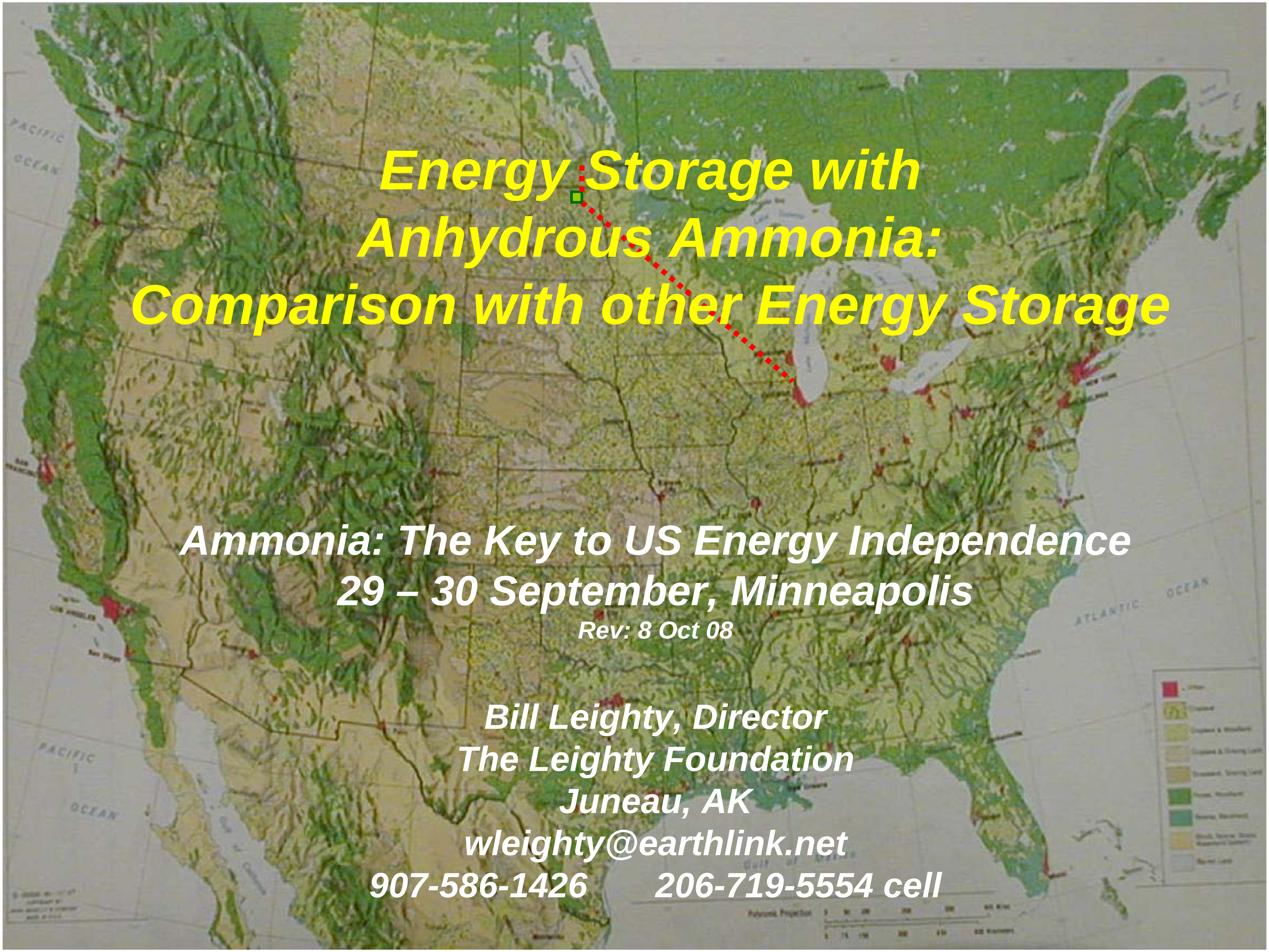

Energy Storage with Anhydrous Ammonia: Comparison with other Energy Storage

Ammonia: The Key to US Energy Independence
29 – 30 September, Minneapolis
Rev: 8 Oct 08

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Energy Storage Alternatives

"Electricity"

- Batteries
  - Lead-acid
  - Nickel-cadmium
  - Lithium ion
  - Sodium sulfur
- Pumped hydro (PHS)
- Compressed air (CAES) (large ans small scale)
- Natural gas - coupled (NGS)
- Flow batteries (FBES)
- Flywheel (FES)
- Superconducting magnetic (SMES)
- Supercapacitors

Energy Storage Alternatives

Other

- Natural gas
- Chemical
- Synthetic hydrocarbons (HC's) (FTL's)
- Thermal energy (TES)
- NEW
  - Compressed hydrogen (35 – 70 bar typical) → ICE or fuel cell (FC-HES)
  - "Hydricity"
    - Conversion from / to electricity
    - Hydrogen in caverns and pipelines
    - LH2: liquid hydrogen
  - Ammonia liquid in tanks

Energy Storage System Characteristics - A

- **Storage capacity (Mwh, scf, nM3, Mt, gallons ….)**
- **Power (kW, MW, scfm, tpd, gpm ….) In / out rate**
- **Costs**
  - **Capital**
  - **O&M**
- **Efficiency**
- **Response time**
- **Durability (cycling capacity, lifetime)**
- **Depth of discharge**
- **Self-discharge**

Energy Storage System Characteristics - B

- **Reliability**
- **Autonomy**
- **Adaptation to the generating source**
- **Mass and volume energy density**
- **Monitoring and control equipment**
- **Operational constraints**
- **Feasibility**
- **Environmental**
- **Safety**

Benefit / Cost Perspective

- **This presentation:**
  - **Analytical framework**
  - **Not all answers**
- **Must think long-term**
- **Benefits: aggregate; external**
- **Costs: aggregate; external**
- **Systems thinking → tech, econ analysis**

Pickens Plan

- Bold, large-scale, motivates thinking
- GW scale: economies
- Underestimates
  - Transmission cost, obstacles
  - Grid integration, thermal gen plant abuse
  - Firming storage needed
- Disregards Hydrogen demand
  - Gulf Coast refineries
  - Transport fuel
- Disregards Ammonia demand
  - Fertilizer
  - Fuel
- Attract new turbine manufacturers, designs ?

The Great Plains Wind Resource

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
Iowa	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**

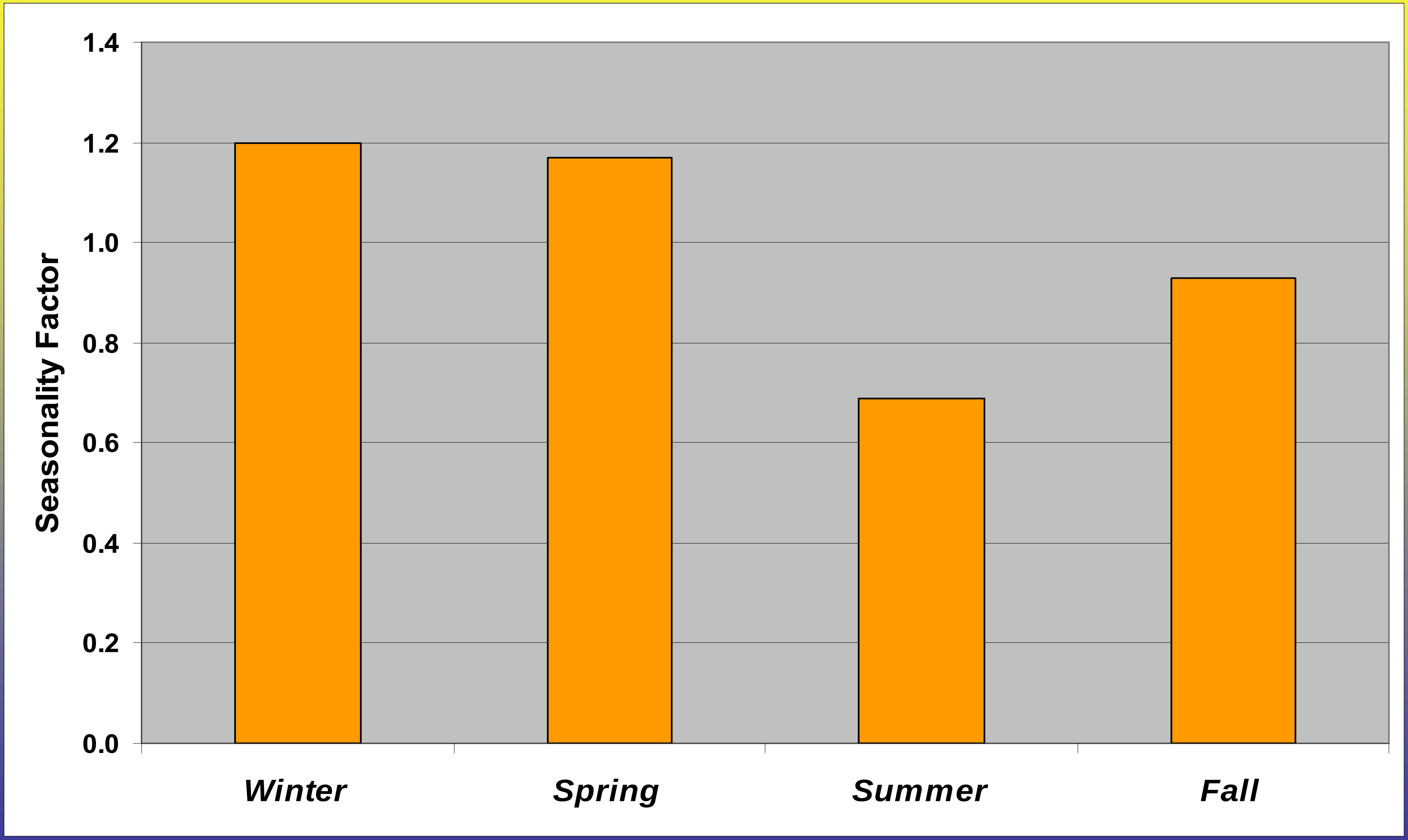
Wind seasonality, Great Plains
Normalized to 1.0 per season

- **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



Annual – scale "Firming"
Great Plains Wind

- **Potential, 12 states, ~50% of land area:**
  - **10,000 TWh = 100 quads = entire USA energy, all sources, all uses**
  - **2,800,000 MW nameplate**
- **Seasonality:**
  - **Summer minimum**
  - **Spring – Summer maximum storage**
  - **"Firming" energy storage need per 1,000 MW wind = 450 GWh**

NH_3 Ag Fertilizer Tanks, Wind Generators, NW Iowa

"Nurse tanks"

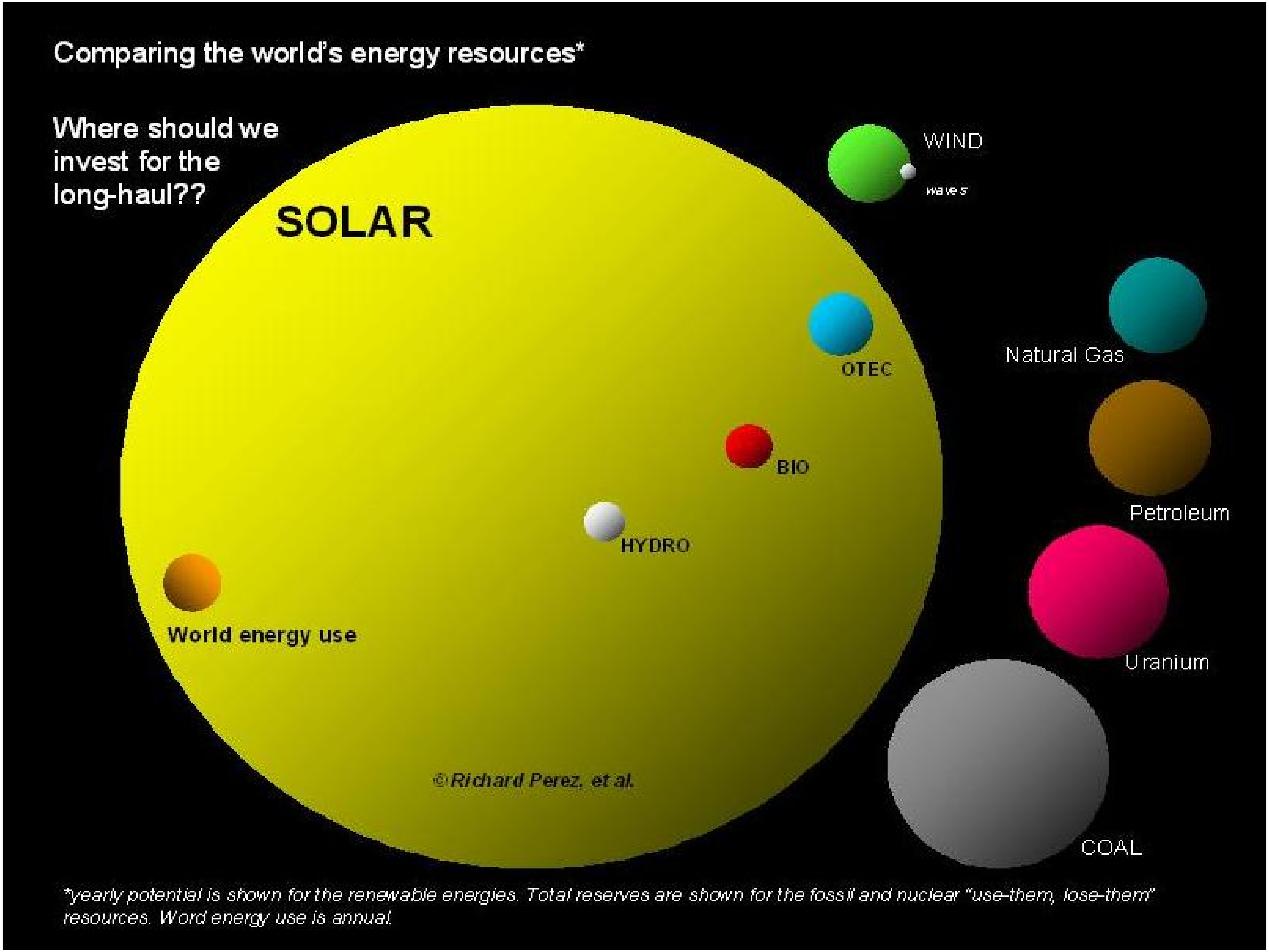
- **Cost 1,000 gallon $ 6,321**
- **Cost 1,450 gallon $ 9,502**
- **Usually owned by Co-ops**

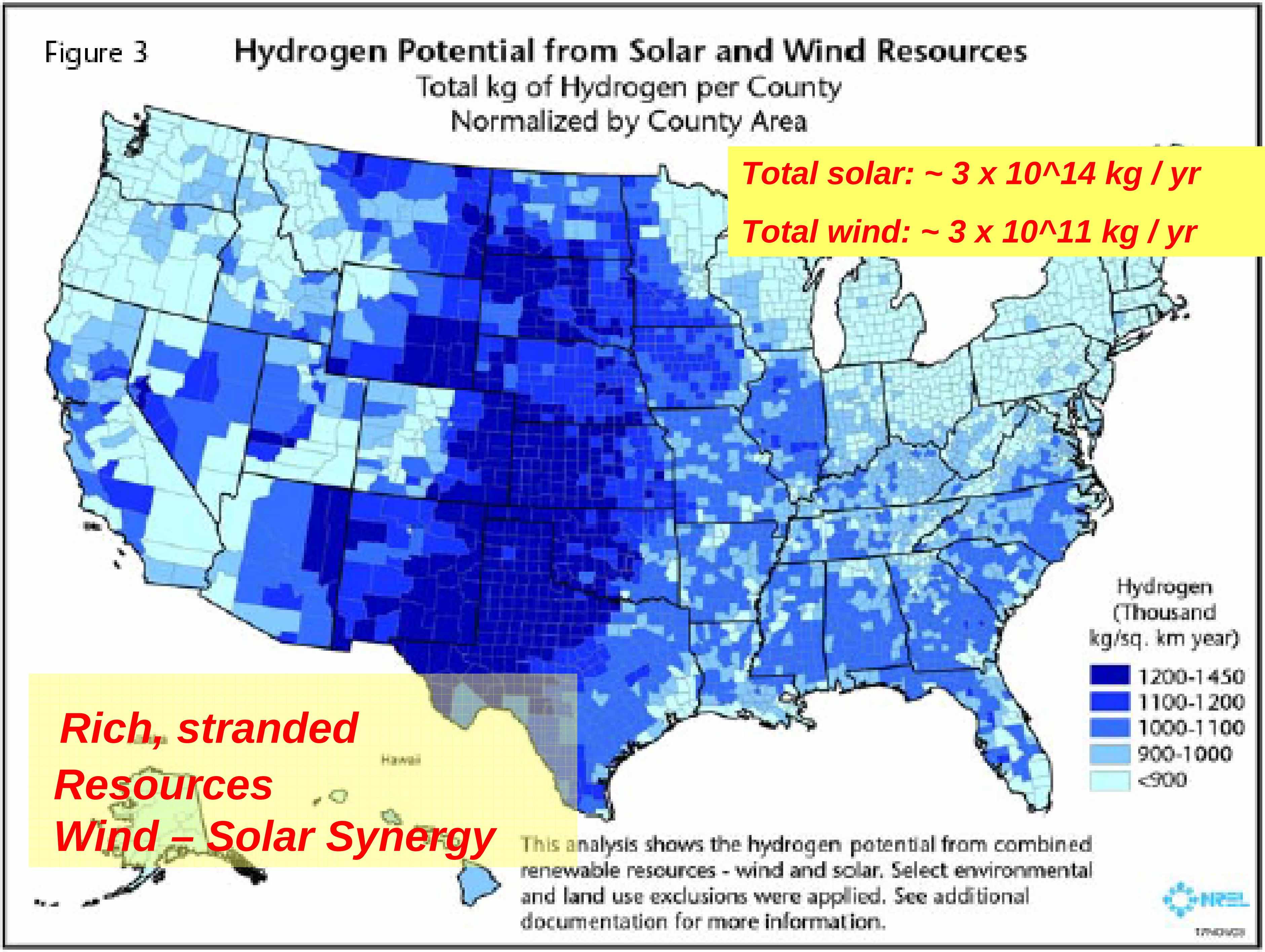
Ammonia

620 kg H_2

Hydrogen gas

350 kg H_2


Comparing the world's energy resources*
Where should we invest for the long-haul??
SOLAR
WIND
waves
OTEC
Natural Gas
BIO
Petroleum
HYDRO
World energy use
Uranium
© Richard Perez, et al.
COAL
*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.



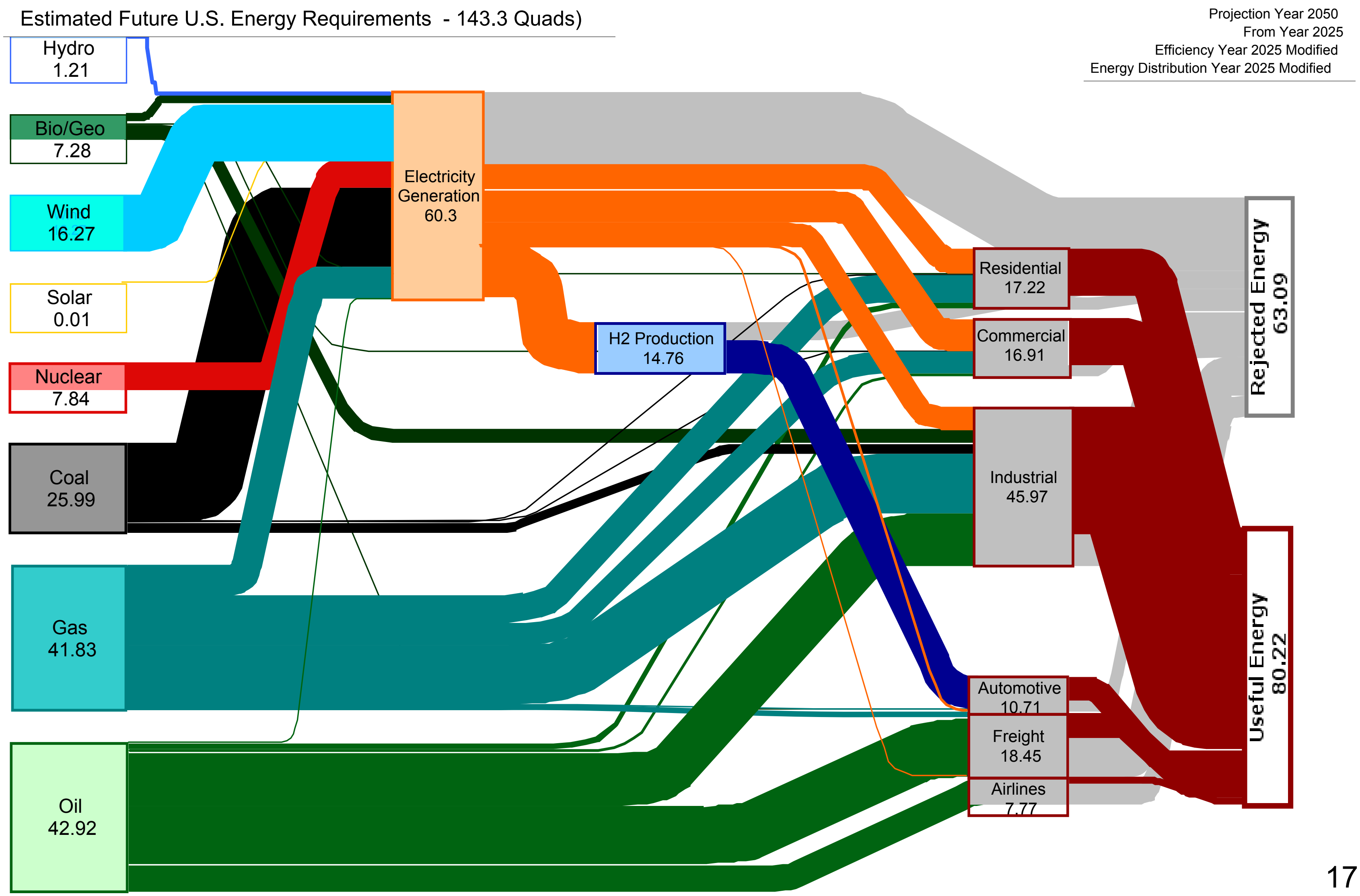
Total solar: ~ 3 x 10^14 kg / yr

Total wind: ~ 3 x 10^11 kg / yr

Rich, stranded Resources

Wind – Solar Synergy

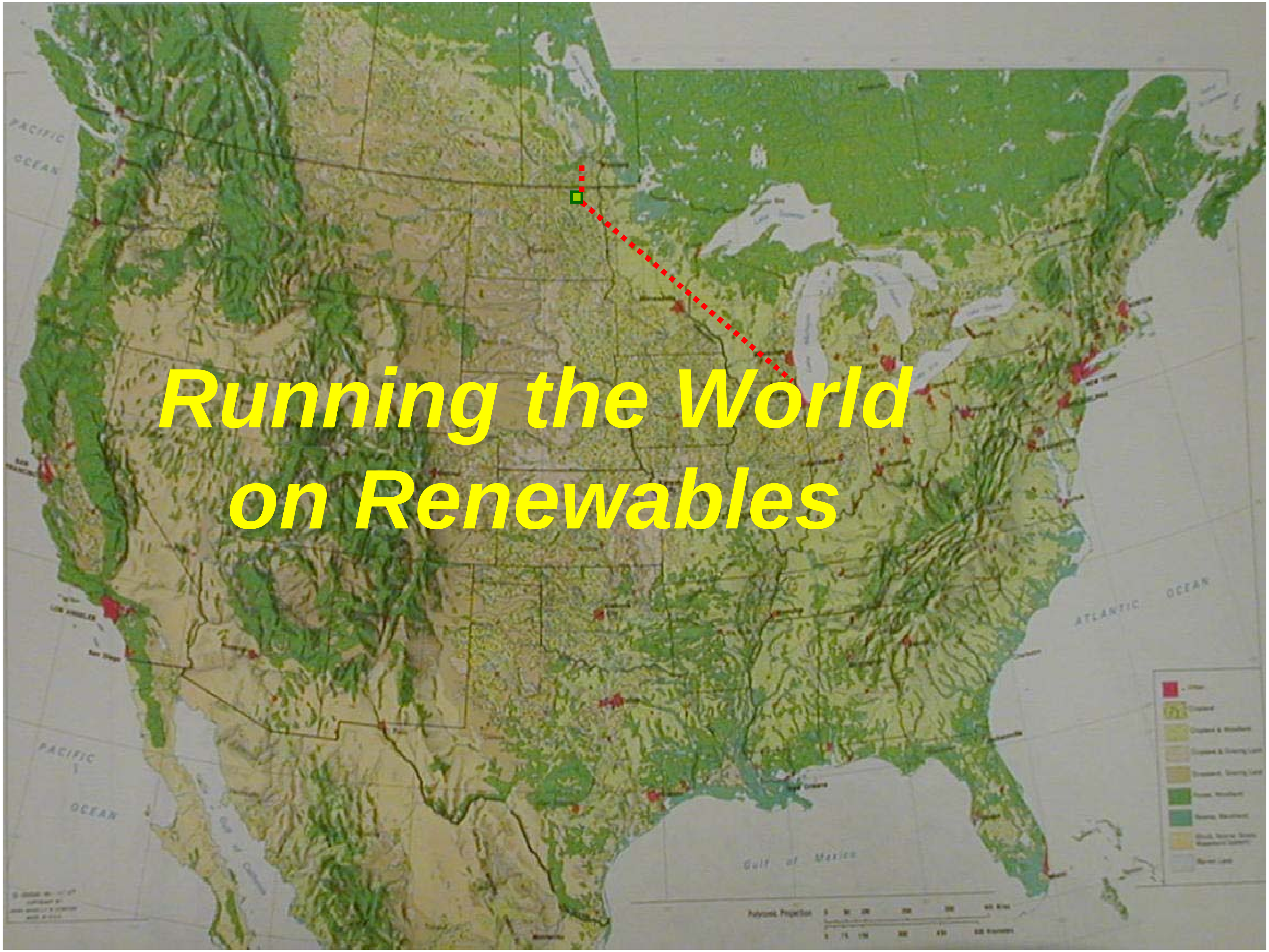
USDOE-EIA: Estimated 2050 energy use (All auto fleet using H_2 from wind electrolysis)



The Great Plains Wind Resource

How shall we bring the large, stranded, Great Plains *renewables* to market ?

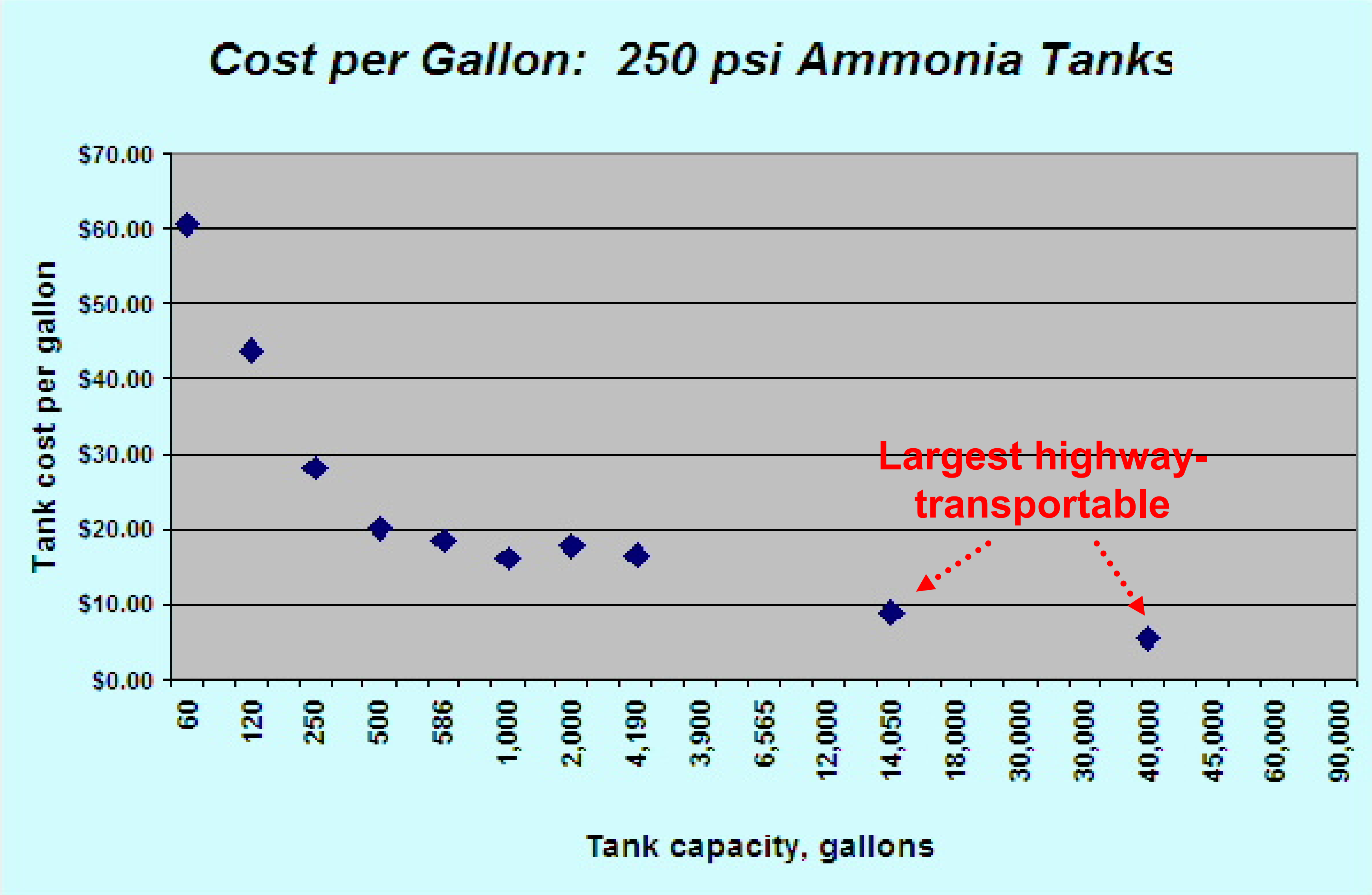
Running the World on Renewables

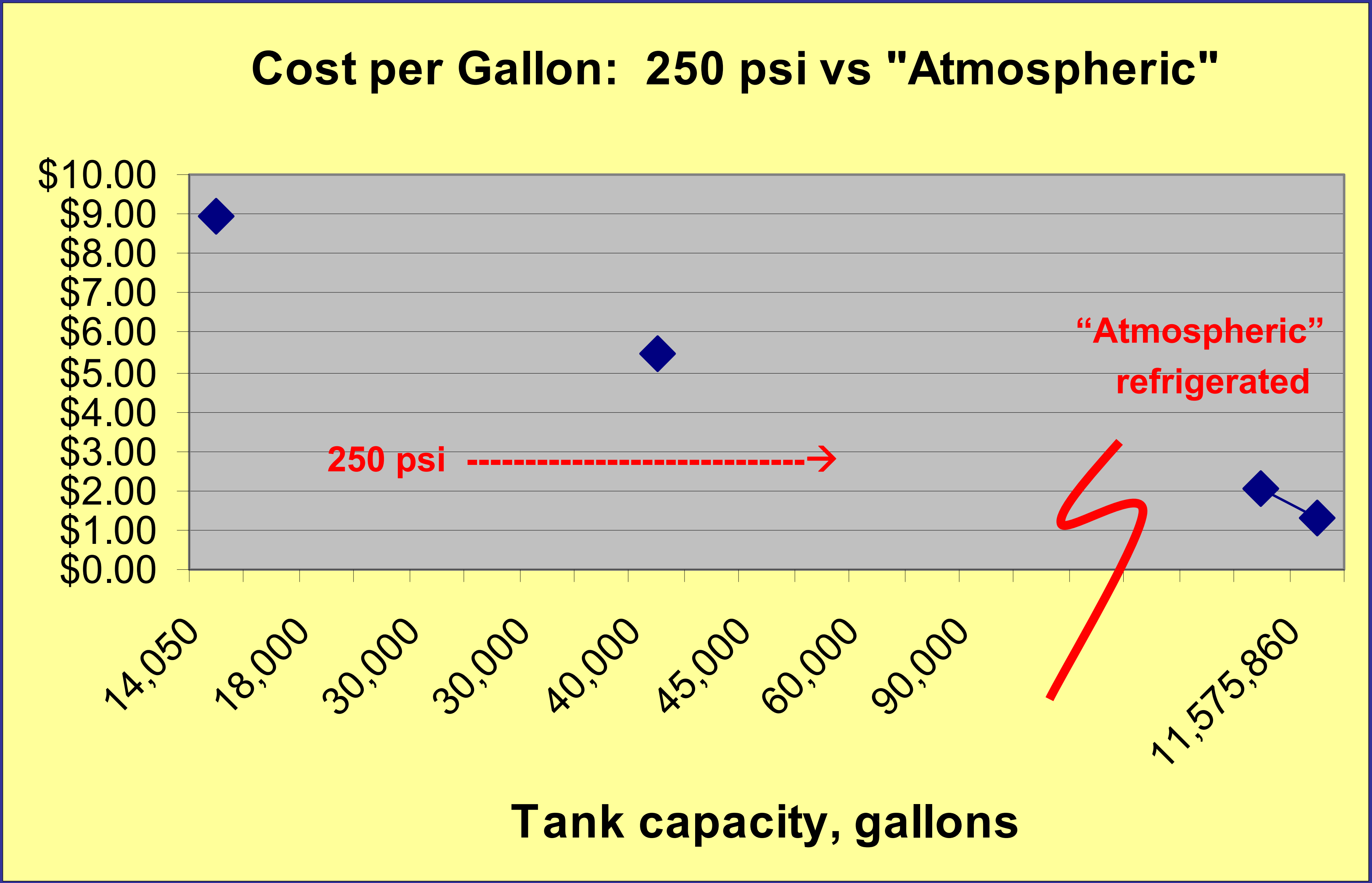


The Trouble with Renewables

- Diffuse, dispersed: gathering cost
- Richest are remote: “stranded”
- Time-varying output:
  - “intermittent”
  - “firming” storage required
- Transmission:
  - Costly: $B
  - Low capacity factor (CF) or curtailment
  - NIMBY
- Distributed or centralized ?

Liquid Ammonia Tank Storage




Cost per Gallon: 250 psi vs "Atmospheric"
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
14,050
18,000
30,000
30,000
40,000
45,000
60,000
90,000
11,575,860
250 psi ----------------------------→
"Atmospheric"
refrigerated
Tank capacity, gallons

“Atmospheric”

Liquid Ammonia Storage Tank

30,000 Tons

$15M turnkey

-33 C

1 Atm

Hydrogen vs Ammonia Storage: Large-scale, capital cost per MWh

GH2 salt cavern: **$ 120 → $ 55**

- **150 bar, 200,000 m^3 physical**
- **$70 → $30 per m^3 physical**
- **Alton project, Nova Scotia: new, bedded, 5-15 caverns**

NH3 tank **$ 60**

- **30,000 Mt optimal econimic size**
- **“Atmospheric” refrigerated**

Diesel, large surface tanks **$??**

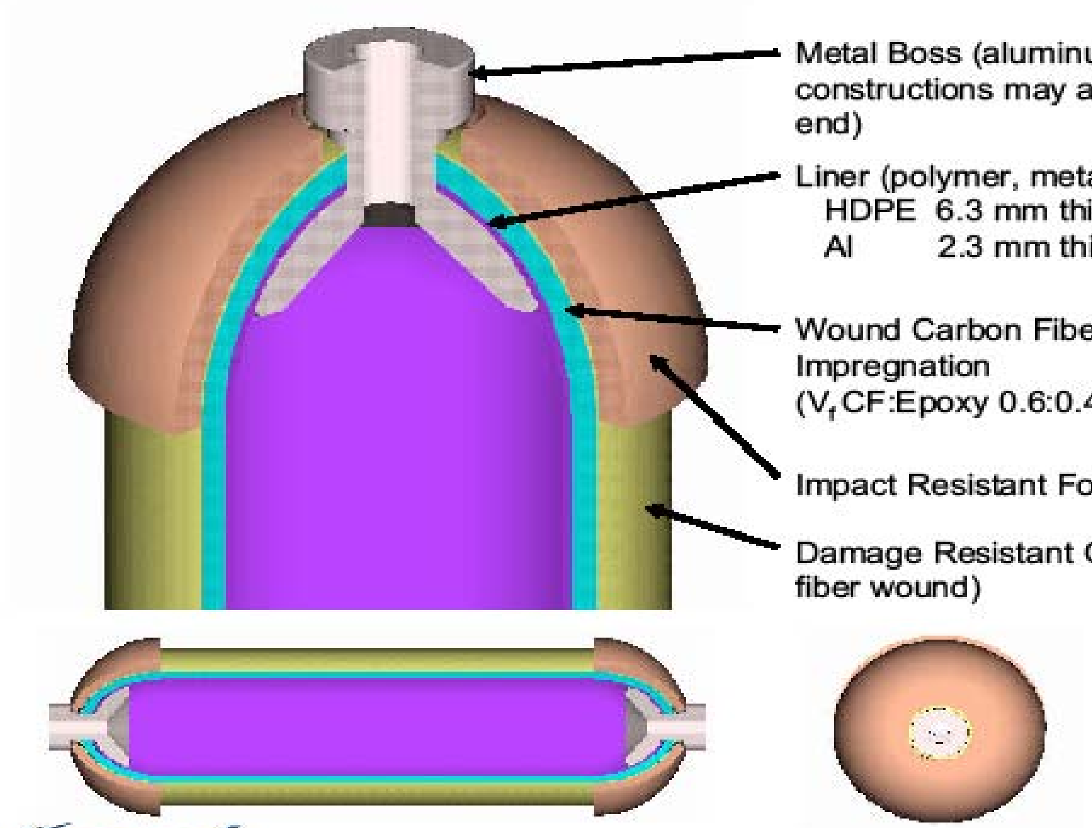
Personal Vehicle On-board Storage 300 mile range: estimated OEM cost per vehicle

	Storage cost	Hybrid drive train efficiency	Storage capacity
Gasoline, diesel	$ 100	25 %	10 gal
Electricity: batteries	$ 10,000	90 %	? kWh
CNG	$ 300	25 %	? scf
H2 (70 bar) ICEHV	$ 4,000	35 %	5 kg
H2 (70 bar) FCHEV	$ 3,000	60 %	3 kg
Ammonia (20 bar)	$ 300	45 %	15 gal

35 – 70 bar Gaseous Hydrogen On-board Vehicle Storage: ~ $ 3,000

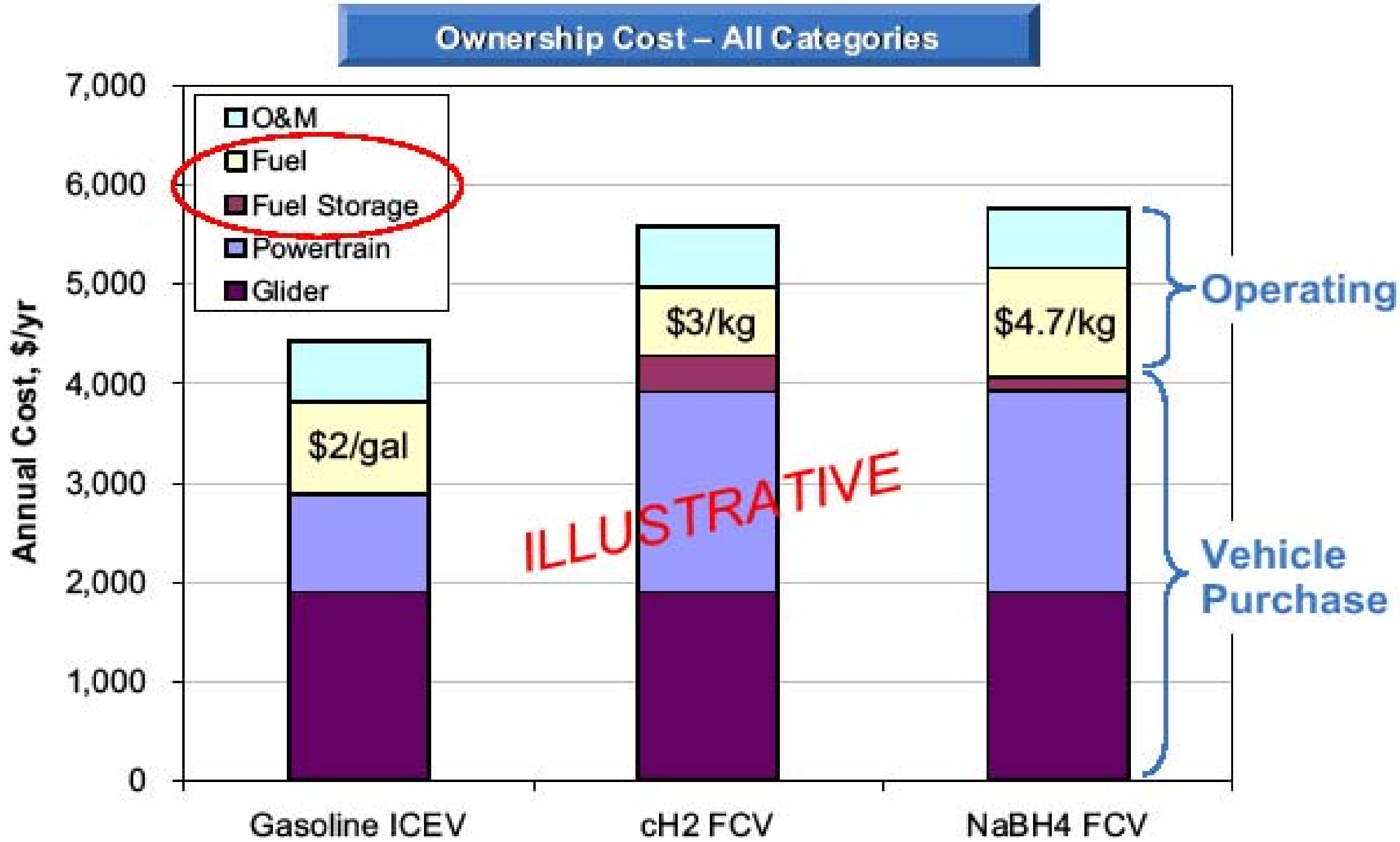
Preliminary Results – Do Not Cite

Under a previous DOE contract, we evaluated the cost of compressed H_2 tank systems designed to accommodate 5,000 and 10,000 psi pressures.



Car Ownership Cost – GH2 fueled

A complete ownership cost assessment will require that both vehicle purchase cost and operating costs be considered.



Benefit / Cost Perspective

- **Analytical framework: Not all answers**
- **Long-term**
- **Benefits**
- **Costs**
- **Systems thinking → tech, econ analysis**

1: Adequate Renewables

- **Run the world; humanity's <u>needs</u>**
- "Distributed" and "Centralized"
- Affordable, benign
- Diverse, synergistic
- Richest are "stranded"
  - Far from markets
  - No transmission

2: When we realize these as emergencies:

- Global Warming, Rapid Climate Change
- Energy Security and Cost
- Peak Oil and Natural Gas

We must quickly invest in:

- Energy conservation, efficiency
- Large, new energy supplies:
  - CO_2 – emissions - free
  - Indigenous
  - Both distributed, centralized

3: Shortest path to benign, secure, abundant energy

- Renewables
  - Diverse
  - Diffuse
  - Dispersed
- Centralized:
  - Large, rich; lower cost than distributed ?
  - **But stranded (no transmission)**
- Ammonia and Gaseous hydrogen (GH2) pipelines
  - Conversion, gathering
  - Transmission
  - Storage: tanks, salt caverns
  - Distribution
- Affordable annual-scale firming:
  - Ammonia: surface tanks
  - GH2: salt caverns – large, deep, solution-mined, geology-limited
- Pilot plants needed:
  - Every major new industrial process
  - IRHTDF

3: Shortest path to benign, secure, abundant energy

- Anhydrous Ammonia (NH3) pipelines, tanks
  - Conversion, gathering
  - Transmission
  - Storage: tanks
  - Distribution
- Pilot plants needed:
  - Every major new industrial process
  - ’08 Farm Bill Sec 9003:

    “Renewable Fertilizer Research”
- Gaseous Hydrogen (GH2) also candidate

4: Ammonia's principal value

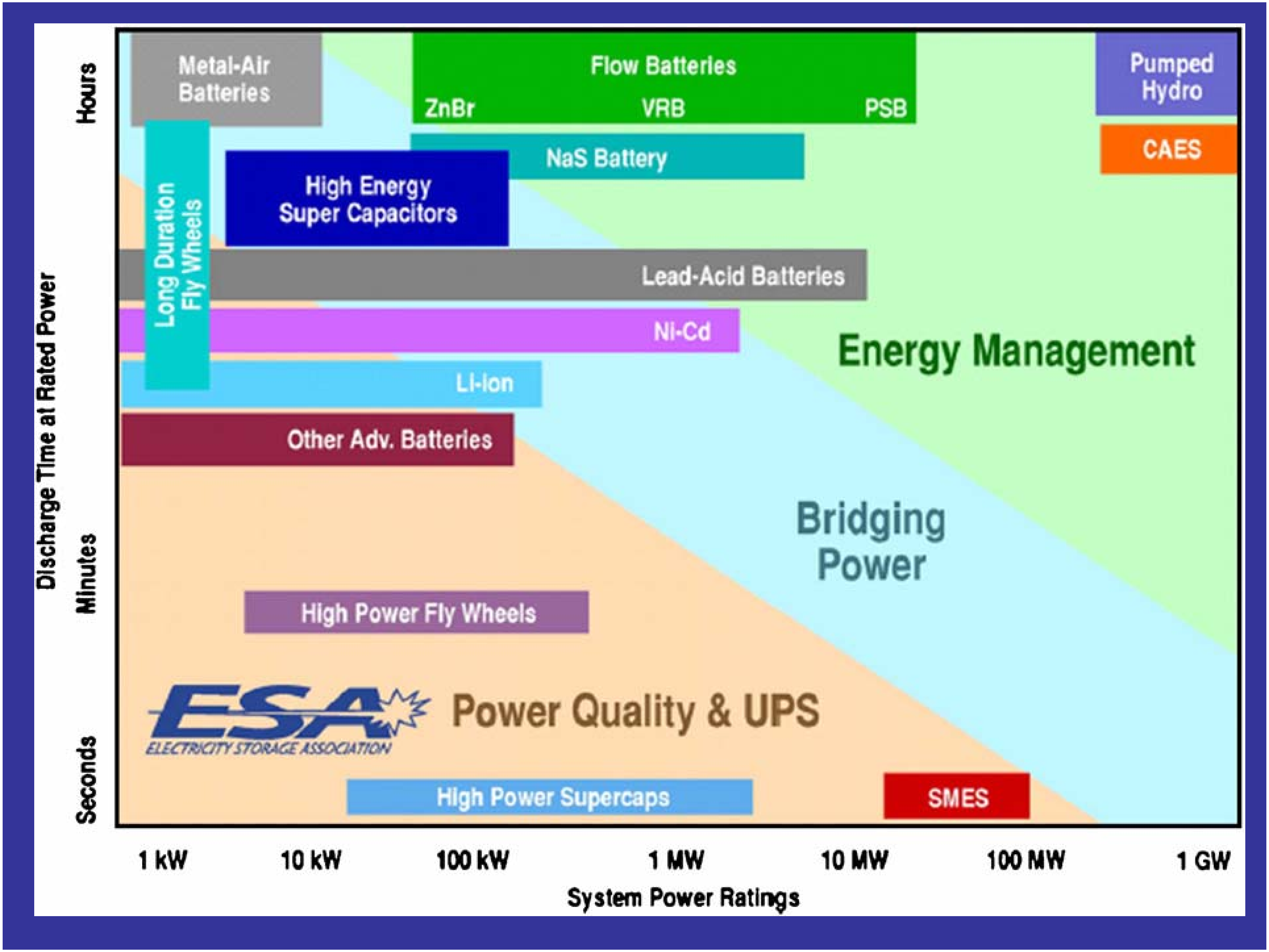
- NOT fuel or fertilizer
- Gather, transmit, store:
  - Large-scale, diverse, stranded renewables
  - FIRM time-varying-output renewables
    - Pipeline transmission, storage
    - "Renewables – nuclear Synergy …", C. Forsberg
- Benign, if from renewables
- Global opportunity
- Ammonia "sector", not "economy"
  - Transportation fuel: ground, air
  - DG electricity, CHP, retail value
  - Fertilizer

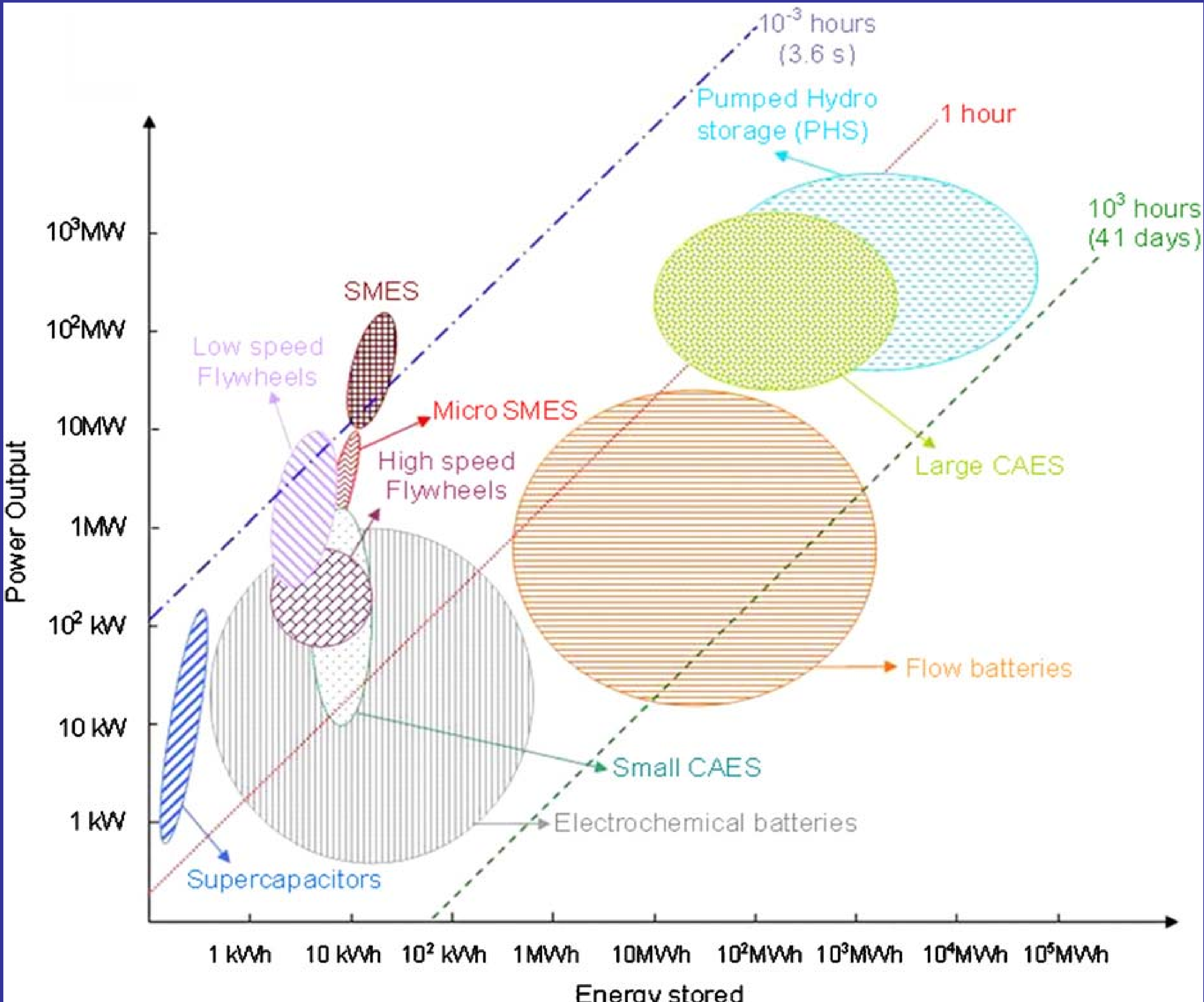
5: Pilot plants needed

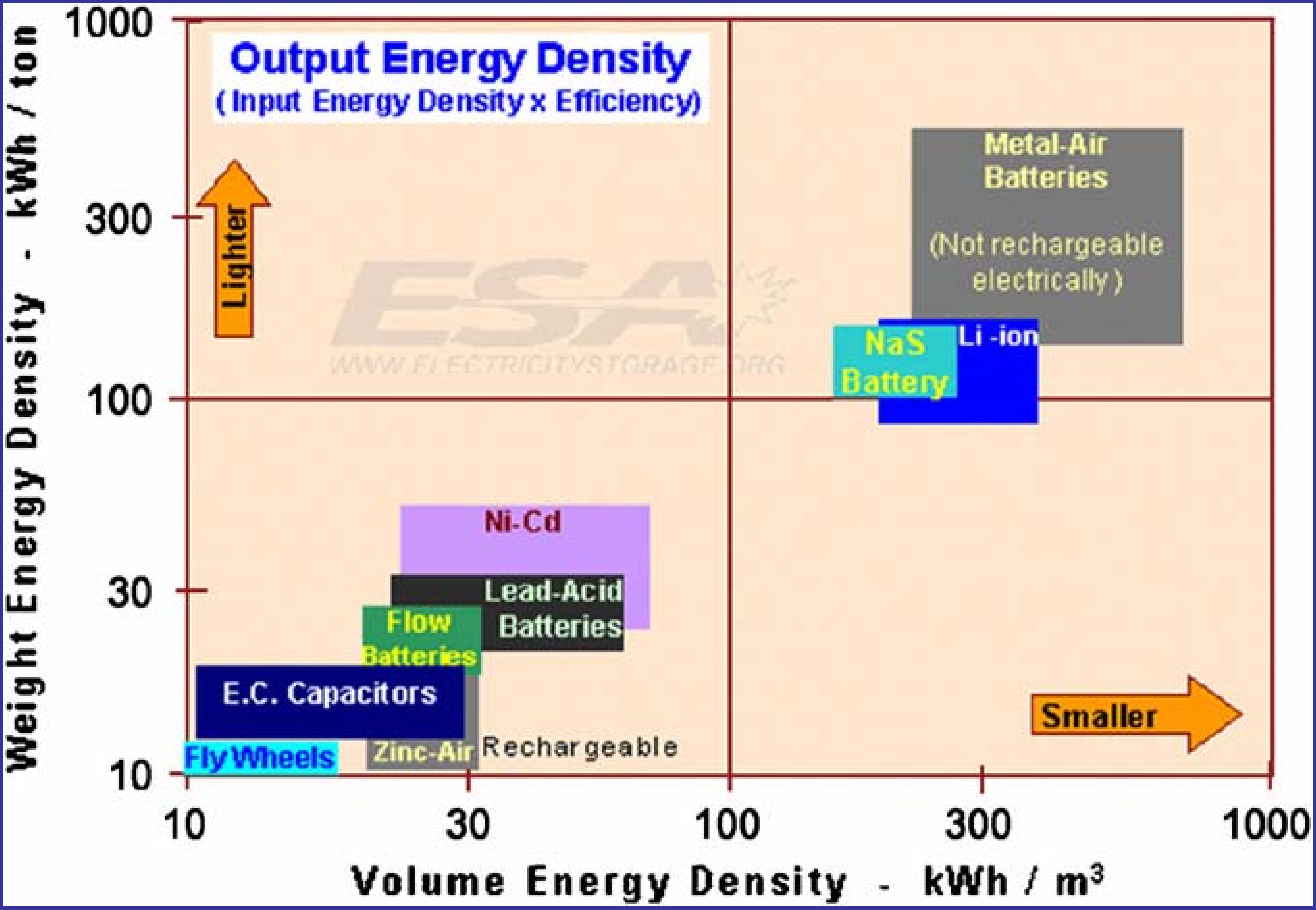
- **Every major new industrial process**
- **Diverse, large-scale, stranded**
- **Renewables-source systems**
- **IRHTDF ? International Renewable Hydrogen Transmission Demonstration Facility: include ammonia ?**

Energy Storage System Characteristics --
Ammonia off the charts ?

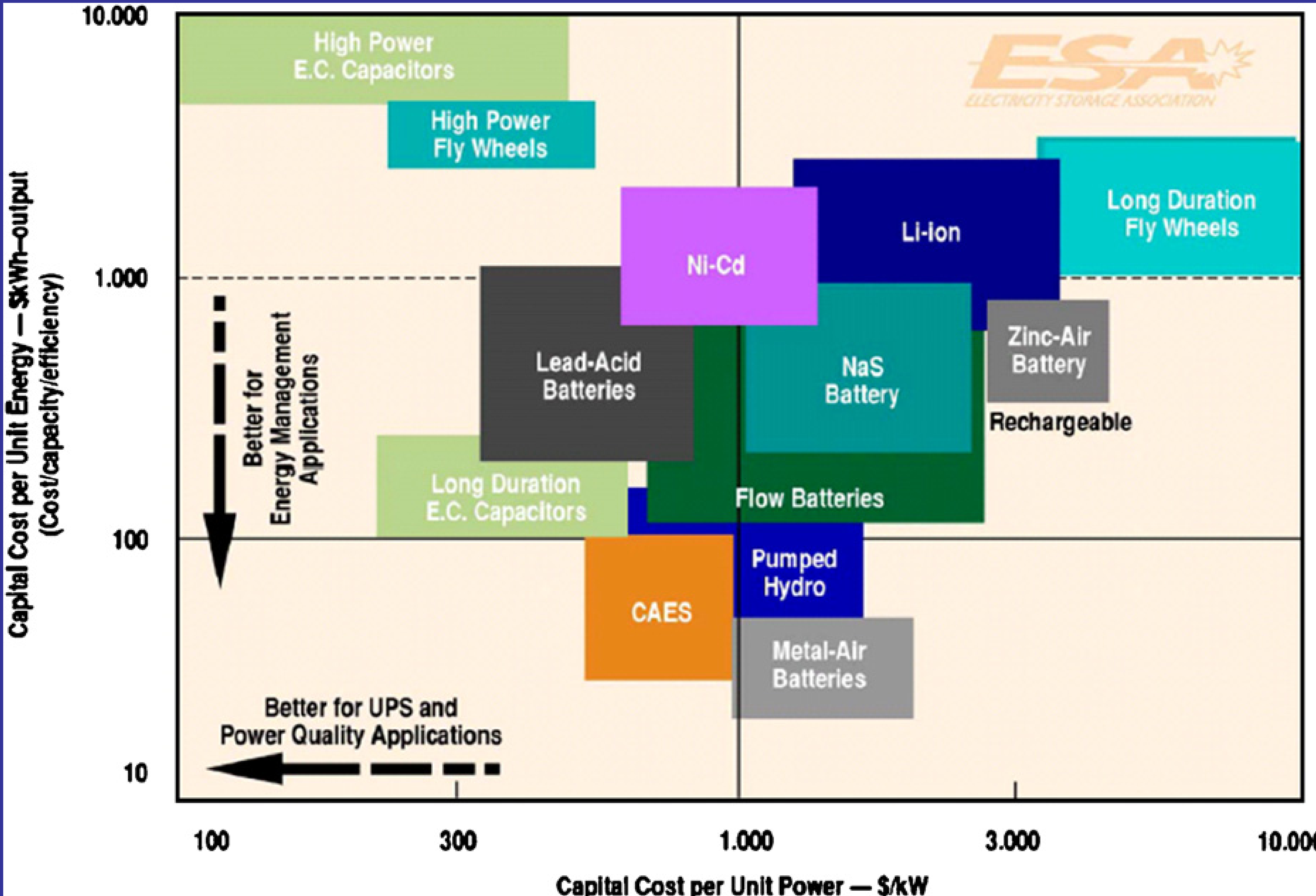
- **Storage capacity (Mwh, scf, nM3, Mt, gallons ….)**
- **Power (MW, scfm ….)   In / out rate**
- **Costs**
  - **Capital**
  - **O&M**
- **Efficiency**
- **Response time**
- **Durability (cycling capacity)**
- **Reliability**
- **Autonomy**
- **Self-discharge**
- **Depth of discharge**
- **Adaptation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


Metal-Air Batteries
Flow Batteries
ZnBr
VRB
PSB
Pumped Hydro
CAES
NaS Battery
High Energy Super Capacitors
Long Duration Fly Wheels
Lead-Acid Batteries
Ni-Cd
Energy Management
Li-Ion
Other Adv. Batteries
Bridging Power
High Power Fly Wheels
ESA
ELECTRICITY STORAGE ASSOCIATION
Power Quality & UPS
High Power Supercaps
SMES
Hours
Minutes
Seconds
Discharge Time at Rated Power
1 kW
10 kW
100 kW
1 MW
10 MW
100 MW
1 GW
System Power Ratings

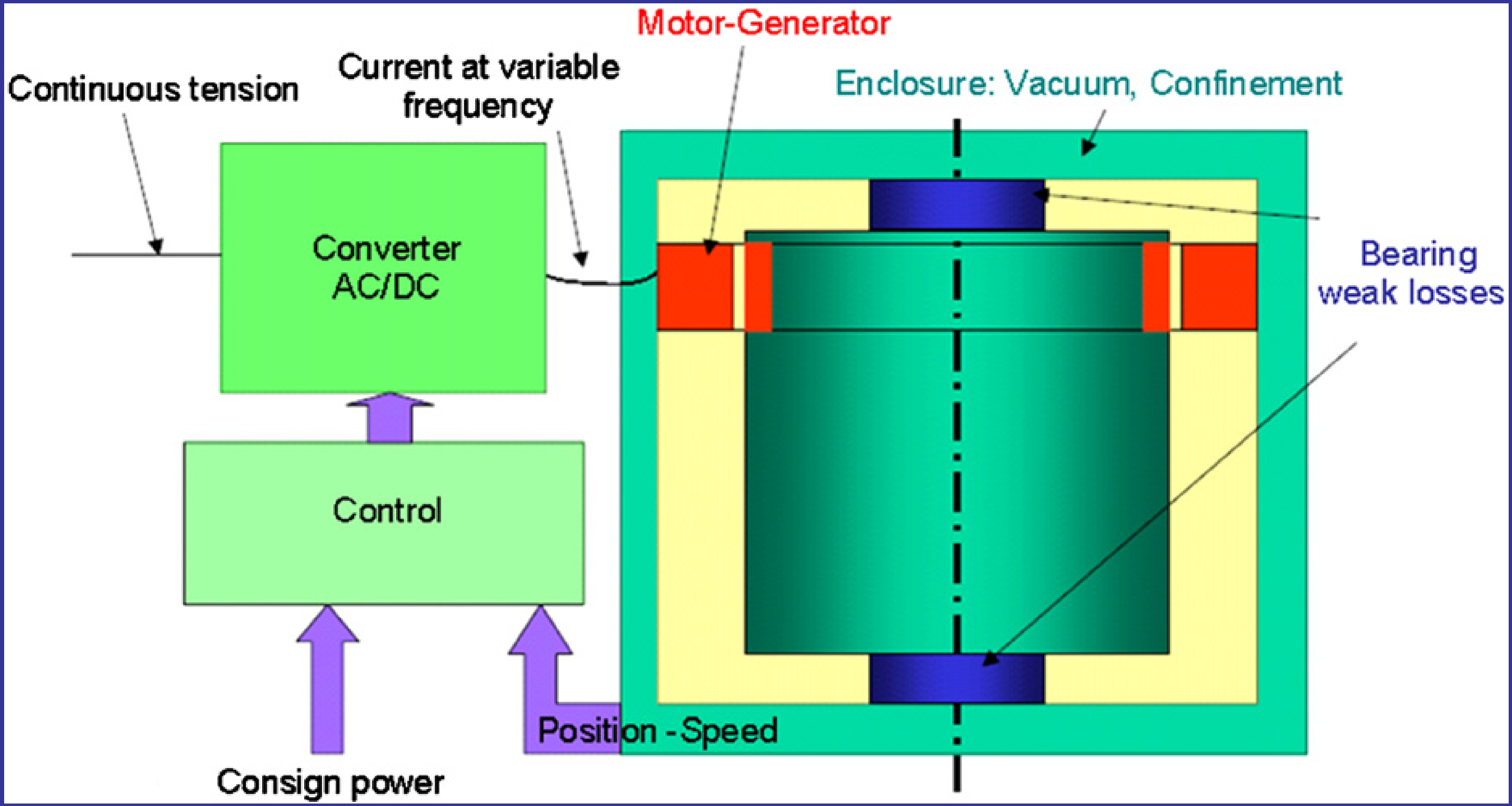

10^-3 hours
(3.6 s)
Pumped Hydro
storage (PHS)
1 hour
10^3 hours
(41 days)
SMES
Low speed
Flywheels
Micro SMES
High speed
Flywheels
Large CAES
Flow batteries
Small CAES
Electrochemical batteries
Supercapacitors
Power Output
10³MW
10²MW
10MW
1MW
10² kW
10 kW
1 kW
1 kWh
10 kWh
10² kWh
1MWh
10MWh
10²MWh
10³MWh
10⁴MWh
10⁵MWh
Energy stored



Output Energy Density
(Input Energy Density x Efficiency)
Lighter
Smaller
Metal-Air Batteries
(Not rechargeable electrically)
NaS Battery
Li -ion
Ni-Cd
Lead-Acid Batteries
Flow Batteries
E.C. Capacitors
Fly Wheels
Zinc-Air Rechargeable
WWW.ELECTRICITYSTORAGE.ORG
1000
300
100
30
10
10
30
100
300
1000
Weight Energy Density - kWh / ton
Volume Energy Density - kWh / m³



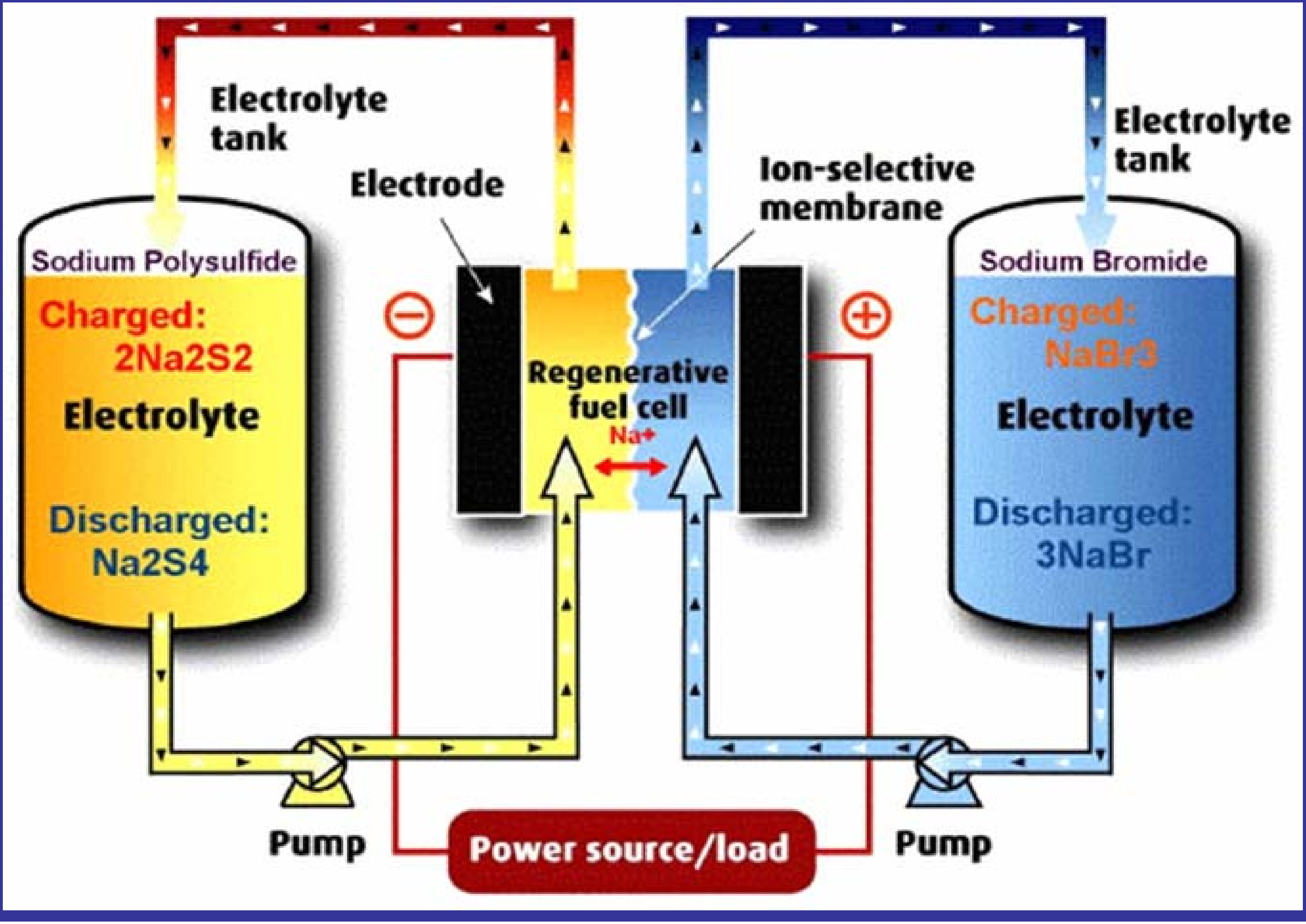
High Power E.C. Capacitors
High Power Fly Wheels
ESA
ELECTRICITY STORAGE ASSOCIATION
Long Duration Fly Wheels
Li-ion
Ni-Cd
Lead-Acid Batteries
NaS Battery
Zinc-Air Battery
Rechargeable
Better for Energy Management Applications
Long Duration E.C. Capacitors
Flow Batteries
Pumped Hydro
CAES
Metal-Air Batteries
Better for UPS and Power Quality Applications
Capital Cost per Unit Energy — $/kWh-output (Cost/capacity/efficiency)
10.000
1.000
100
10
100
300
1.000
3.000
10.000
Capital Cost per Unit Power — $/kW

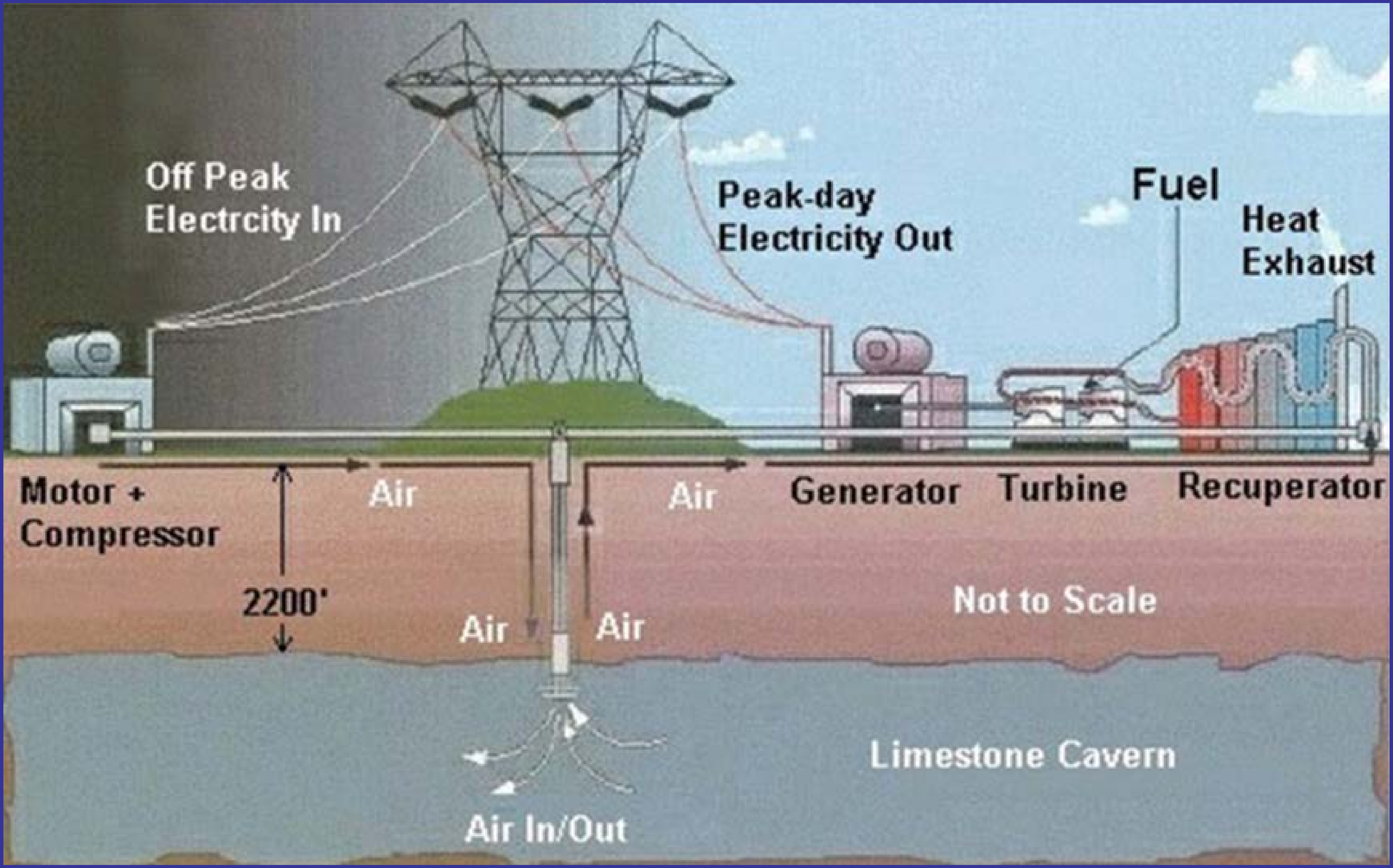


Flywheel:

- ***"Electricity" example***
- ***Fast out, slow in***
- ***Short-term: millisecond – minute***
- ***High volume energy density***
- ***High cost / MWh***

Flow Battery: Electrochemical





Compressed Air Energy Storage - CAES

CAES
Compressed Air Energy Storage

- **Lowest-cost "electricity" storage**
- **Geology-dependent**
- **Requires generation fuel: NG**
- **Hours to days storage capacity; not seasonal renewables**

CAES

- McIntosh Unit 1, AL , began '91 110 MW
- Bremen, Germany, began '78 290 MW

- Iowa Energy Storage Park 268 MW
  - Capital cost ~ $220M = engrg + construction (Nov 06 estimate)
  - Construction cost @ 268 MW @ $800 / kW = $214M
  - Mt. Simon site, Dallas Center; several others rejected
  - DOE, via SNL = $2.9M, mostly geology
  - Completion May '11
  - Energy storage capacity ??

Storage Projects, Manufacturers

WIND ENERGY STORAGE PROJECTS (minute to weekly scale)

- **California Wind Integration**
- **Huxley Hill**
- **Iowa Stored Energy Park**
- **Minwind**
- **Palmdale MicroGrid**
- **Sorne Hill**
- **Windy Harbour**

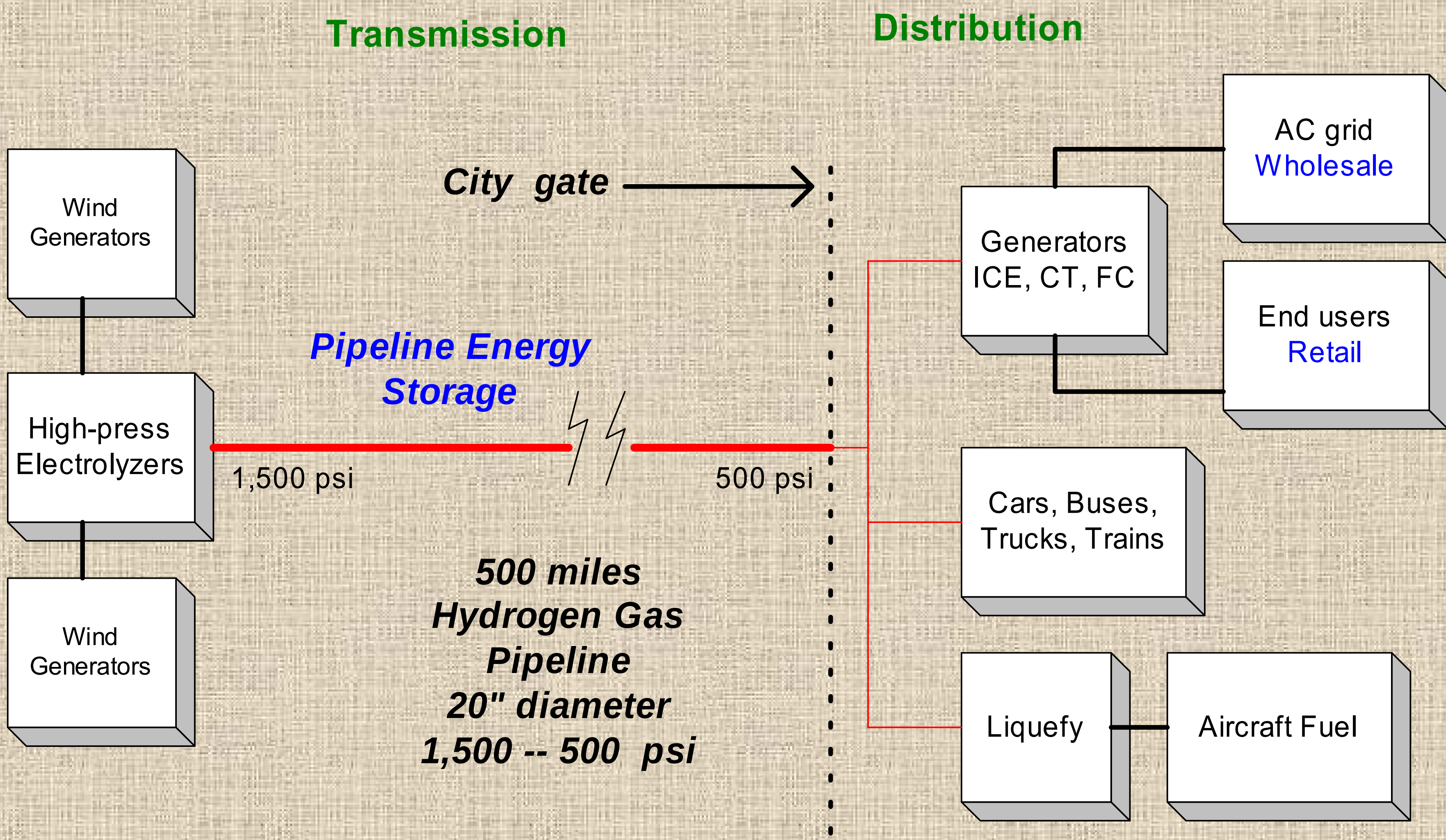
MAJOR ENERGY STORAGE MANUFACTURERS

- **Beacon Power**
- **General Compression**
- **Maxwell Technologies**
- **NGK Insulators**
- **Ridge Energy Storage**
- **Sumitomo Electric**
- **Flow: VRB-ESS, VRB Power Systems**
- **Flow:**

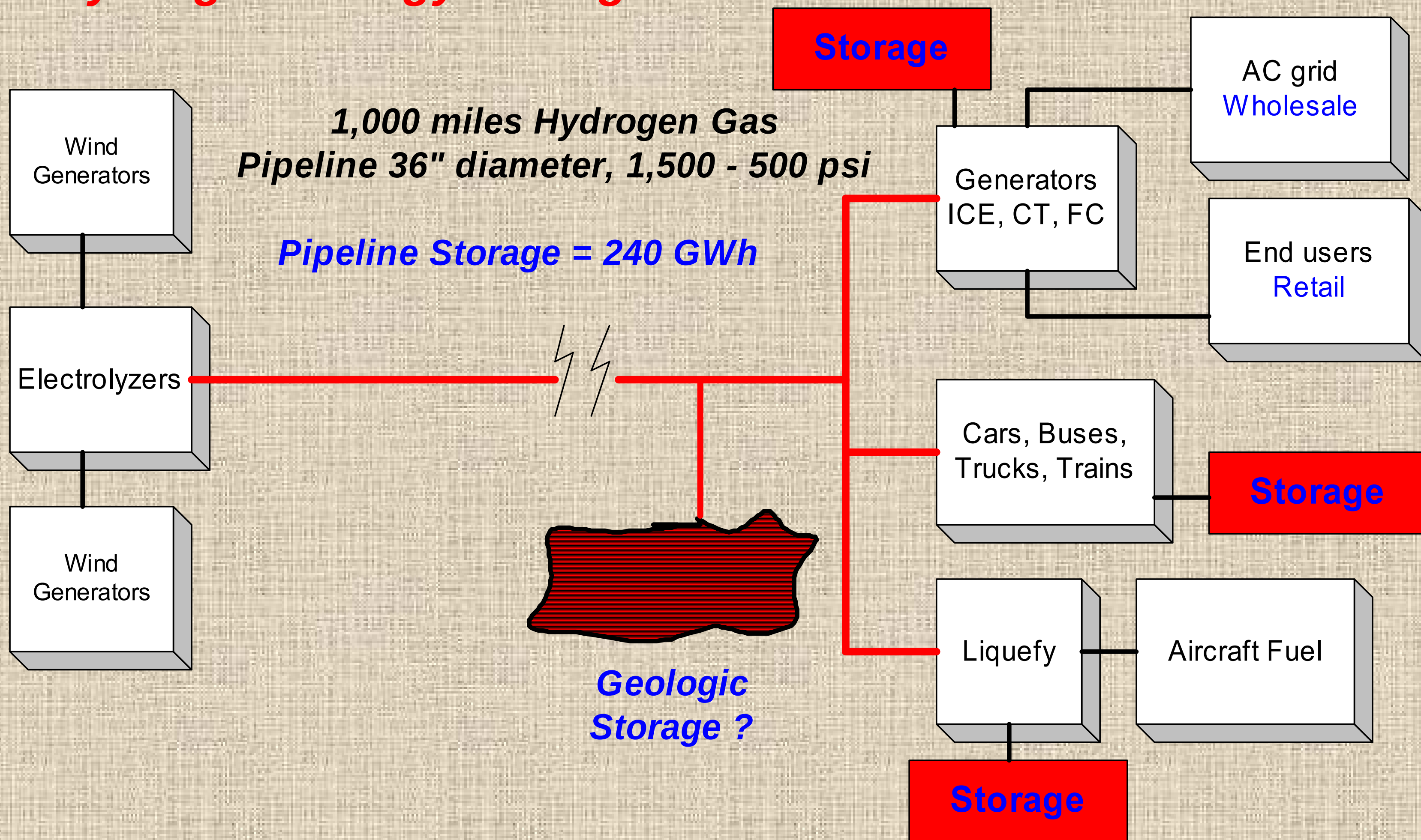
Benefit / Cost Perspective

- **Analytical framework: Not all answers**
- **Long-term**
- **Benefits**
- **Costs**
- **Systems thinking → tech, econon analysis**
  - **Whence the hydrogen ? Conversion cost, loss ?**
  - **Whence the ammonia ? Conversion cost, loss ?**

Hydrogen Transmission Scenario



Hydrogen Energy Storage



Same principle for GH2 storage

Alton, Nova Scotia Natural Gas Cavern Storage

Alton, Nova Scotia Natural Gas Storage

4 salt caverns, each:

– 1- 1.5 bcf gas @ 150 bar

– 700 m deep

– Physical volume 225,000 m^3

Total project cost $60M CDN

Cost per m^3 = $60

Expandable to 15 caverns:

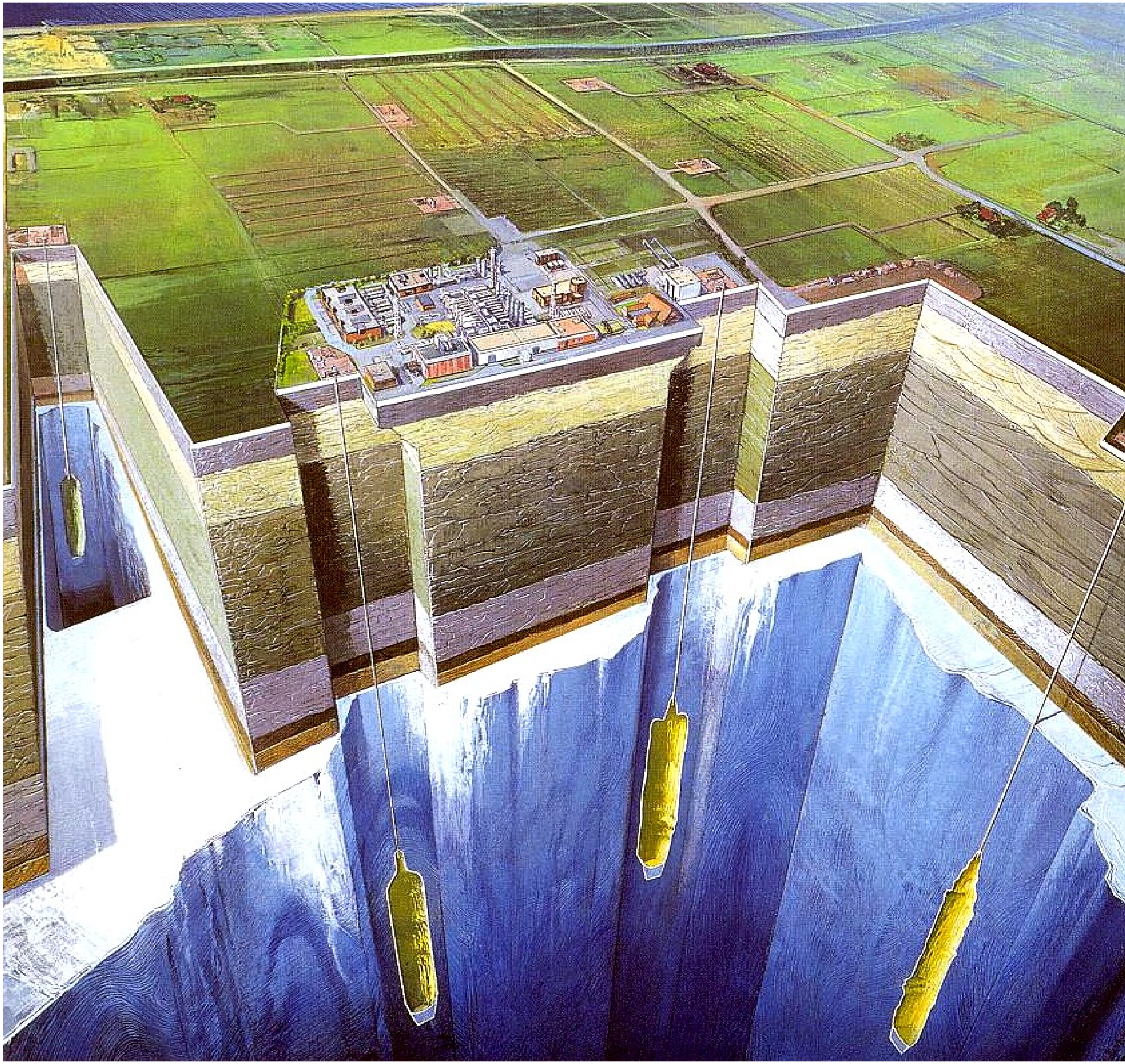
- **Total physical volume = 4 M m^3**
- **Incremental cost per cavern = $3M**
- **Total project cost $93M CDN**
- **Cost per m^3 = $24**

Alton Gas Storage: Hydrogen Example

Expandable to 15 caverns:

- **Total physical volume = 3.6M m^3**
- **Incremental cost per cavern = $3M**
- **Total gas storage @ 150 bar = 540M Nm3 ***
- **Hydrogen = 3.36 kWh / Nm3 ***
- **Total energy storage as hydrogen = 1,920 MWh**
- **Total project cost $93M CDN**
- **Cost per m^3 = $27**
- **Cost per MWh = $120 → $55**

*** Normal cubic meter**

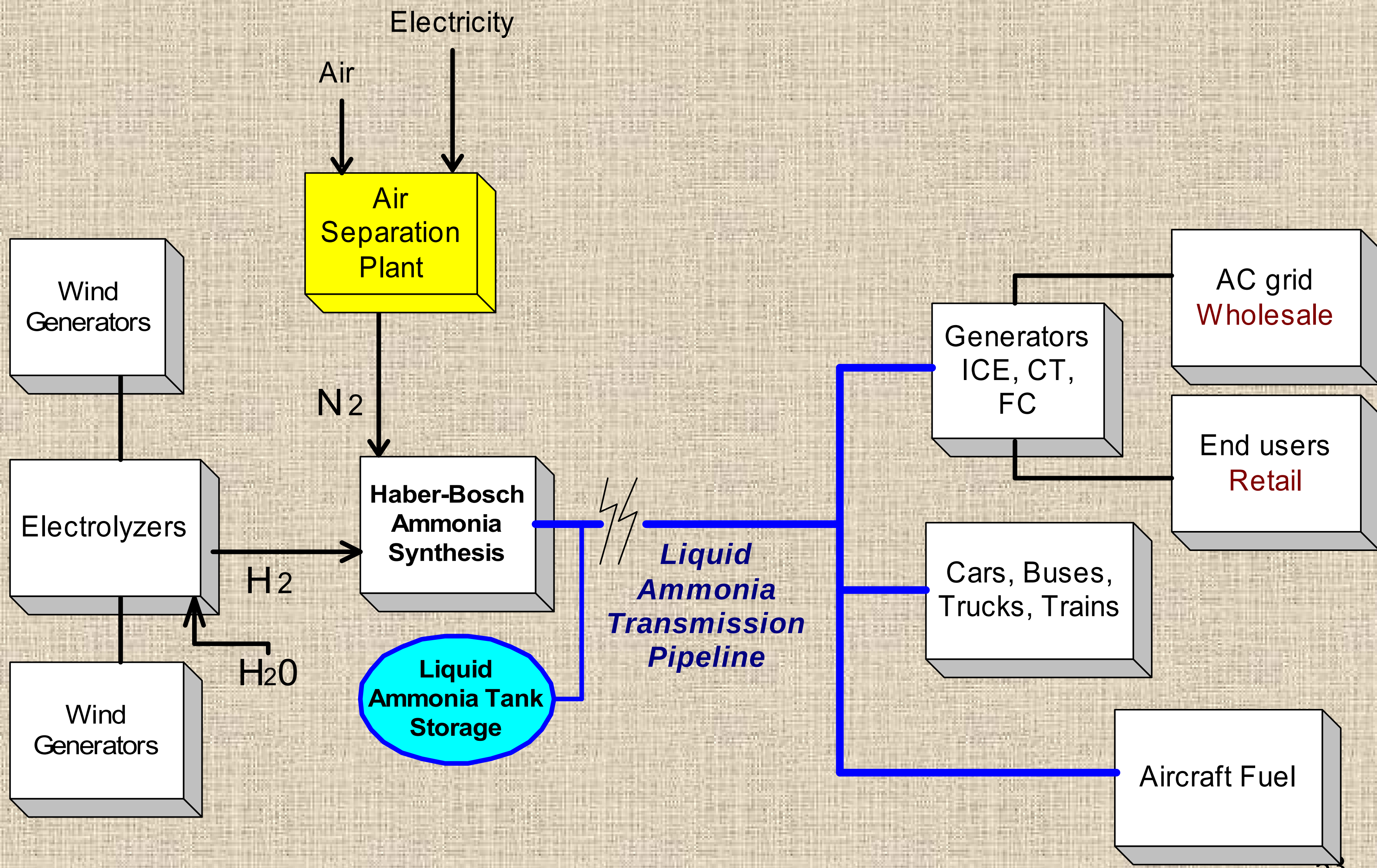


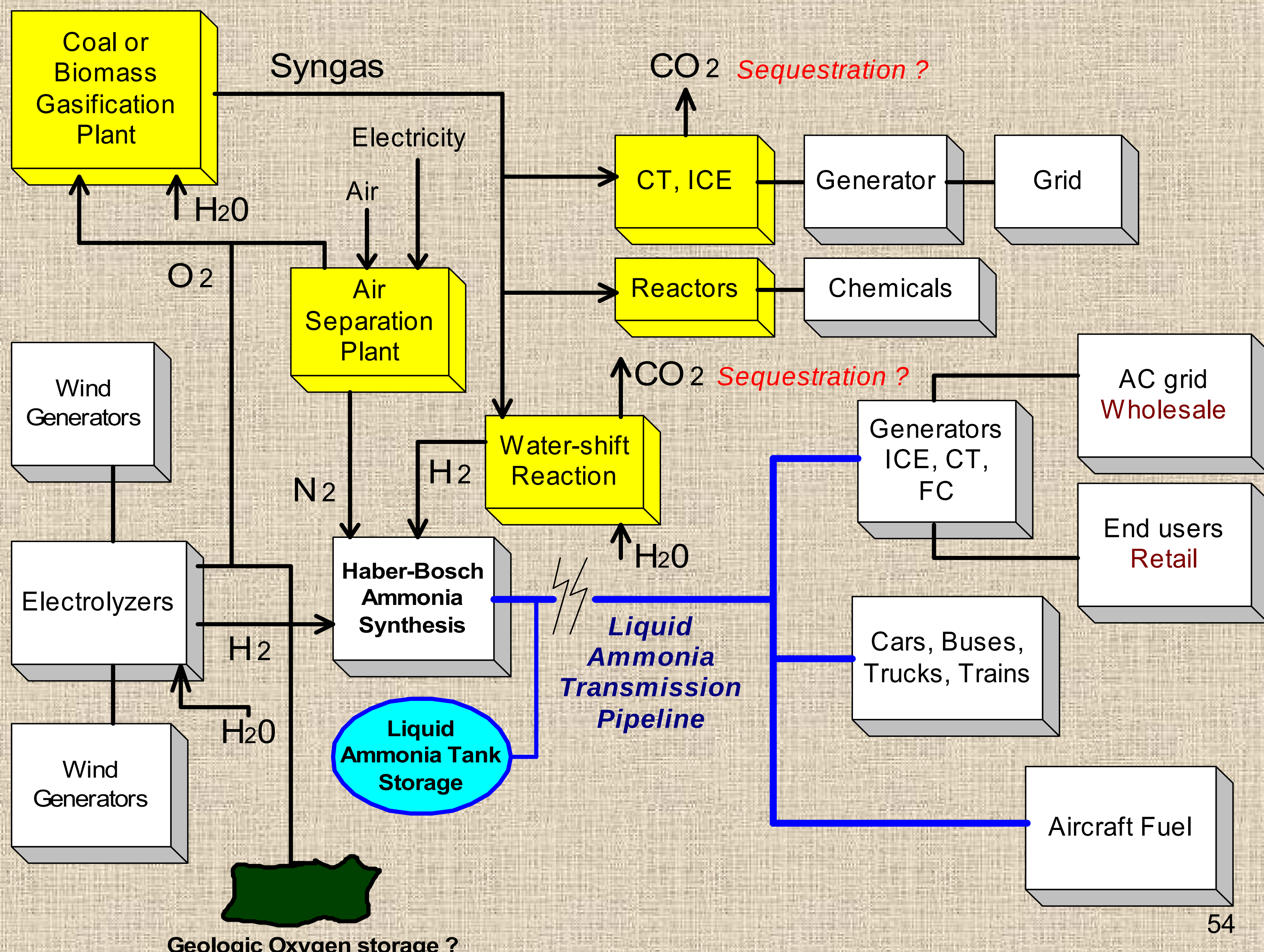
Domal Salt Storage Caverns

Natural gas

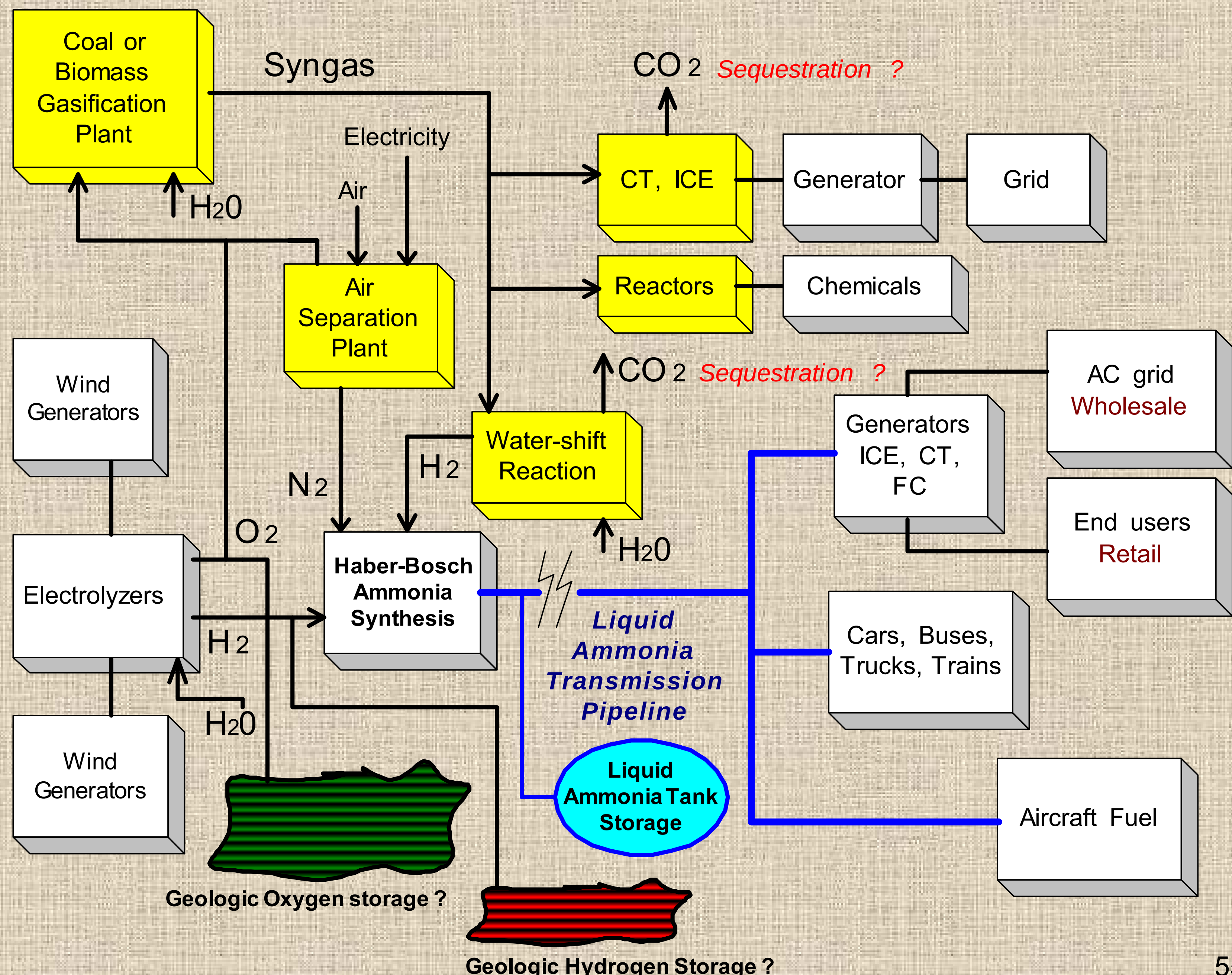
Hydrogen

Ammonia Transmission Scenario



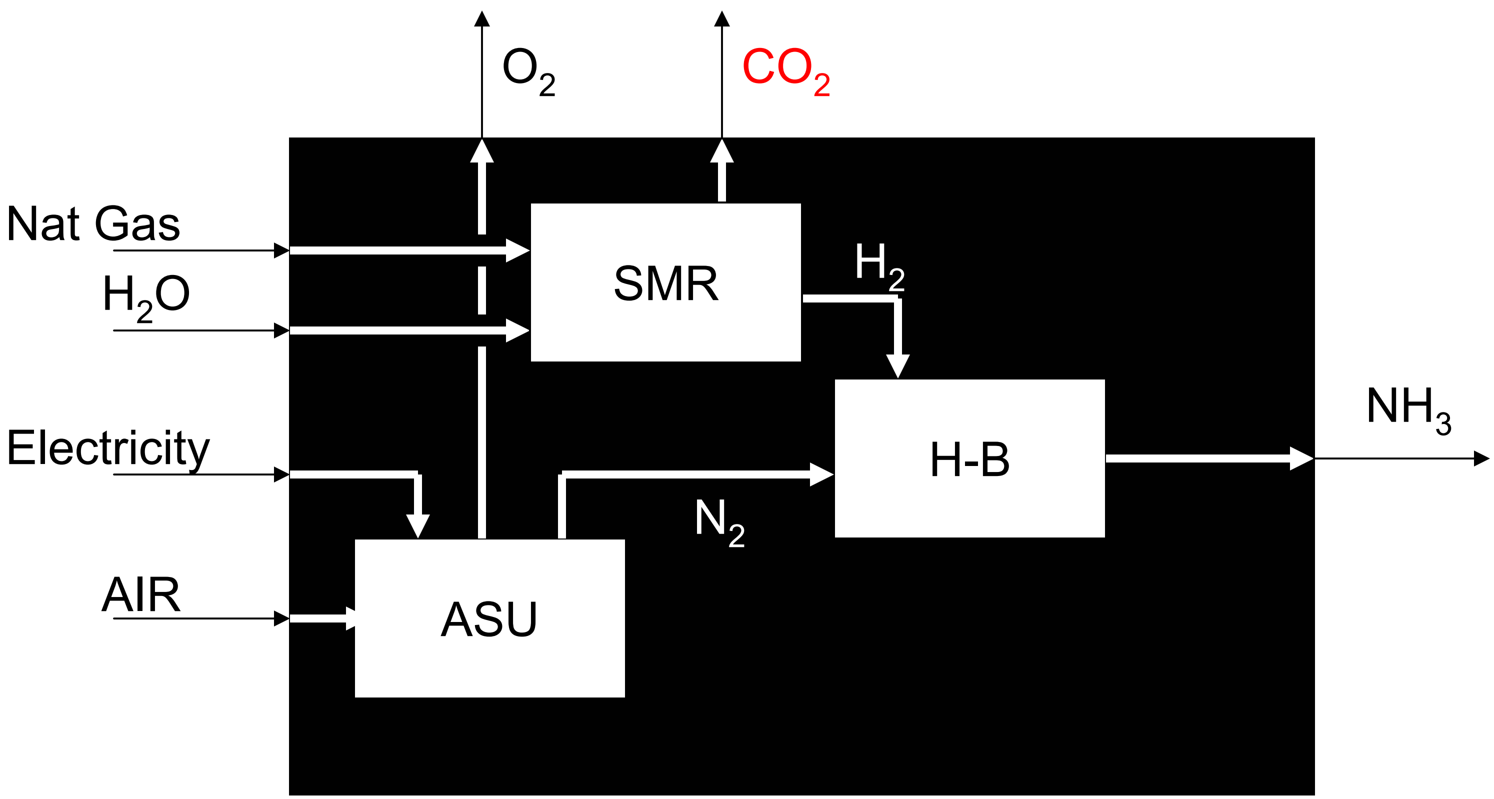


Coal or Biomass Gasification Plant
Syngas
CO_2 Sequestration ?
Electricity
Air
H_2O
CT, ICE
Generator
Grid
O_2
Air Separation Plant
Reactors
Chemicals
Wind Generators
CO_2 Sequestration ?
AC grid Wholesale
Water-shift Reaction
H_2
N_2
Generators ICE, CT, FC
End users Retail
Electrolyzers
Haber-Bosch Ammonia Synthesis
H_2O
H_2
Liquid Ammonia Transmission Pipeline
Cars, Buses, Trucks, Trains
H_2O
Liquid Ammonia Tank Storage
Wind Generators
Aircraft Fuel
Geologic Oxygen storage ?


Coal or Biomass Gasification Plant
Syngas
H2O
Electricity
Air
Air Separation Plant
CO2 Sequestration ?
CT, ICE
Generator
Grid
Reactors
Chemicals
Wind Generators
CO2 Sequestration ?
Water-shift Reaction
H2
N2
O2
Electrolyzers
Haber-Bosch Ammonia Synthesis
H2O
H2
H2O
Wind Generators
Liquid Ammonia Transmission Pipeline
Liquid Ammonia Tank Storage
Generators ICE, CT, FC
AC grid Wholesale
End users Retail
Cars, Buses, Trucks, Trains
Aircraft Fuel
Geologic Oxygen storage ?
Geologic Hydrogen Storage ?

Inside the Black Box: Steam Reforming + Haber-Bosch

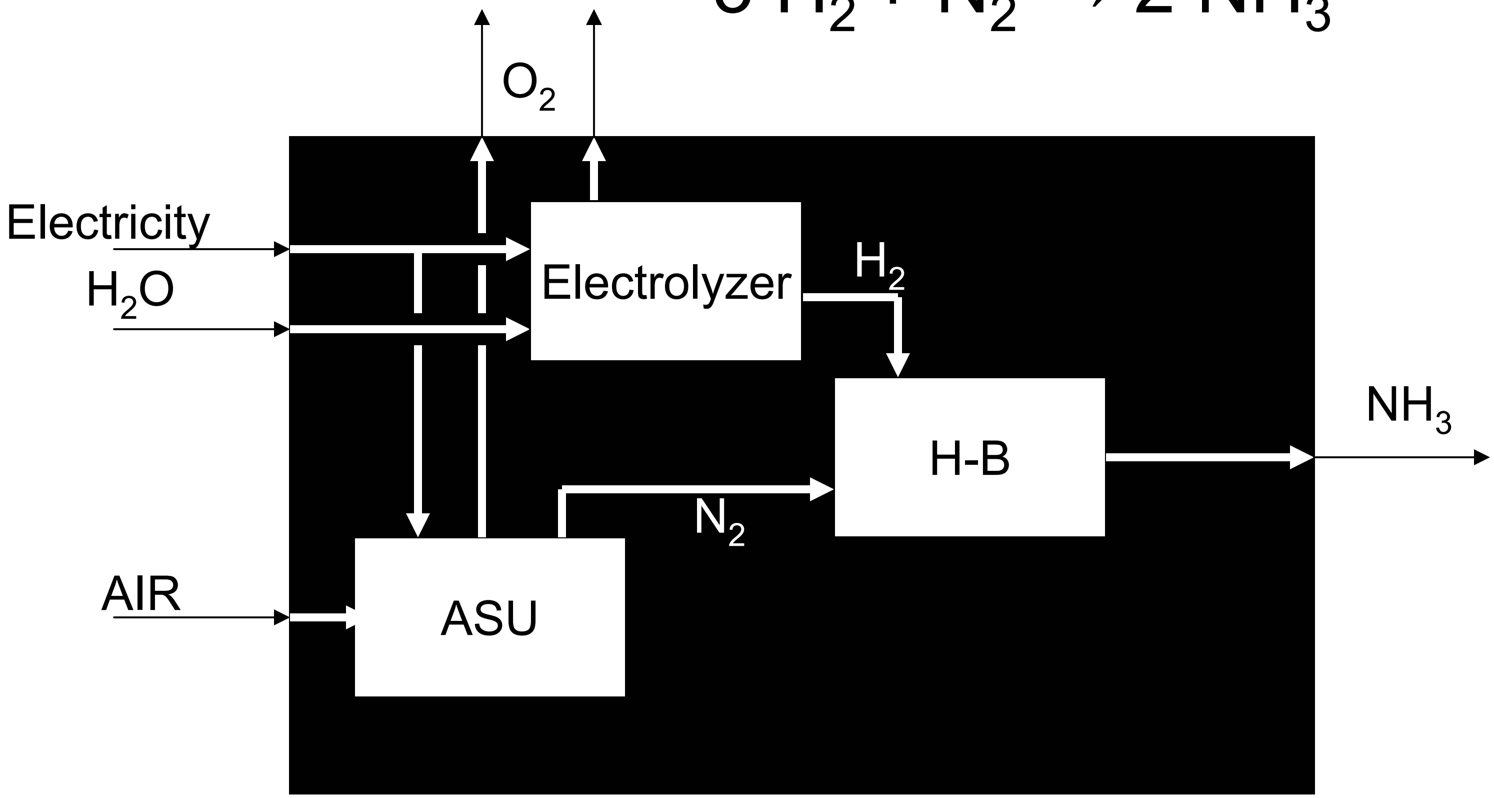
$$3\ CH_4 + 6\ H_2O + 4\ N_2 \rightarrow 3\ CO_2 + 8\ NH_3$$



Energy consumption ~33 MBtu (9500 kWh) per ton NH_3

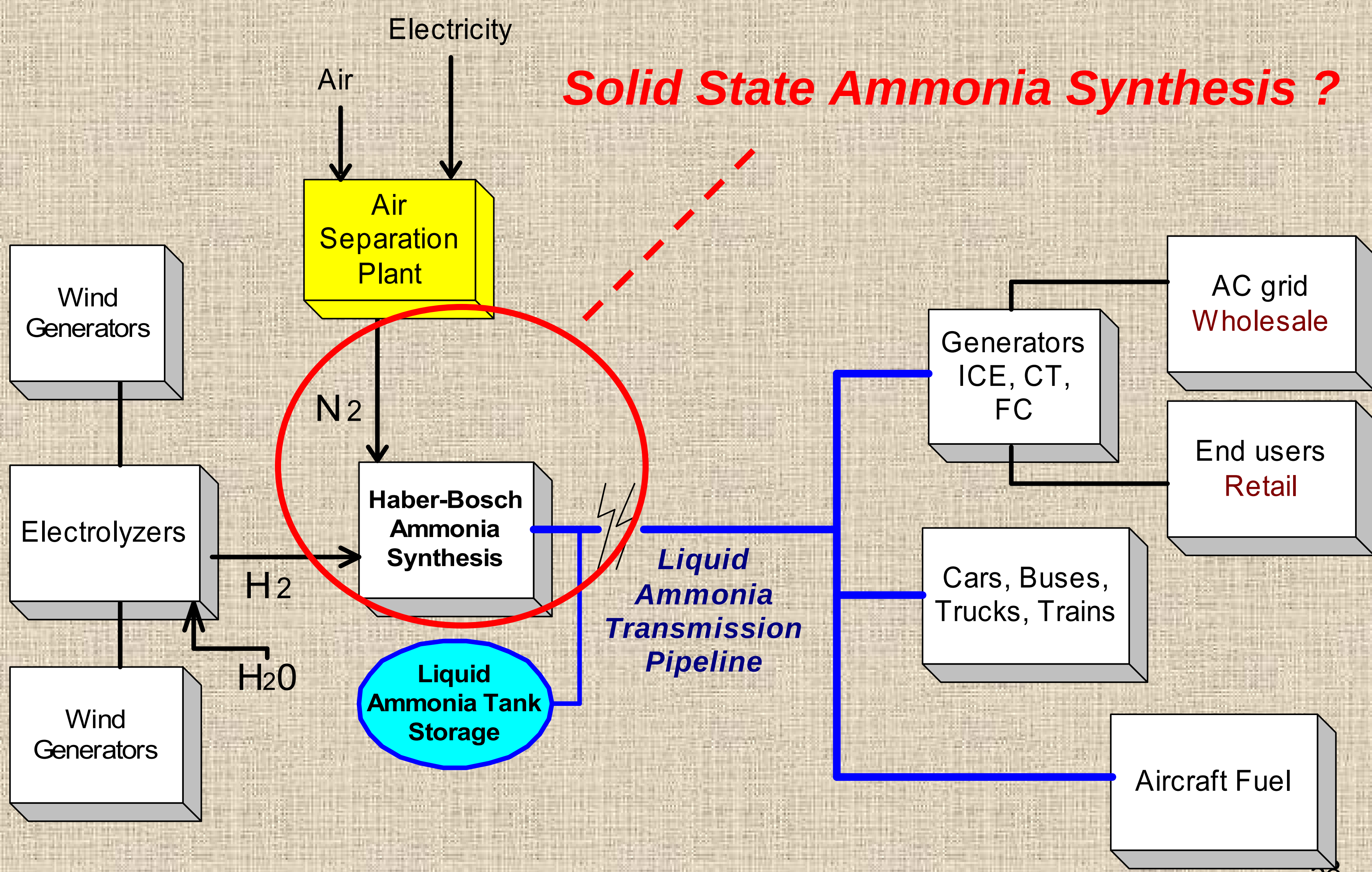
Inside the Black Box: HB Plus Electrolysis

$$3\ H_2O \rightarrow 3\ H_2 + 3/2\ O_2$$
$$3\ H_2 + N_2 \rightarrow 2\ NH_3$$



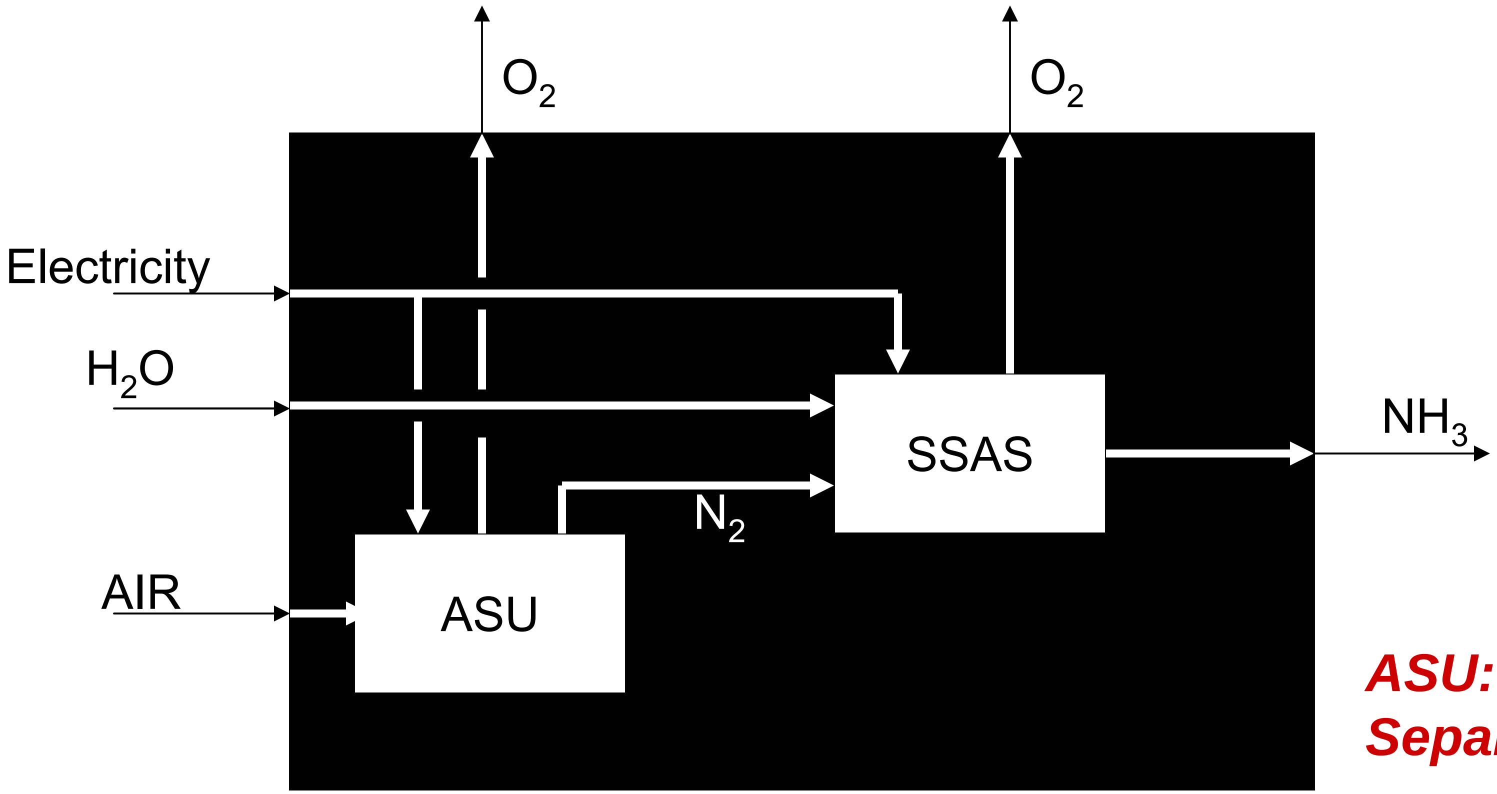
Energy consumption ~12,000 kWh per ton NH_3

Ammonia Transmission Scenario



Inside the Black Box: Solid State Ammonia Synthesis

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



ASU: Air Separation Unit

Energy consumption 7,000 – 8,000 kWh per ton NH_3

SSAS vs H-B NH3 Synthesis

(Solid State Ammonia Synthesis vs Haber – Bosch)

- **H-B**
  - **$1.5 M per MWe input**
  - **2 tons / day output per MWe input**
  - **O&M cost / ton: ??**

- **SSAS**
  - **$650 K per MWe input**
  - **3.2 tons / day output per MWe input**
  - **O&M cost / ton: lower ?**

Incremental Capital Cost Analysis: With and without Annual-scale Firming Storage

- **From "Ammonia '06 …" presentation**
- **Simple capital recovery factor (CRF) method**
- **Novel system: no experience**
- **Rough estimates of NH3 system components**
- **Many other cases to consider**

2,000 MW (nameplate) Great Plains Windplant Output

Energy production at windplant 40 % Capacity Factor:

As electricity: **19,200 MWh / day**
7,000,000 MWh / year

	tons/hr	tons/day	tons/yr
As H_2 @ 80% electrolysis efficiency	16	390	142,350
As NH_3 @ 70% conversion efficiency	97	2,321	847,321
10” NH_3 pipeline capacity as H_2	11	264	96,360
10” NH_3 pipeline capacity as NH_3	60	1,440	525,600

Case 4a: Capital costs, no firming
2,000 MW Great Plains windplant

Elec → GH2 → NH3 → Liquid Pipeline → "Terminal" or "City gate"

Capital costs:

–	Wind generators, 1.5 MW @ $1,500 / kW	$ 3,000 M
–	Electrolyzers, 450 psi out @ $350 / kWe	$ 700 M
–	Electrolyzer power electronics saving	$ 0 M
–	H2 compressors	$ 10 M
–	NH3 synthesis plants (2)	$ 750 M
–	Pipeline	$ 800 M
–	Pipeline pumping	$ 8 M
–	Pipeline infrastructure	$ 2 M
	Total, without firming storage	**$ 5,270 M**

Case 4a: Annual costs, no firming

Elec → GH2 → NH3 → Liquid Pipeline → "Terminal" or "City gate"

Unsubsidized [1]

Production capital costs @ 15% CRF @ $ 5,270 M	**$ 790 M**
Conversion and transmission losses	
– **Electrolyzer conversion loss @ 20% AEP [2]**	**$ 80 M**
– **Compression energy**	**$ 1 M**
– **NH3 synthesis plant**	**$ 80 M**
– **Pipeline pumping energy**	**$ 2 M**
– **Pipeline misc O&M**	**$ 1 M**
Total annual costs	**$ 954 M**

Total cost per mt NH3 = $ 1,126

Total cost per kg NH3 = $ 1.13

[1] **Subsidies, value-adders: PTC, O_2 sales, REC**

[2] **Annual Energy Production @ $US 0.057 / kWh**

Case 4b: Capital costs, Firming storage tanks
2,000 MW Great Plains windplant
Elec → GH2 → NH3 → Liquid Pipeline → Firming tanks → "Terminal" or "City gate"

Capital costs

– Wind generators, 1.5 MW @ $1,500 / kW	$ 3,000 M
– Electrolyzers, 450 psi out @ $350 / kWe	$ 700 M
– Electrolyzer power electronics saving	$ 0 M
– H2 compressors	$ 10 M
– NH3 synthesis plant	$ 750 M
– Pipeline	$ 800 M
– Pipeline pumping	$ 8 M
– Pipeline infrastructure	$ 2 M
– Tanks: 4 tanks @ $ 25 M	$ 100 M
Total, with firming storage	$ 5,370 M

Incremental capital cost of NH3 tanks = $ 100 / 5,370 = ~ 0.2 %

Case 4b: Annual costs, Firming storage tanks
2,000 MW Great Plains windplant
Elec → GH2 → NH3 → Liquid Pipeline + tanks → City gate

• Capital costs @ 15% CRF @ $ 5,370	$ 805 M
• Conversion and transmission losses	
– Electrolyzer conversion loss @ 20% AEP	$ 80 M
– Compression	$ 1 M
– NH3 synthesis plants (2)	$ 80 M
– Pipeline pumping energy	$ 2 M
– Pipeline misc O&M	$ 1 M
– Tank in / out	$ 0 M
Total annual costs	$ 969 M

Total cost per Mt NH3 = $ 1,144

Case 4c: Annual costs, Firming storage, tanks, reform to H2

Elec → GH2 → NH3 → Liquid Pipeline +Tanks → Reform to H2

Unsubsidized

Production capital costs @ 15% CRF @ $ 5,370 M	**$ 806 M**
Conversion and transmission losses	
– Electrolyzer conversion loss @ 20% AEP	$ 80 M
– Compression energy	$ 1 M
– NH3 synthesis plant	$ 80 M
– Pipeline pumping energy	$ 2 M
– Pipeline misc O&M	$ 1 M
– Reformer conversion loss @ 15% AEP	$ 60 M
Total annual costs	**$ 1,030 M**

Total cost per Mt H2 = $ 7,253

Total cost per kg H2 = $ 7.25

Alaska Renewable Energy Grant Program

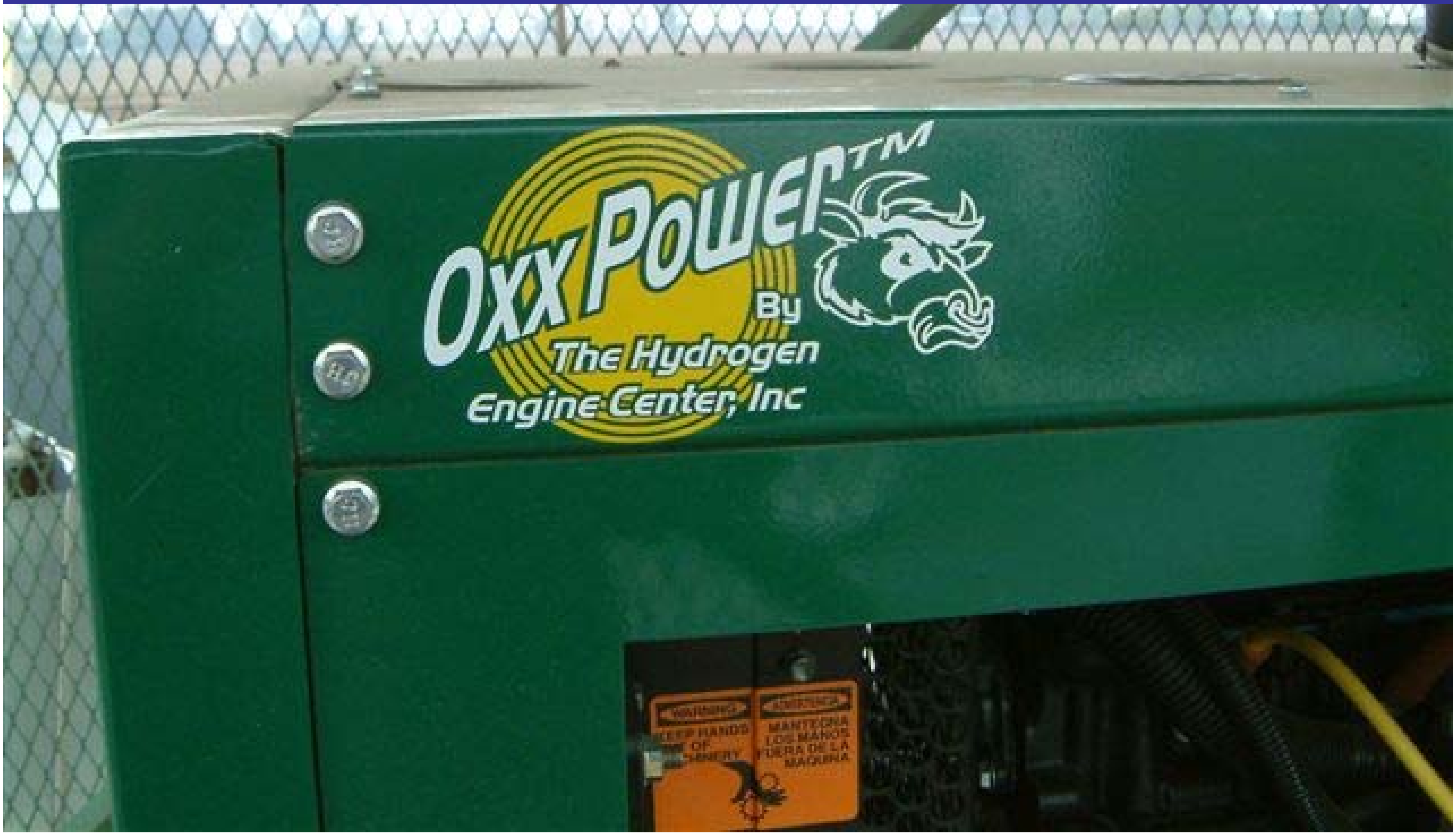
- **$50M + $50M this FY for "commercialization" projects**
- **Some left for R&D&D**
- **Next session: new R&D&D program ?**
- **Apply now for SSAS, R+D+D project**
  - **Alaska Electric Light & Power (AEL&P), Juneau**
    - **Applicant**
    - **Manage**
    - **Host on-site**
  - **Goal: Alaska village energy independence via RE-NH3**
    - **Annually-firm**
    - **All energy needs**
    - **Must have RE resources**
- **System:**
  - **RE electricity source: Juneau hydro**
  - **SSAS module ~ 10 kWe input**
  - **NH3 storage tank**
  - **NH3-fueled ICE genset ~ 50 kW: return to grid**
  - **Village energy system prototype**

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

Hydrogen Engine Center, Algona, IA

1,000 hours, ICE, 6 cyl, 100 hp

75% ammonia, 25% propane



Alaska Renewable Energy Grant Program

Budget:

– SSAS R&D from AEL&P to NThree, LLC	$ 500K
– Build 5-50 kW RE-NH3 system for AEL&P	$ 100K
– Build identical system for co-applicant	$ 100K
– Management + system integration + contingency	<u>$ 200K</u>
Total	$ 900K

Applications due 8 Oct, 10 Nov 08

Potential co-applicants:

- **Iowa Power Fund: preliminary app → "Diligence Committee"**
- **Other states**
- **Industry**

'08 Farm Bill "Renewable Fertilizer Research"

- **Section 9003, Congress passed May 08**
- **RE – NH3 concept, commercialize**
- **Report to Secy USDA: 18 months**
- **$1M authorized**
  - **No appropriation**
  - **Next admin, congress ?**

'08 Farm Bill
"Renewable Fertilizer Research"
Genesis: collaboration

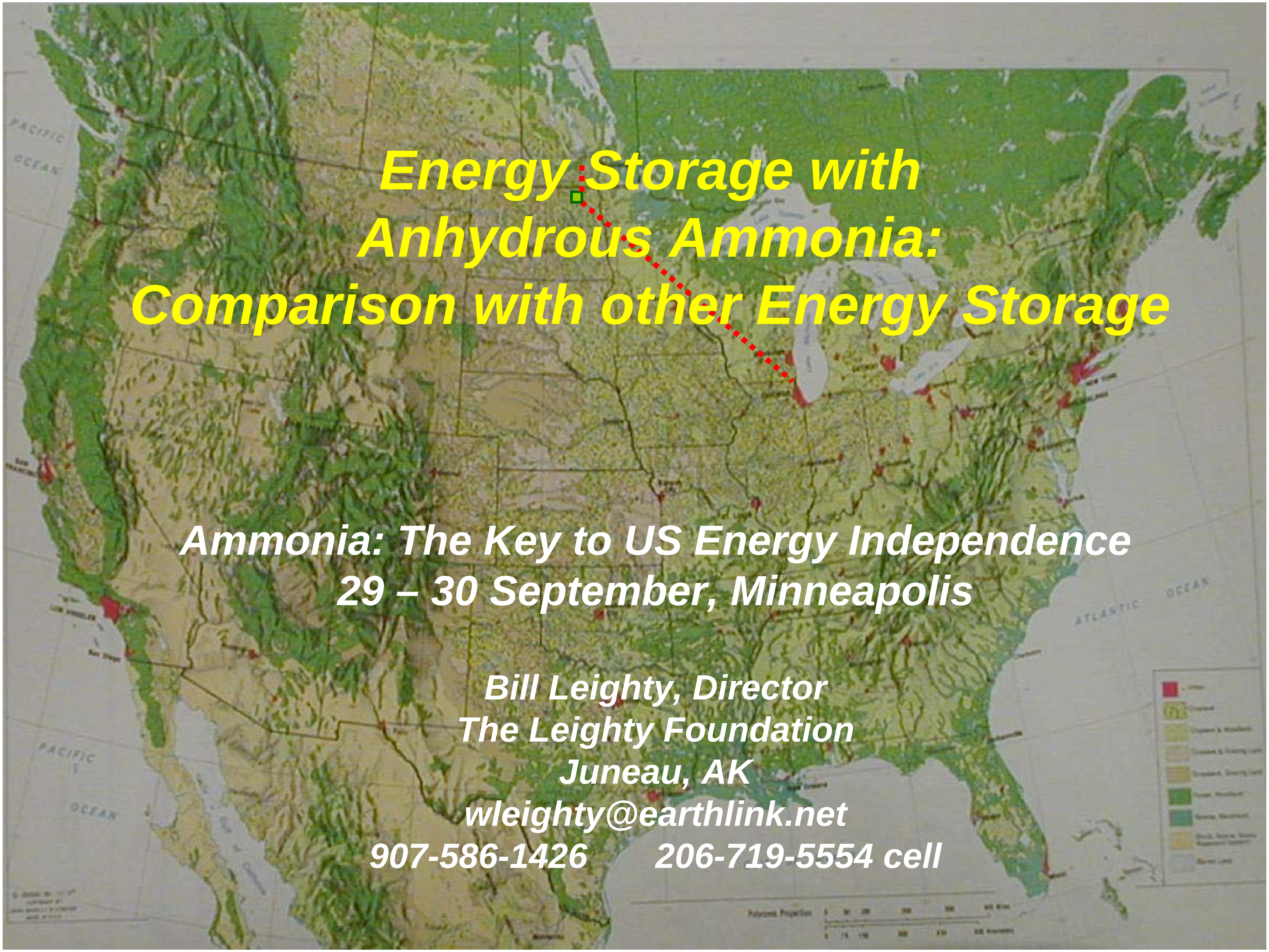
- **Environmental Law and Policy Center (ELPC), Chicago**
  Jesse Kharbanda, John Moore, Howard Learner (ED)

- **The Leighty Foundation (funds ELPC)**
  Bill Leighty

- **AmmPower**
  John Holbrook

Helped compose for House + Senate Ag Committees: (handouts)
- **"Farm Energy Backgrounder"**
- **"Ammonia Q+A"**
- **Proposed Farm Bill language**
- **Proposed appropriation at $950 K**

Delivered to House and Senate Ag Committees June 07
- **House: Peterson (MN), Holden (PA)**
- **Senate: Harkin (IA), Eldon Boes (staff; ASME Congress Fellow)**



Energy Storage with Anhydrous Ammonia: Comparison with other Energy Storage

Ammonia: The Key to US Energy Independence
29 – 30 September, Minneapolis

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