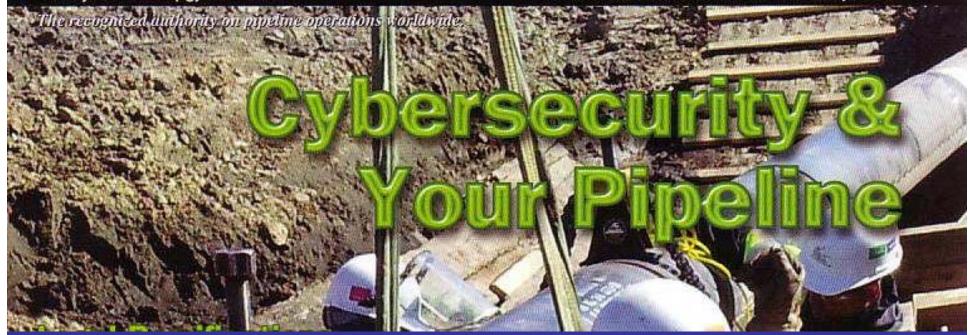


Keynote Speaker: Nick Stavropoulos, Executive Vice President, Gas Operations, PG&E.

Guest Speaker: Jack Weixel, Director, Client Services, BENTEK Energy

154th year • www.pgjonline.com

Volume No. 240 • Number 2 • February 2013



2012 AIChE Ammonia Safety Committee



Front: Danny Franceus (Yara), Jim Richardson (Sud-Chemie), John Mason (Agrium),

Venkat Pattabathula (Incitec Pivot), AK Singh (IFFCO), Dorothy Shaffer (Baker Risk), Ali Jama (QAFCO)

Back: Ruben Wagek (Vale Fertilizers), John Brightling (Johnson Matthey), Neal Barkley (Coffeyville

Resources), Robert Collins (KBR), David Pierce (Southern Ionics), Harrie Duisters (OCI Nitrogen),

Svend-Erik Nielsen (Haldor Topsøe), Reinhard Michel (Uhde GmbH), Ian Welch (PCS Nitrogen)

Annual Fresh Water for Energy

- USA today
- · All energy
- 17,000 billion liters in today's "energy" system
 - "Withdrawn"
 - "Consumed"
 - Include all oil & gas "fracking" ?
- If all via GH2 + NH3 fuels, required feedstock:
 - Dissociated, disintegrated: $H_2O \rightarrow H_2 + O_2$
 - 7,650 billion liters "consumed"

Hydrogen Utility Group (HUG)



















ENTERGY NUCLEAR







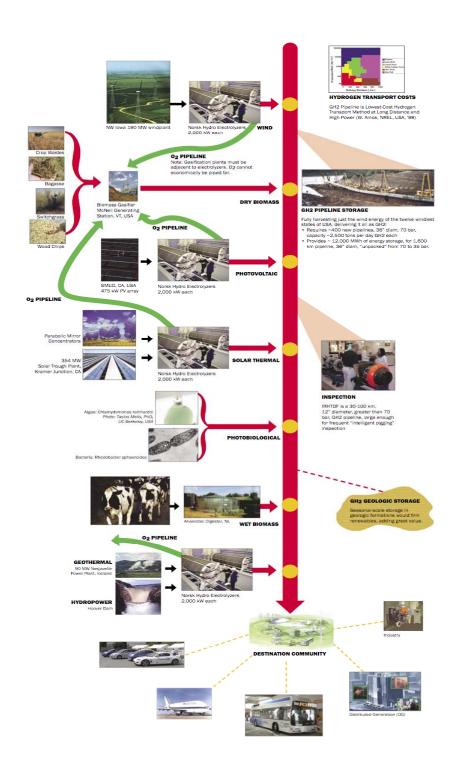












International Renewable Hydrogen Transmission Demonstration Facility (IRHTDF) Pilot plant

Global opportunity: IPHE project

Humanity's Goal

- International Collaboration
- Alternatives to electricity
- R & D
- Pilot plant demonstrations

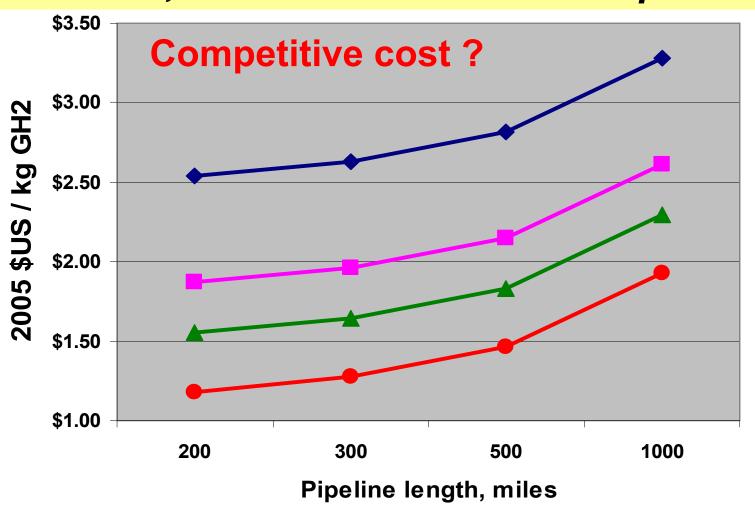
Funding?

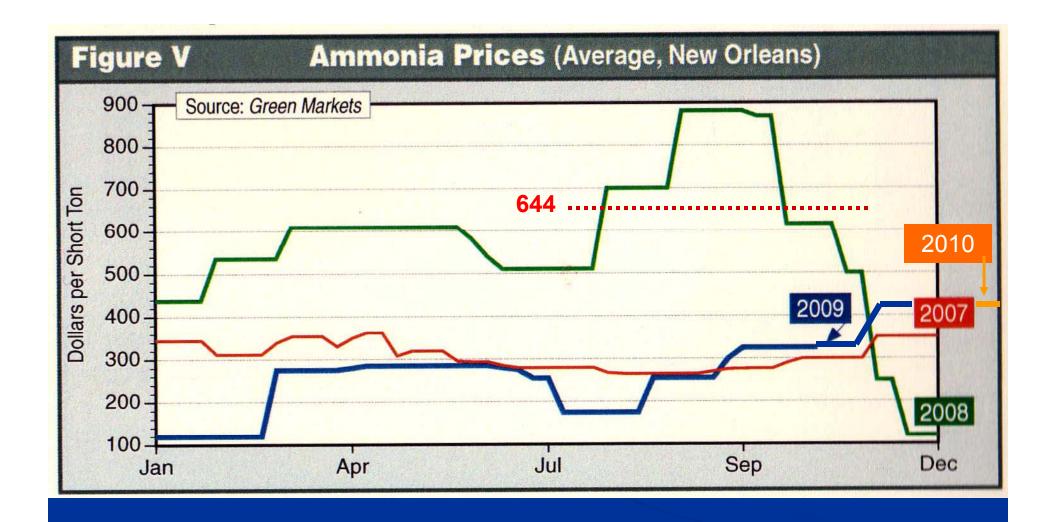
- China, Korea, others
- Big oil
- Military spending
- Global C-tax
- Capital markets

GW-scale Transmission + Storage Options

- Electricity: HVAC, HVDC
 - CAES compressed air energy storage
 - Vanadium Redox battery (VRB Power Systems)
 - Sodium-sulfur battery
 - PHEV, BEV (distributed)
- Gaseous Hydrogen (GH2)
 - Pipeline
 - Geologic: salt caverns (man-made)
 - Geologic: natural formations? Terra incognita
- Liquid Hydrogen (LH2)
 - Pipeline, truck, rail car, ship
 - 1/3 energy to liquefy Ammonia (NH3) liquid
 - Tank, refrigerated, 10K 60K ton
 - Truck, rail car, ship
- Liquid anhydrous ammonia (NH3)
 - Pipelines
 - Tanks
- Liquid synthetic HC's zero net C
 - Pipeline
 - Tank, truck, rail car, ship
 - Geologic: salt caverns (man made)
- "Energy Pipeline", EPRI: LH2 in pipeline, SC LVDC electric
- Chemicals
 - Hydrides
 - Al Ga ← → Alumina

OPTIMISTIC City-gate GH2 cost @ 15% CRF, 20" pipeline, from 2,000 MW Great Plains windplant

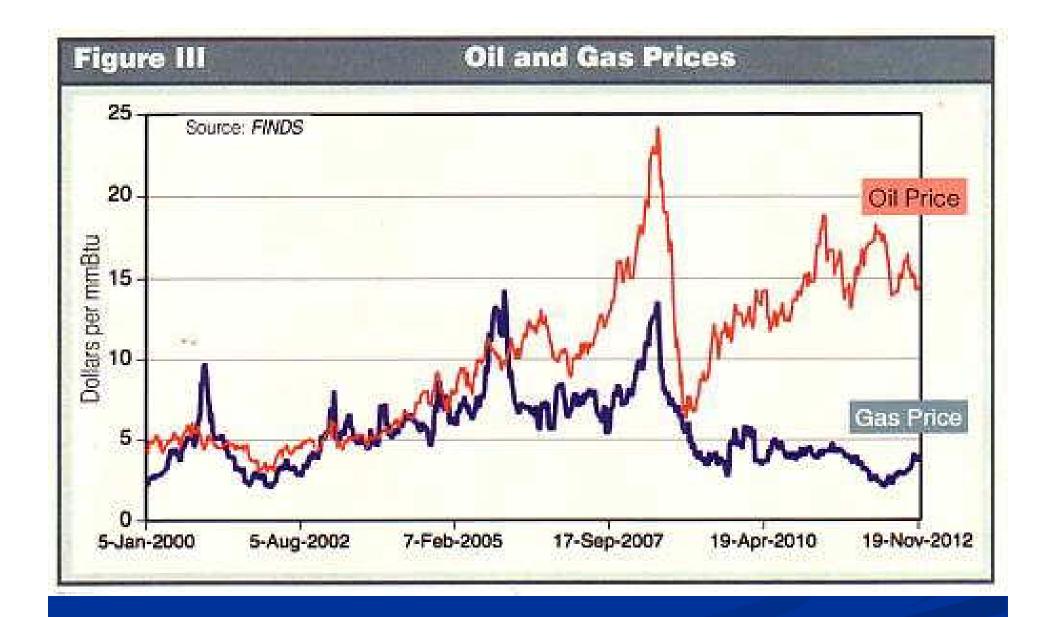




Anhydrous Ammonia (NH3) wholesale price, NOLA (New Orleans, LA)



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



Oil and Natural Gas Prices, late 2012

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?

Alaska Energy Authority Emerging Energy Technology Fund \$750K grant to Alaska Applied Sciences, Inc.

- SSAS Proof-of-concept pilot plant
- Alaska applications
 - Village energy independence
 - RE export as NH3 fuel
 - Hydro firming, annual-scale
- 2-year project

Project Fundamentals

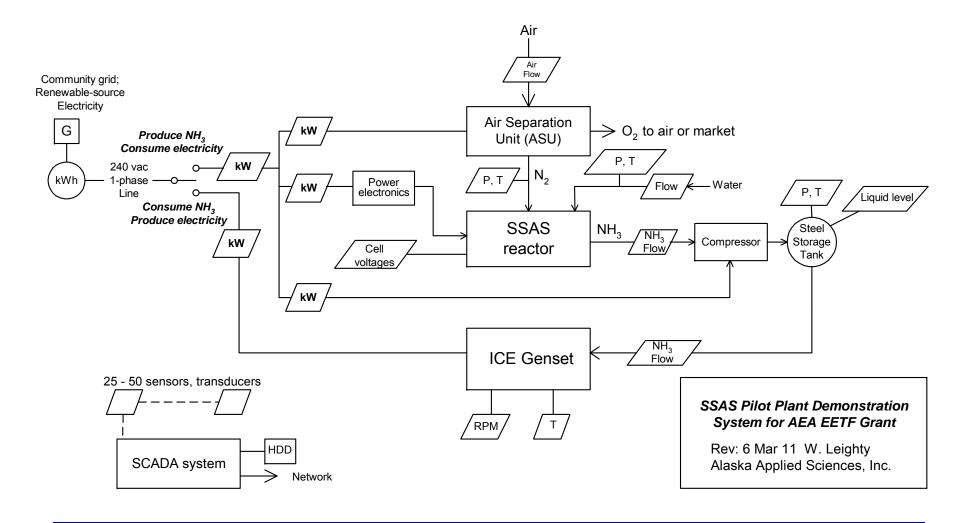
- 1. Anhydrous ammonia (NH3) is a fuel and transmission and low-cost energy storage medium
- 2. NH3 made from renewable energy (RE) electricity, water, and air (Nitrogen, N2) by:
 - a. Electrolysis + Haber-Bosch (EHB)
 - b. Solid State Ammonia Synthesis (SSAS)
- 3. SSAS should best EHB in:
 - a. Capital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

Project Fundamentals

- 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 - NH₃ SSAS Storage System

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

Humanity's Goal

A global, sustainable, benign, equitable, energy economy

Humanity's Goal

- International Collaboration
- Alternatives to electricity
- R & D
- Pilot plant demonstrations

Funding?

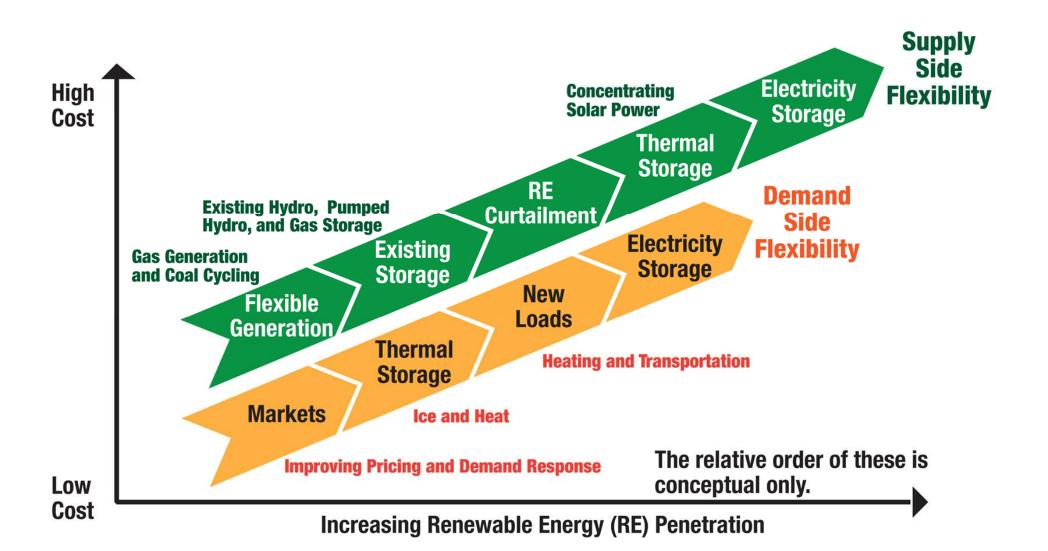
- China, Korea, others
- Big oil
- Military spending
- Global C-tax
- Capital markets: Mike Eckhart, 19 Oct

Trouble with Renewables: Electricity Transmission

- Grid nearly full
 - New must pay for transmission
 - Costly: AC or DC
- Integration
 - Continental energy system
 - Quality
 - Generation O+M: fatigue, wear, low efficiency
- Low capacity factor (CF) or curtailment
- Costly "firming" storage: CAES, VRB
- Overhead vulnerable: God or man
- Underground: Only HVDC, 6x cost
- FERC no interstate jurisdiction
- Wide ROW
- NIMBY: site, ROW delay + cost



Flexibility Supply Curve



NREL: Systems Integration

Exporting From 12 Windiest Great Plains States

Number of GH2 pipelines or HVDC electric lines necessary to export total wind resource Wind energy source: PNL-7789, 1991 * at 500 miles average length

State	AEP, TWh	Wind Gen MW (nameplate) (40% CF)	6 GW 36" GH2 export pipelines	\$ Billion Total Capital Cost *	3 GW export HVDC lines	\$ Billion Total Capital Cost *
North Dakota	1,210	345,320	50	50	100	60
Texas	1,190	339,612	48	48	100	60
Kansas	1,070	305,365	43	43	100	60
South Dakota	1,030	293,950	41	41	100	60
Montana	1,020	291,096	41	41	90	54
Nebraska	868	247,717	35	35	80	48
Wyoming	747	213,185	30	30	70	42
Oklahoma	725	206,906	29	29	60	36
Minnesota	657	187,500	26	26	60	36
lowa	551	157,249	22	22	50	30
Colorado	481	137,272	19	19	40	24
New Mexico	435	124,144	17	17	40	24
TOTALS	9,984	2,849,316	401	\$ 401	890	\$ 534

Stanford wind energy study: 2003

- Underestimated: PNNL, NREL
- 80 m hub height
- 1.3 1.7 m / s faster windspeed
- IF transmission network: steady, reliable, abundant supply

"Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements"

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D9, 4289, 2003

Jan '09 Transmission Backlog

California: 13 GW wind

30 GW solar

Upper Midwest 70 GW wind

Lower Midwest 40 GW wind

Great Lakes + Mid Atlantic 40 GW wind

Texas
 50 GW wind

Total 243 GW

Potential Great Plains Wind 3,000 GW

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

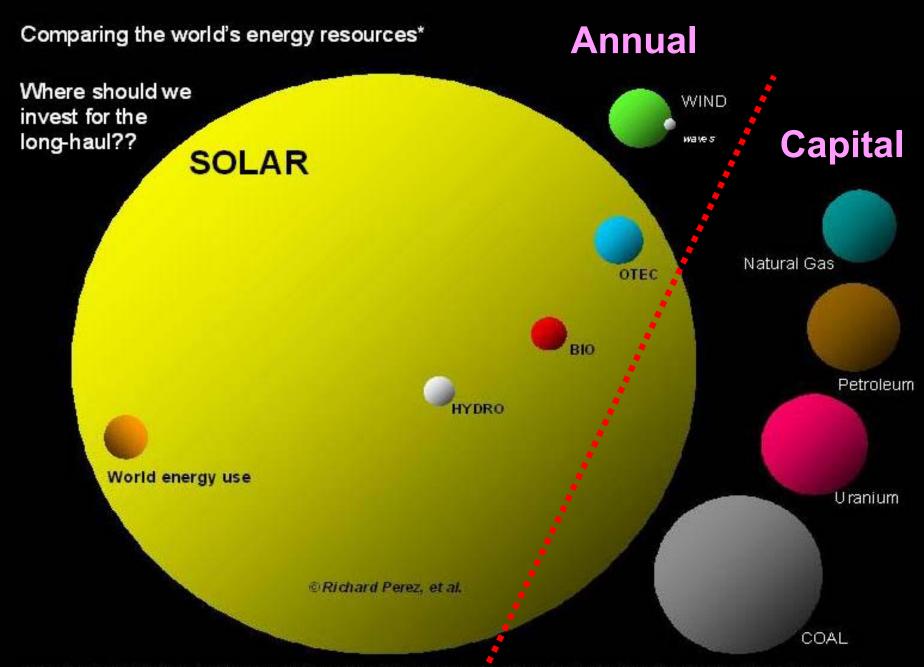
EETF Emerging Energy Technology Fund, State of Alaska

AEA Alaska Energy Authority, State of Alaska

AASI Alaska Applied Sciences, Inc.

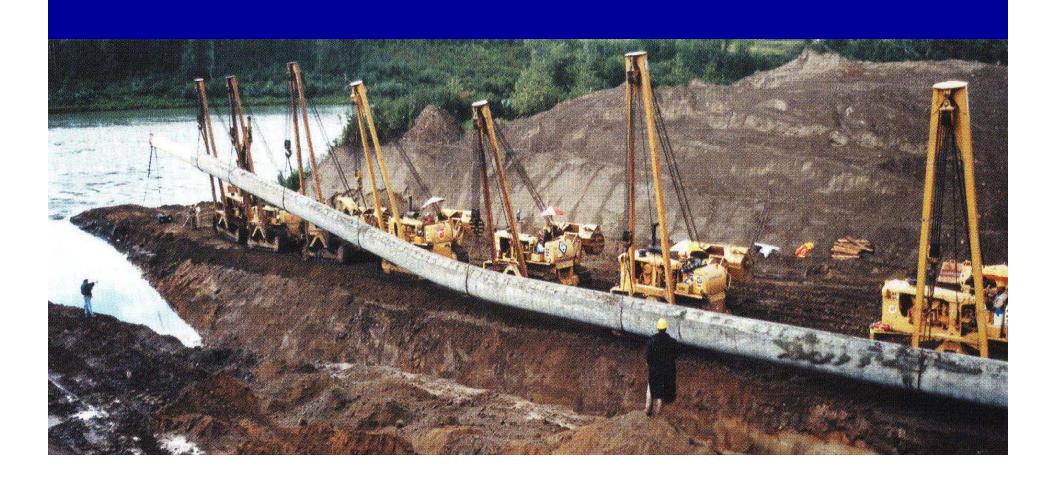
SSAS Pilot Plant Schedule: 24 months from ~ Dec '12

- 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



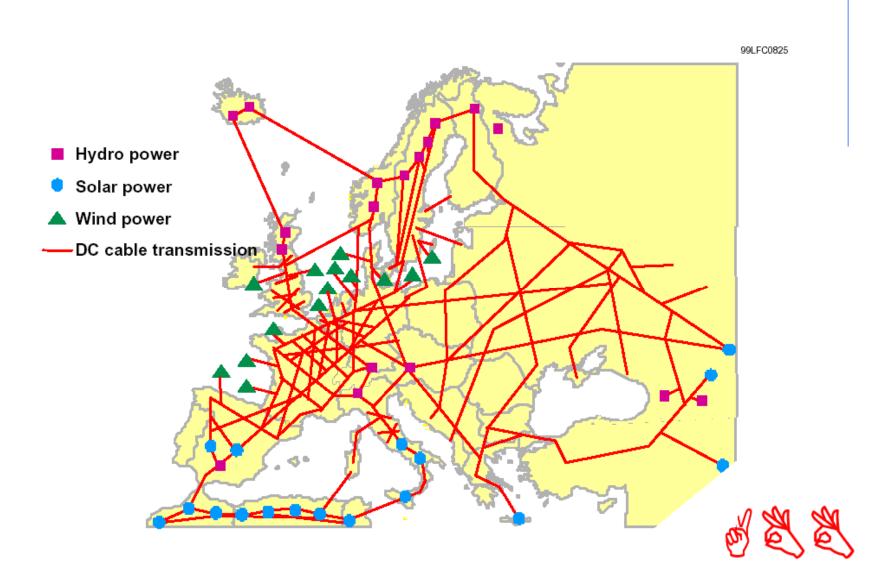
*yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. Word energy use is annual.

Gaseous Hydrogen (GH2) 36" diam, 500 miles No compression 8,000 MW



Vision: Remote renewable energy sources

connected to loads by DC grid



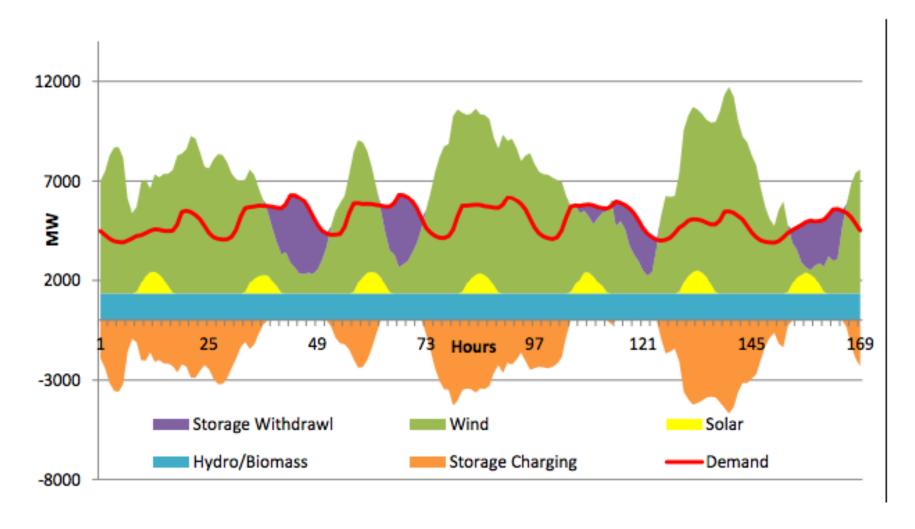
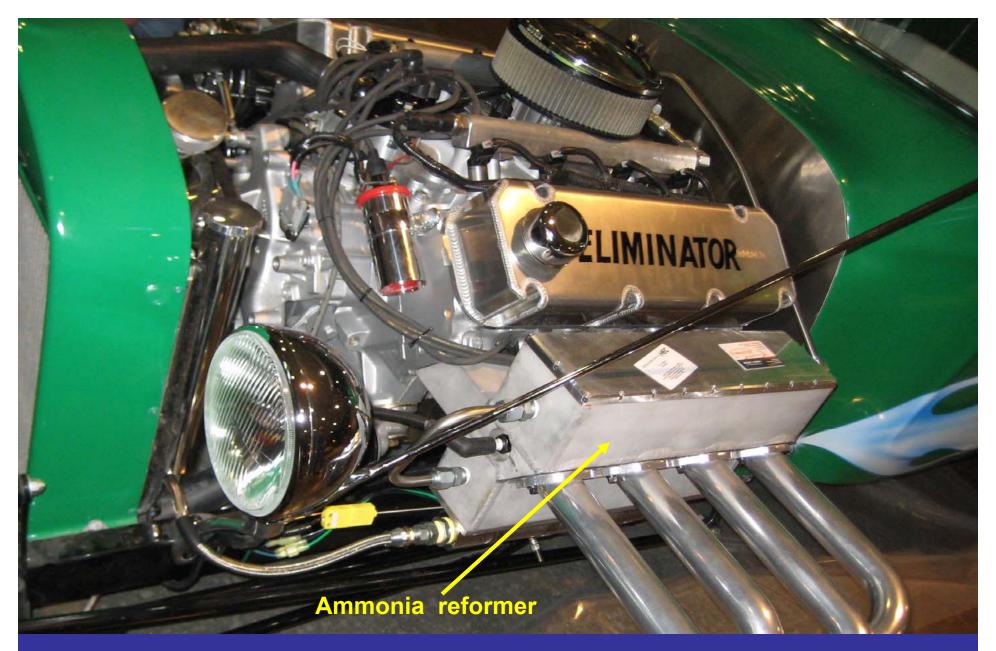


Figure III-6: Hourly supply and demand with storage, January 1-7, 2007. Source: IEER.



Oct '09 Ammonia Fueled V-8 with Hydrogen Injection: Reformed from NH₃
Hydrogen Engine Center, Algona, IA
2009