Fertilizer to Fuel : the '07 US Farm Bill

N- Fertilizer from Renewable Energy

"Ammonia: a Sustainable, Emission-free Fuel"

Rev: 28 Oct 07

October 15, 2007
San Francisco

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Sustainable

“ Meeting our needs without compromising the ability of future generations to meet their own needs ”

United Nations Commission on Environment and Development (UNCED)
“Our Common Future”, 1987

Optimist

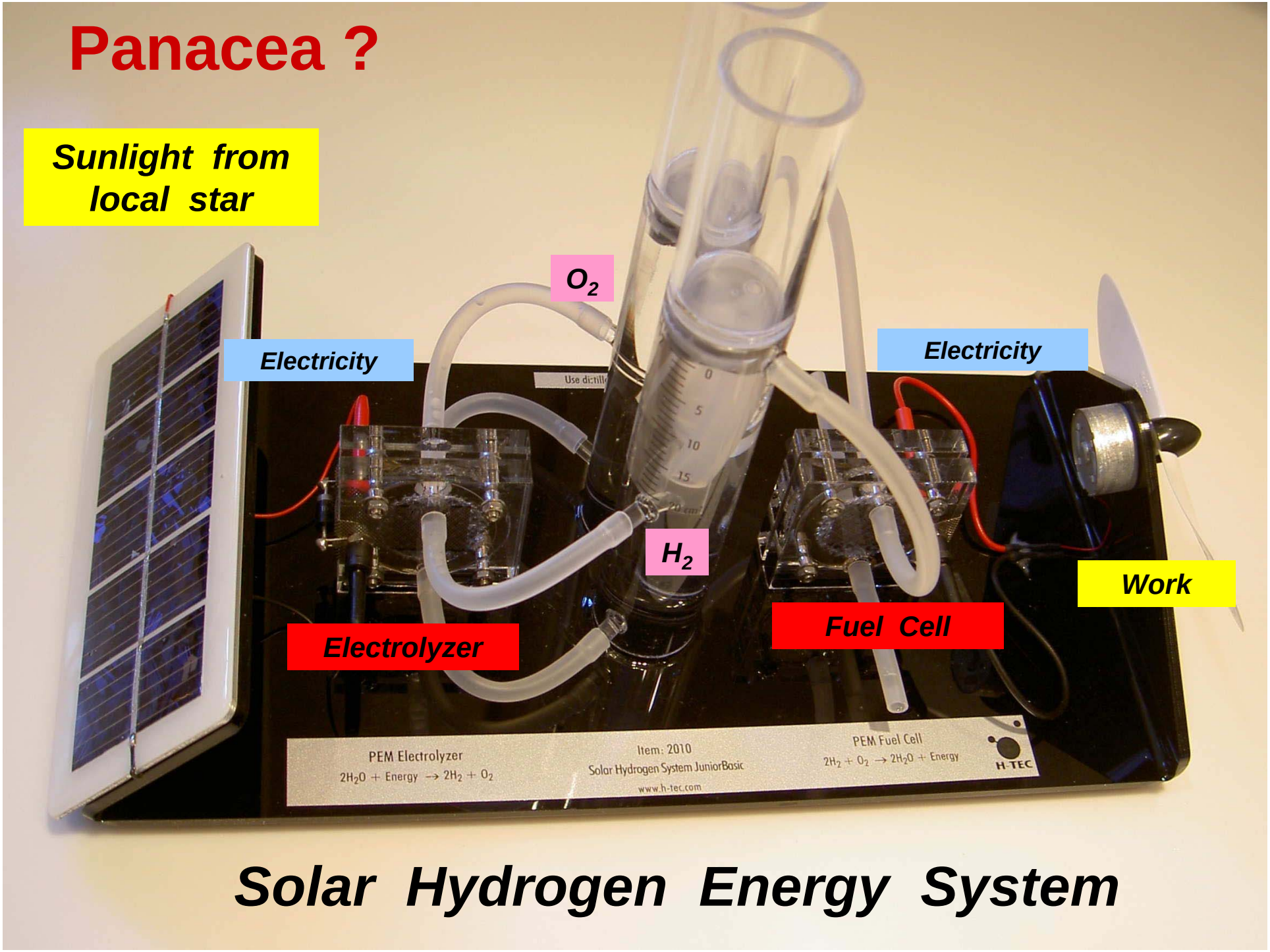
“ You can always count on Americans to do the right thing – after they've tried everything else.”

Winston Churchill

- Opportunities for “Ammonia Fuel Network”
- Systems engineering, analysis required
- Prove NH3 fuel “the right thing”

NH_3 Ag Fertilizer Tanks, Wind Generators, NW Iowa

Panacea ?



Solar Hydrogen Energy System

Hydrogen Fuel Cell

Proton Exchange Membrane (PEM) type

Hydrogen (H2) combines with Oxygen (O2) to make electricity + heat + water (H2O)

Opportunities, Challenges

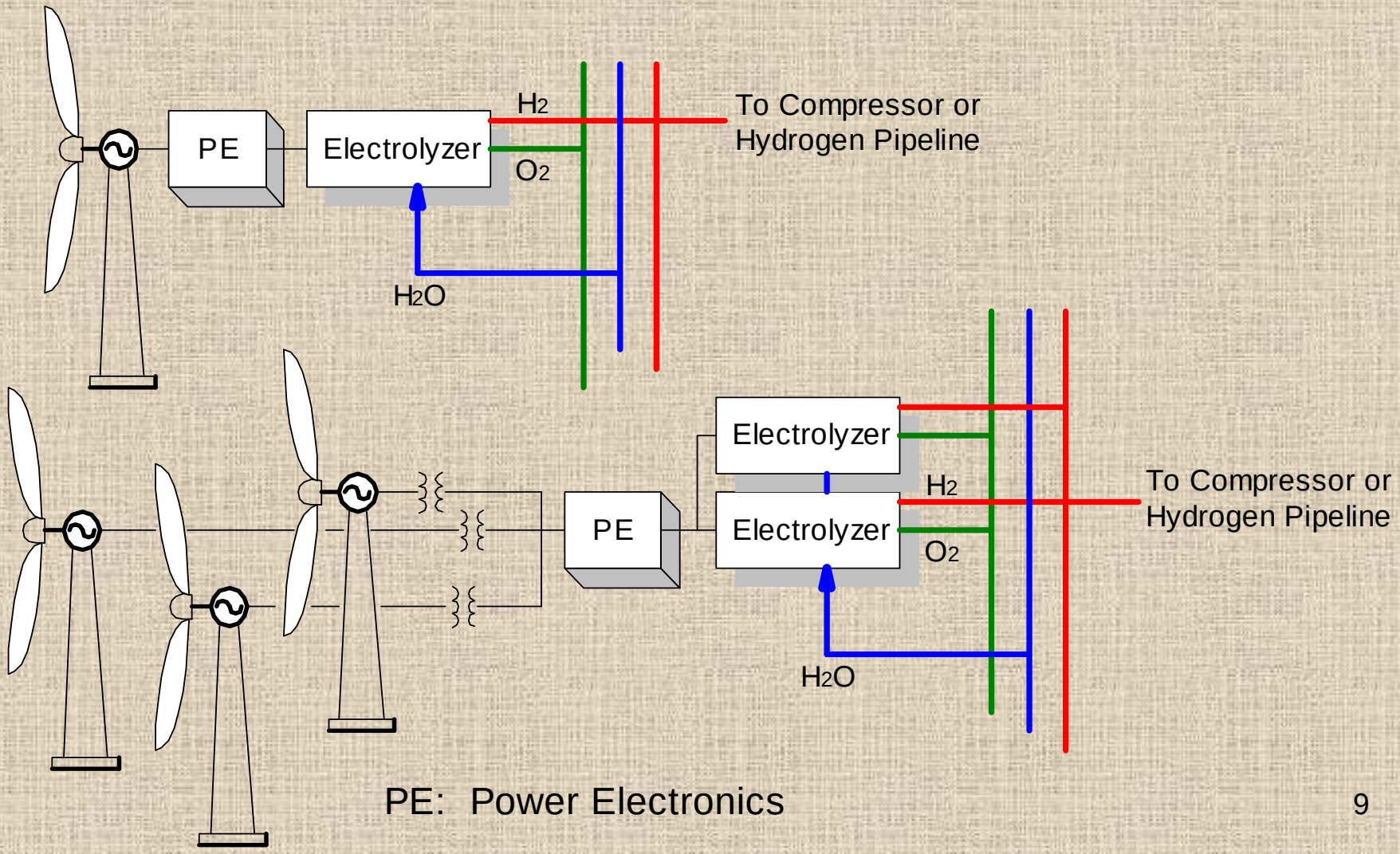
- **Needs and problems:**
  - Energy security
  - Balance of Trade
  - Jobs + rural economic development
  - Rising ag costs: energy, fertilizer, seed, chemicals, land
  - Stranded renewable resources:
    - Gathering + Transmission
    - Firming storage: daily – to – annual scales
- **Solution**: Renewable, Domestic Alternative to Imported N- fertilizer
- **New Industry:** Economic, Environmental
- **Path to Commercialization**
- **'07 Farm Bill Process**
- **Fertilizer → Fuel**
  - Business case: compete
  - Interest, orchestrate

5 Challenges

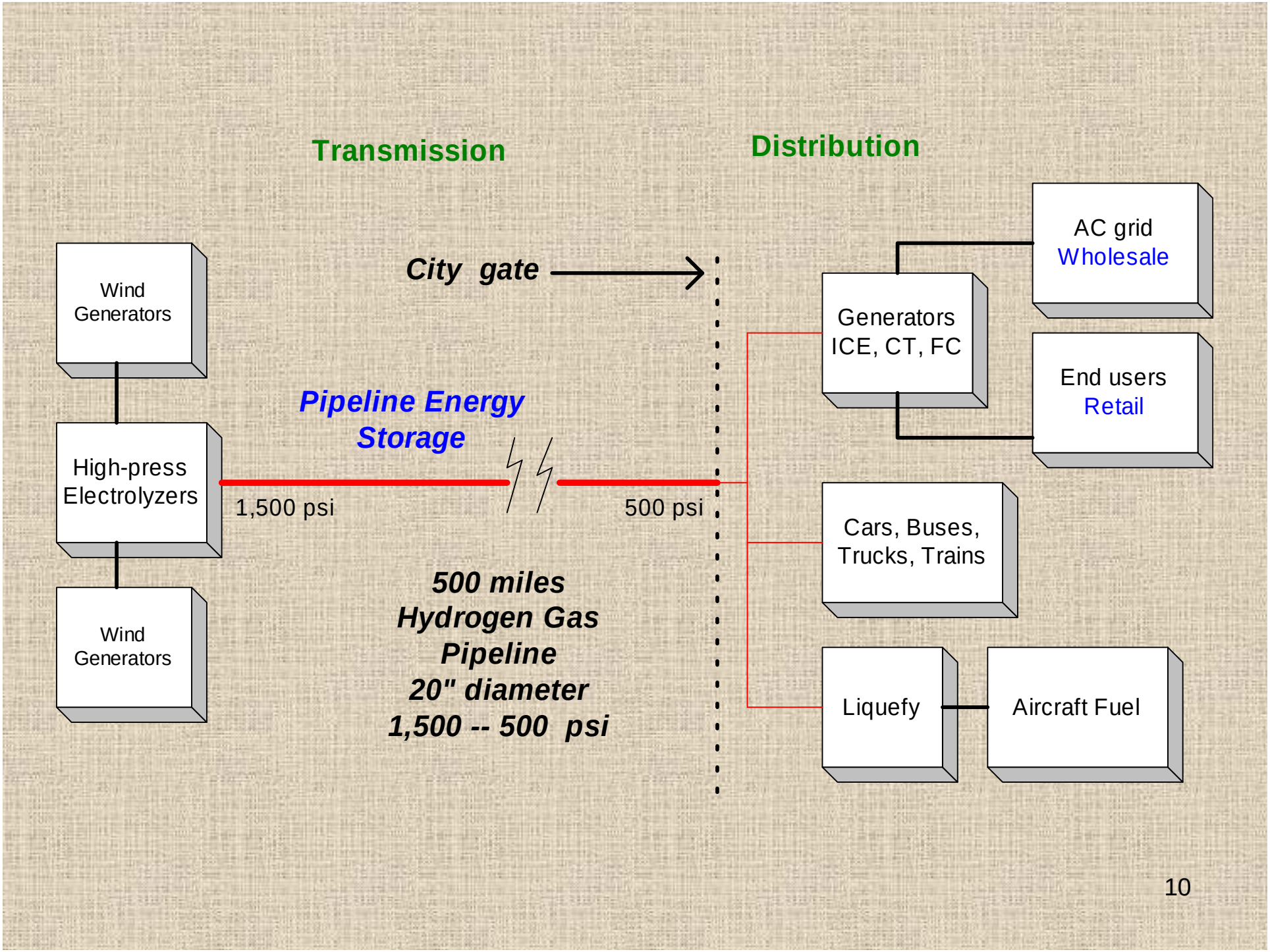
1. N-fertilizer consumption to rise
2. N-fertilizer prices stay high
3. “Stranded” slows renewables production
4. Energy conversion system
5. Competition price, cost

"Hydrogen Transmission Scenario"

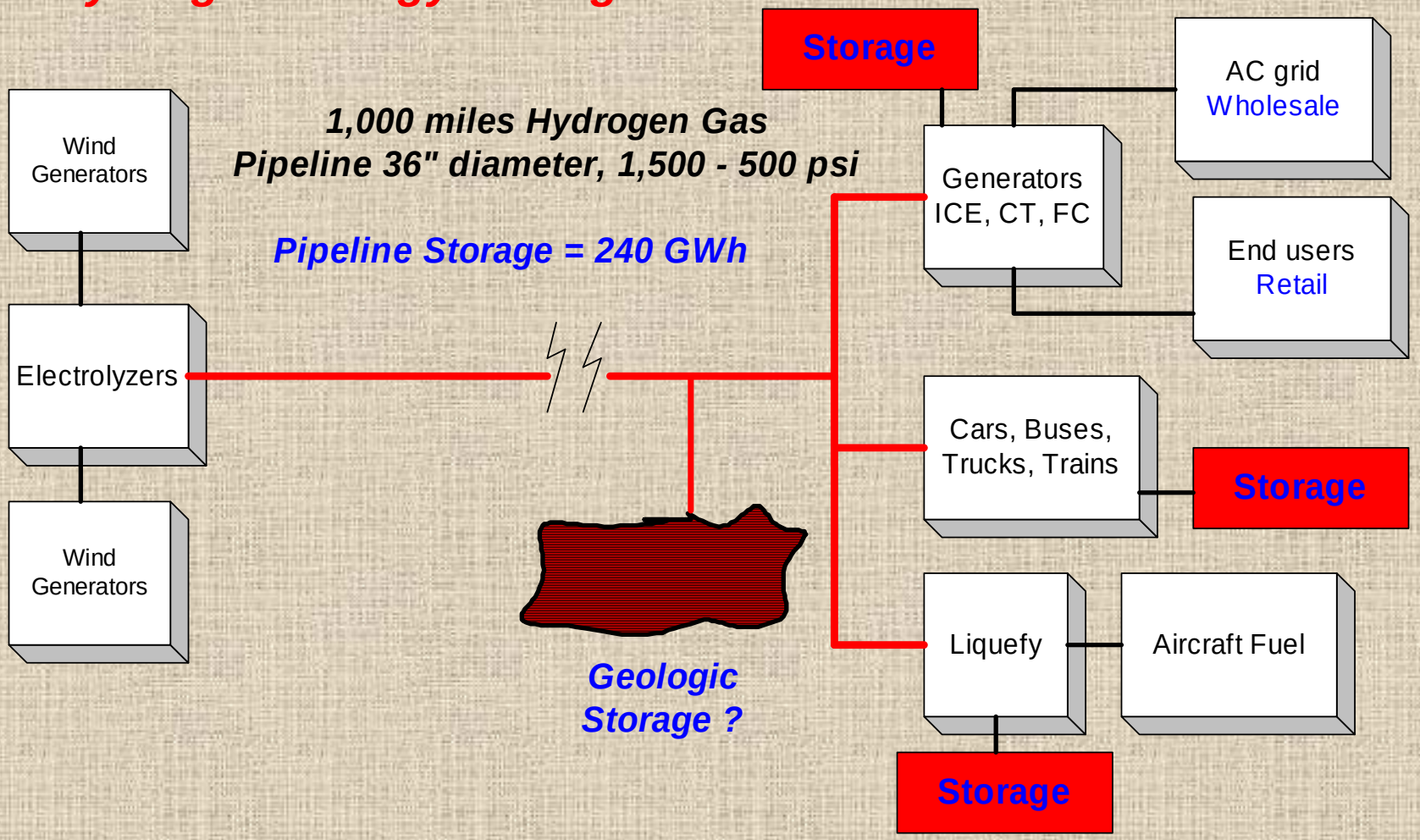
Collection Topology Options:
Electrolyzer and Rectifier Location

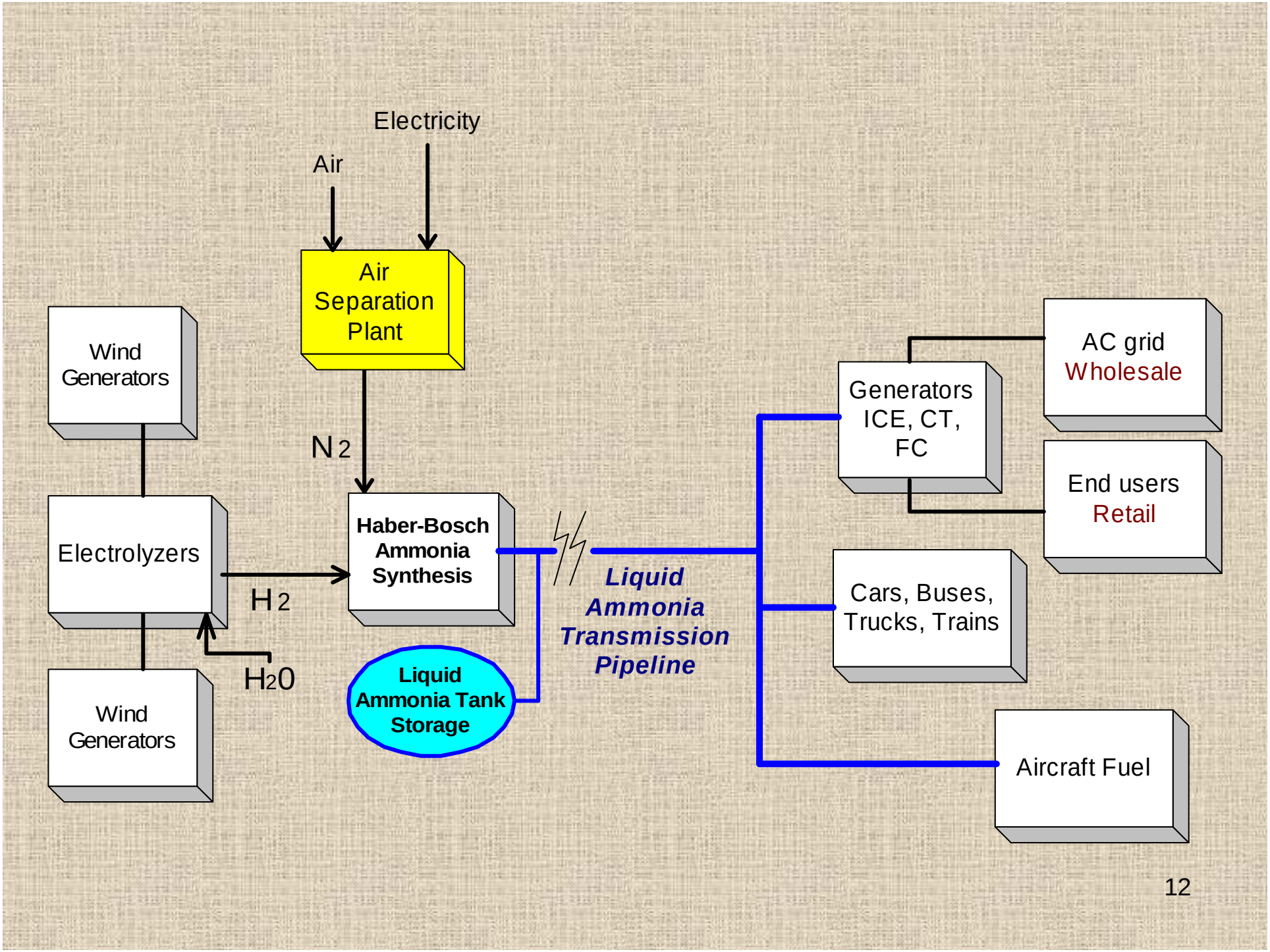


PE: Power Electronics

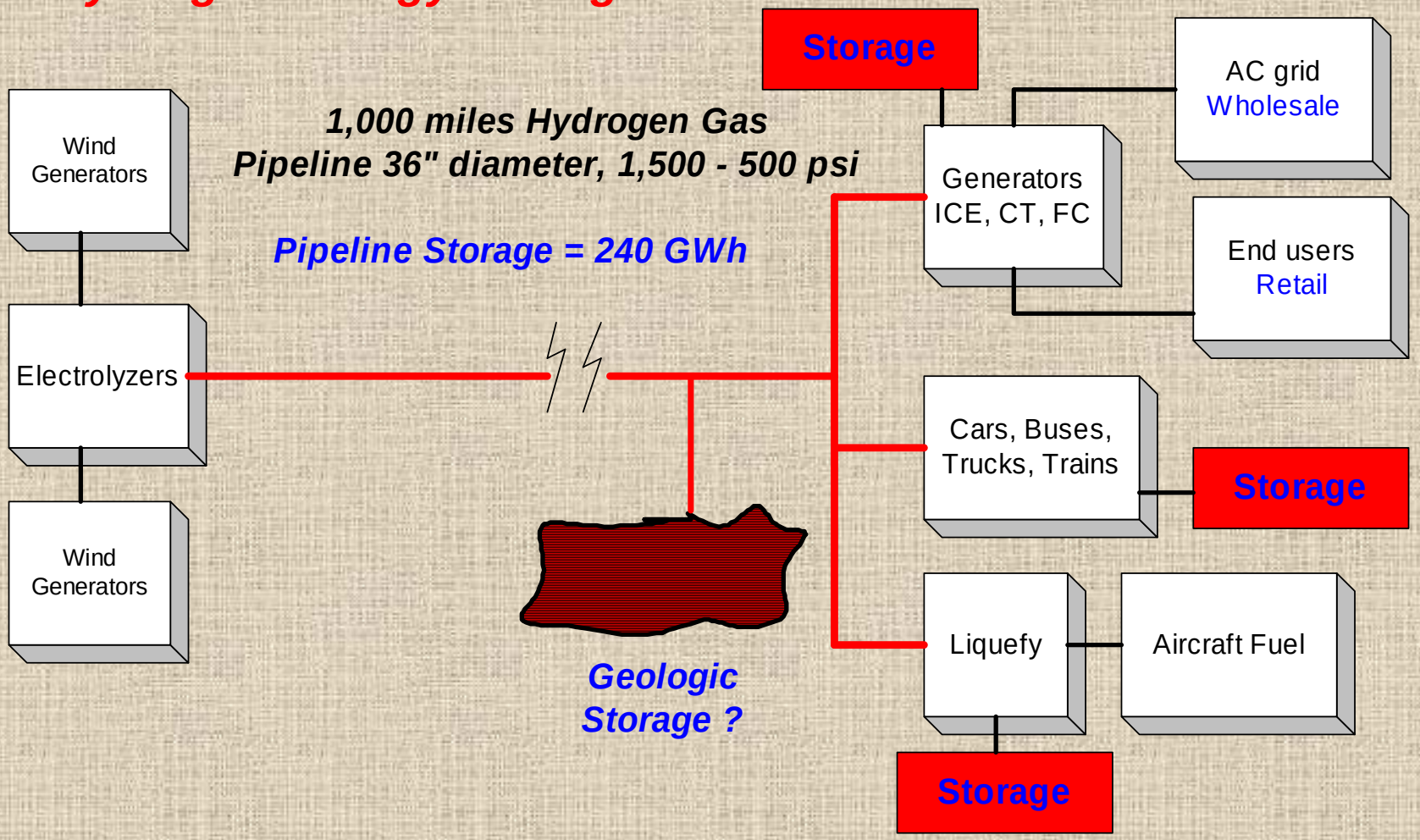

Transmission
Distribution
Wind Generators
High-press Electrolyzers
Wind Generators
City gate
Pipeline Energy Storage
1,500 psi
500 psi
500 miles
Hydrogen Gas
Pipeline
20" diameter
1,500 -- 500 psi
AC grid
Wholesale
Generators
ICE, CT, FC
End users
Retail
Cars, Buses,
Trucks, Trains
Liquefy
Aircraft Fuel

Hydrogen Energy Storage




Electricity
Air
Air Separation Plant
Wind Generators
N2
Electrolyzers
Haber-Bosch Ammonia Synthesis
H2
H20
Wind Generators
Liquid Ammonia Tank Storage
Liquid Ammonia Transmission Pipeline
Generators ICE, CT, FC
AC grid Wholesale
End users Retail
Cars, Buses, Trucks, Trains
Aircraft Fuel

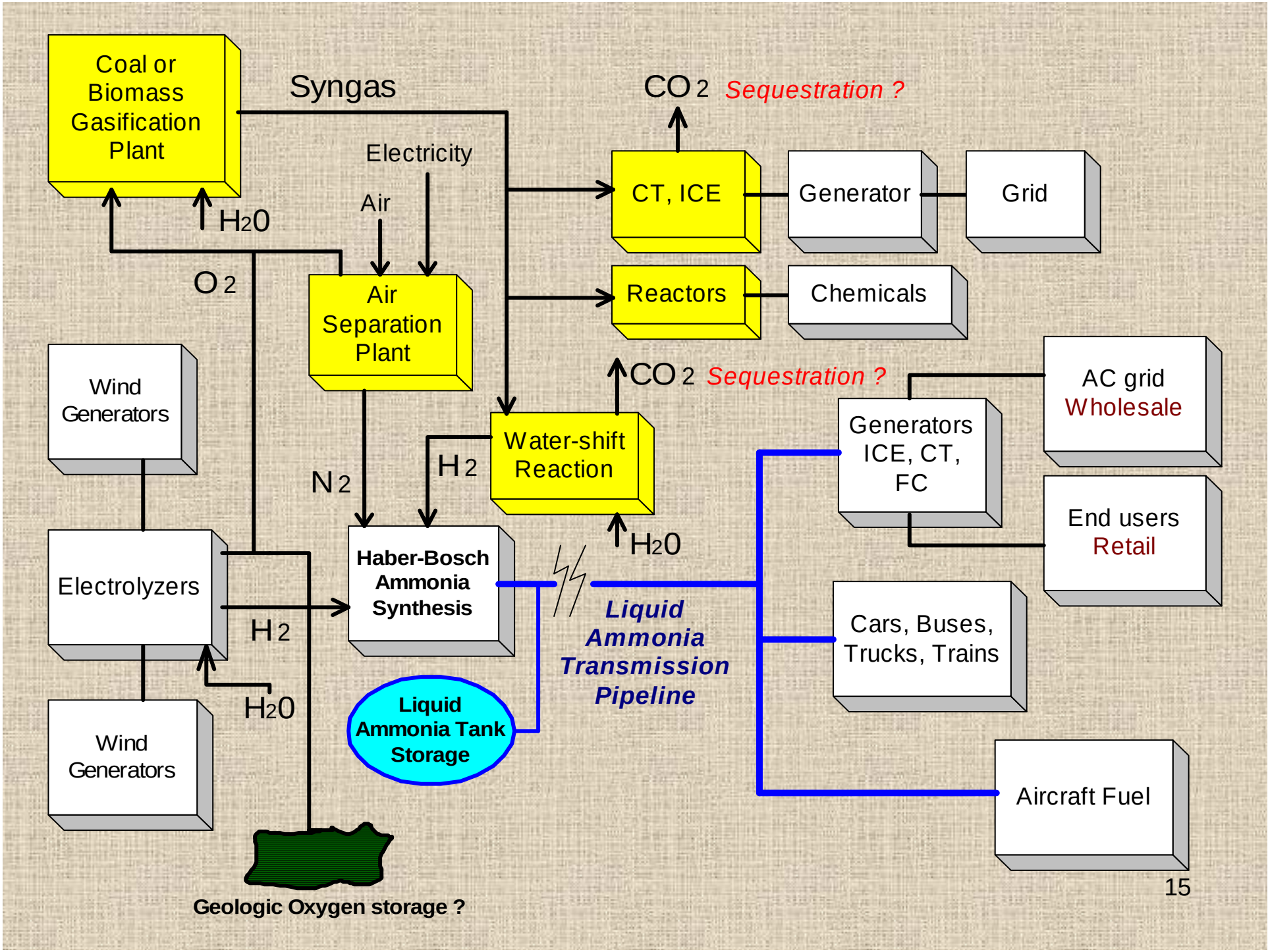
Hydrogen Energy Storage



Liquid Ammonia Storage Tank

60,000 Tons

-28 F


Coal or Biomass Gasification Plant
Syngas
CO2 Sequestration ?
Electricity
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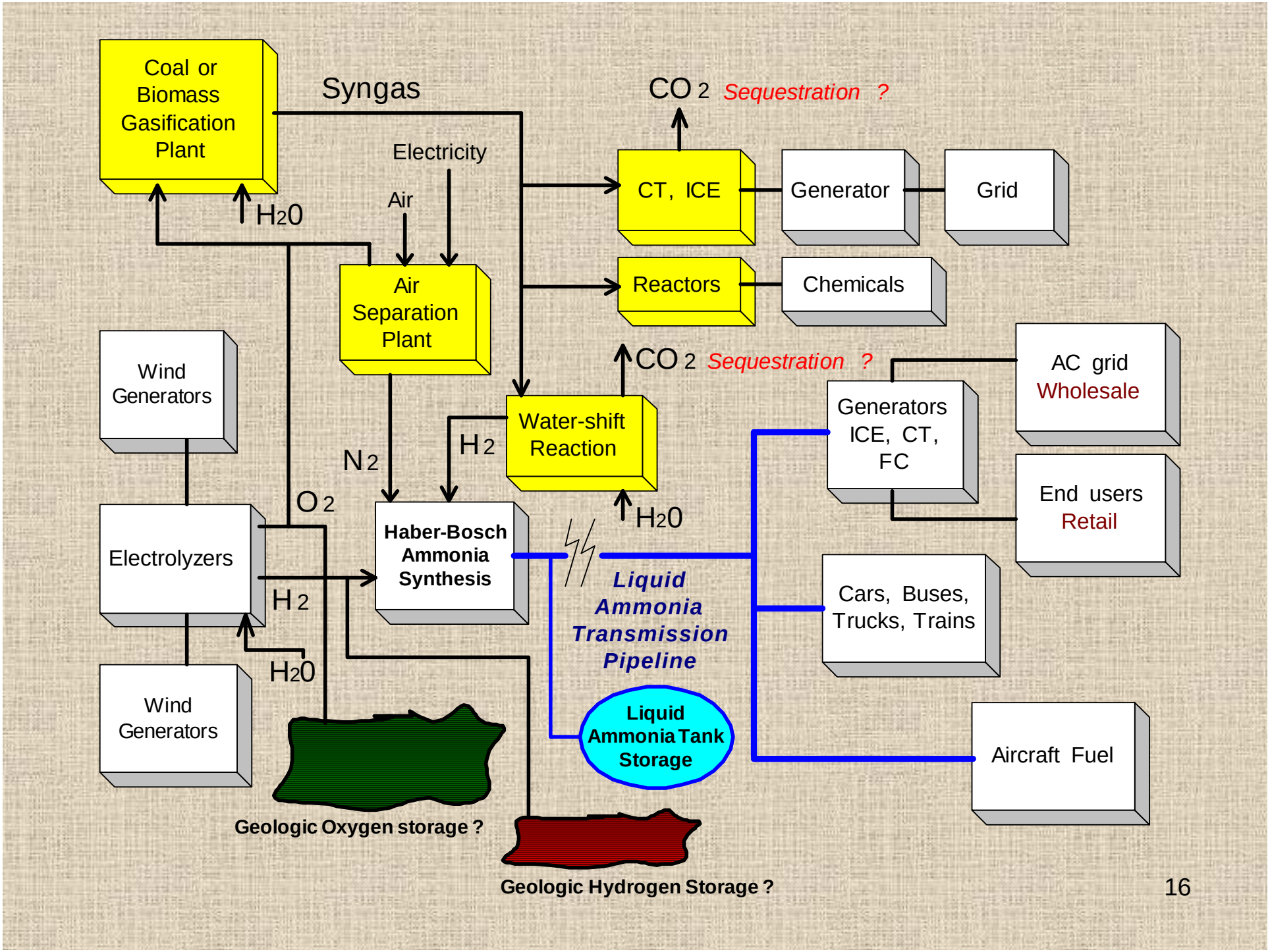
H20
CT, ICE
Generator
Grid
O2
Air Separation Plant
Reactors
Chemicals
Wind Generators
CO2 Sequestration ?
AC grid Wholesale
Generators ICE, CT, FC
N2
H2
Water-shift Reaction
End users Retail
H20
Electrolyzers
Haber-Bosch Ammonia Synthesis
Liquid Ammonia Transmission Pipeline
Cars, Buses, Trucks, Trains
H2
H20
Liquid Ammonia Tank Storage
Wind Generators
Aircraft Fuel
Geologic Oxygen storage ?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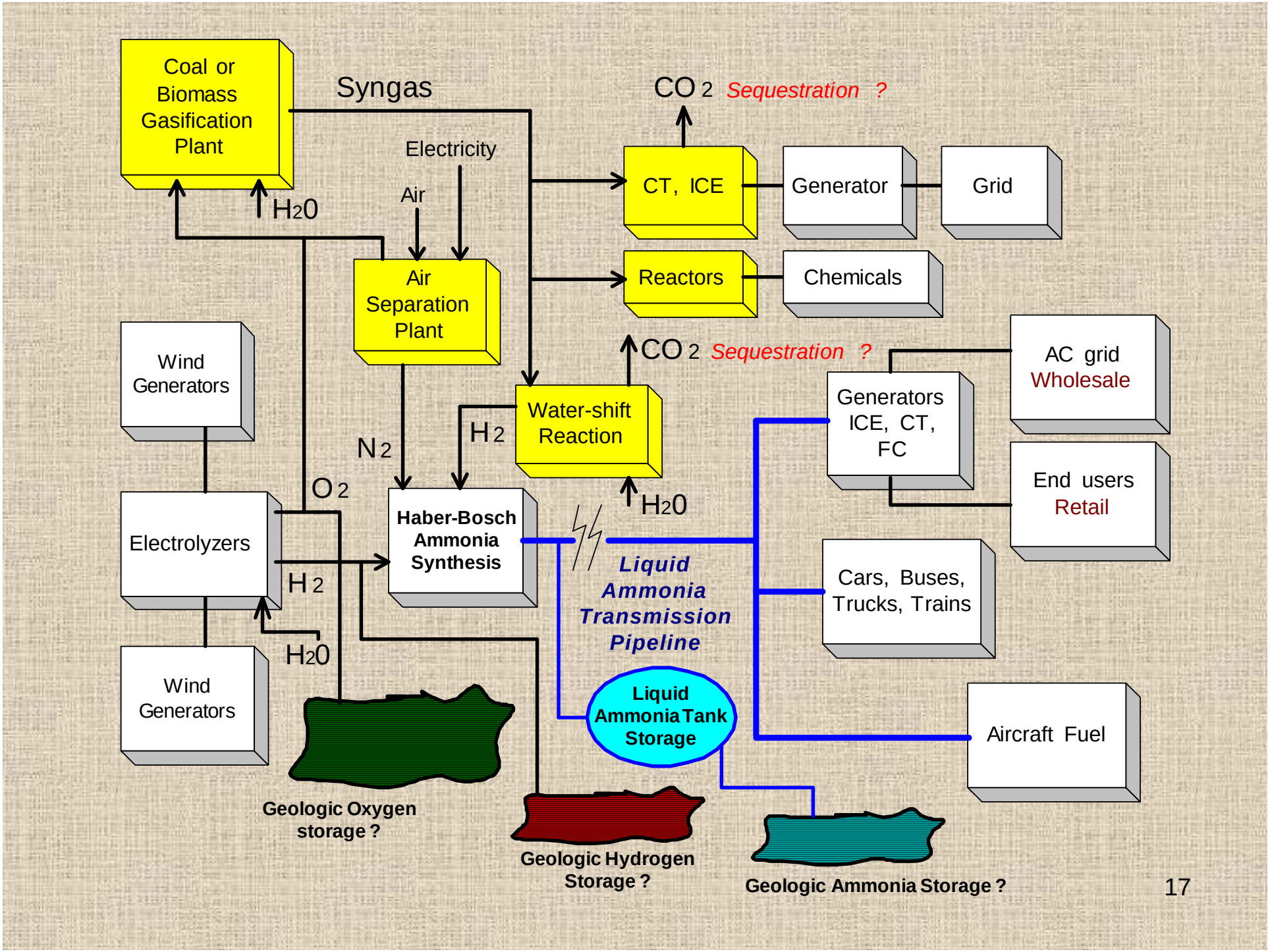
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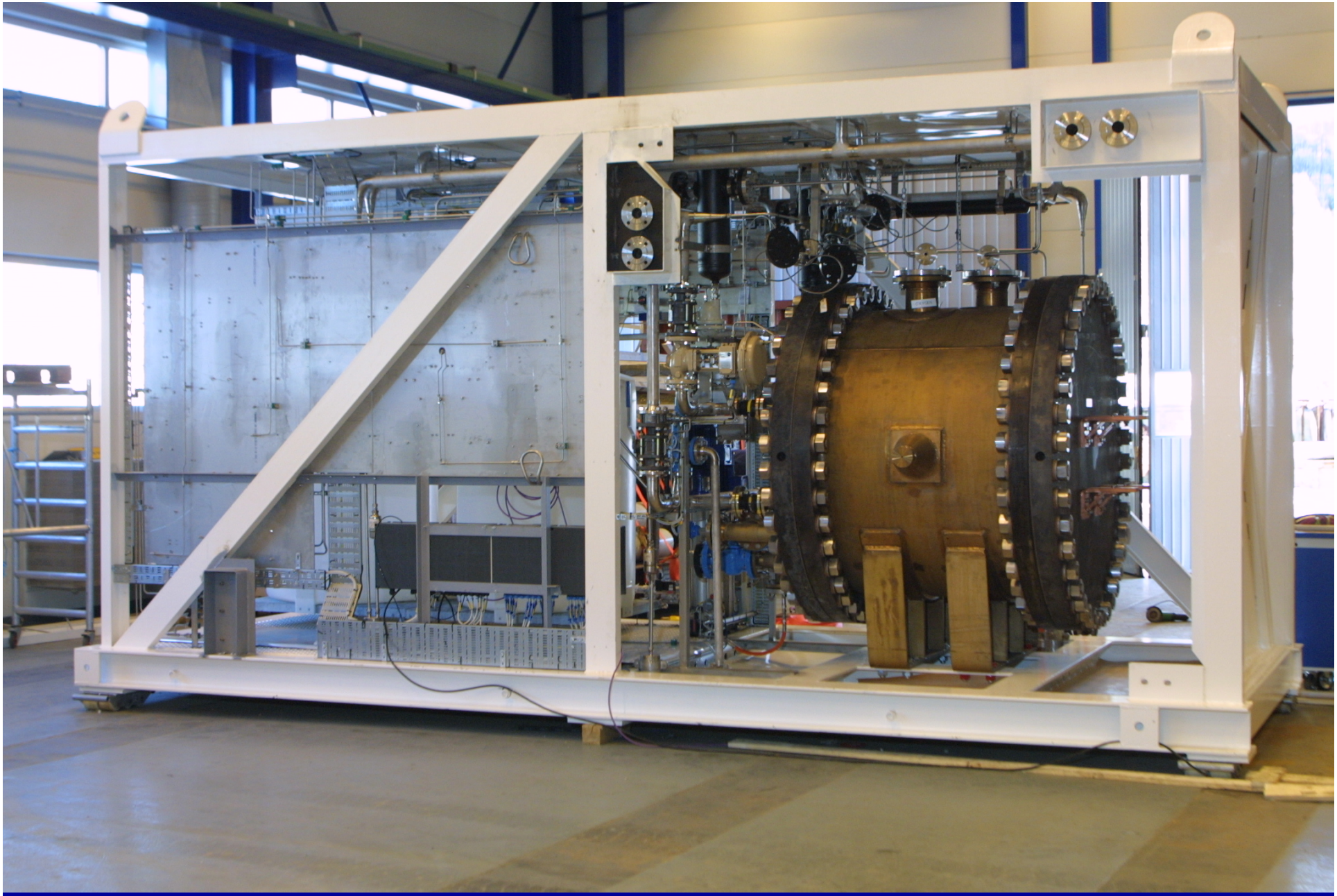
Geologic Oxygen storage ?
Geologic Hydrogen Storage ?
Geologic Ammonia Storage ?


Norsk Hydro
Electrolyzers
2 MW each



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

'07 Farm Bill
"Renewable Nitrogen Fertilizer"
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)**

Farm Bill Title VII (research)

- ***Senate; House***
- ***Agriculture committees***
- ***Two research initiatives***
  - ***Nitrogen fertilizer, NH3 Fuel ?***
  - ***Hydrogen pipeline pilot plant***
- ***Transmission, storage***
- ***New markets, industry***

'07 US Farm Bill

- **Research Initiatives proposed for Title VII:**
  1. **Renewable Nitrogen Fertilizer (Fuel) ~ $1M**
  2. **Renewable Hydrogen Transmission Demonstration Facility (pipeline system) ~ $2M**
- **Related, include:**
  - **hydrogen**
  - **transmission**
  - **firming storage**
- **Ag Committees:**
  - **Neither in House Ag Committee bill passed in July**
  - **Senate Ag Committee passed "Chairman's Mark" 25 Oct**

'07 US Farm Bill

- Ag Committees:
  - House:
    - Peterson, MN, chair
    - Holden, PA, vice-chair
  - Senate:
    - Harkin, IA, chair
- " … we hope to include a "rural ammonia-from-renewables" section in the energy title IX of the farm bill ... "

  -- Senate Ag Committee, Sept 07

Key Objectives
(implied from proposed Farm Bill language)

- Component efficiency improvements
- Other technical challenges
  - Cost competition from “brown” ammonia
  - Modifications to the extant ammonia pipeline/storage system
  - Rail transportation: avoid eschew liability, refuse carriage
  - Impact on nitrogen fertilizer safety regulations
  - Net greenhouse gas benefits
- Two to three renewables-to-fertilizer production models
- Preliminary design for a pilot plant to validate and demonstrate the technical and economic feasibility of production models
- Quantify the economic and environmental impacts

'07 Farm Bill Process

- June: Craft draft legislative language, including a budget
- Present to Ag Committees
- June – Oct: Urge Congressional offices to incorporate into:
  - 2007 Farm bill, or
  - DOE Appropriations bill, or
  - Ag Appropriations bill

07 Farm Bill Process

- House Ag Committee Farm Bill passed July
  - $2.3 billion for Energy Programs
  - RE-NH3 omitted
- Senate version of Farm Bill
  - Committee markup expected Oct 23
  - Demonstrated support for RE-NH3 from:
    - Sen Charles Grassley (R-IA)
    - Sen Amy Klobuchar (D-MN)
- Conference Committee → Congress
- President's signature
- Ag appropriations bill: funding ?

Senate Ag Committee: Majority

- *Tom Harkin, Iowa, CHAIR*
- *Patrick J. Leahy, Vermont*
- *Kent Conrad, North Dakota*
- *Max Baucus, Montana*
- *Blanche Lincoln, Arkansas*
- *Debbie Stabenow, Michigan*
- *E. Benjamin Nelson, Nebraska*
- *Ken Salazar , Colorado*
- *Sherrod Brown , Ohio*
- *Robert Casey, Jr., Pennsylvania*
- *Amy Klobuchar , Minnesota*

Senate Ag Committee: Minority

- *Saxby Chambliss, (R-GA) RANKING*
- *Richard G. Lugar, Indiana*
- *Thad Cochran, Mississippi*
- *Mitch McConnell, Kentucky*
- *Pat Roberts, Kansas*
- *Lindsey Graham, South Carolina*
- *Norm Coleman, Minnesota*
- *Mike Crapo, Idaho*
- *John Thune , South Dakota*
- *Charles Grassley , Iowa*

House Ag Committee: Majority

Colin Peterson, MN, CHAIR
Tim Holden, PA, Vice Chair

Mike McIntyre, NC	***Bob Etheridge, NC***
Leonard L. Boswell, IA	***Joe Baca, CA***
Dennis A. Cardoza, CA	***David Scott, GA***
Jim Marshall, GA	***Jim Costa, CA***
Henry Cuellar, TX	***Brad Ellsworth, IN***
John T. Salazar, CO	***Zachary T. Space, OH***
Timothy J. Walz, MN	***Nancy E. Boyda, KS***
Steve Kagen, WI	***Earl Pomeroy, ND***
Lincoln Davis, TN	***John Barrow, GA***
Nick Lampson, TX	***Joe Donnelly, IN***
Tim Mahoney, FL	
Stephanie Herseth Sandlin , SD	
Kirsten E. Gillibrand, NY	

House Ag Committee: Minority

Bob Goodlatte, VA, RANKING
Frank D. Lucas, OK
Robin Hayes, NC
Sam Graves, MO
Mike Rogers, AL
Marilyn N. Musgrave, CO
John R. "Randy" Kuhl, NY
K. Michael Conaway, TX
Jean Schmidt, OH
Tim Walberg, MI

Terry Everett, AL
Jerry Moran, KS
Timothy V. Johnson, IL
Jo Bonner, AL
Steve King, IA
Randy Neugebauer, TX
Virginia Foxx, NC
Jeff Fortenberry, NE
Adrian Smith, NE
Charles W. Boustany, Jr., LA

"Renewable Nitrogen Fertilizer" (RE-NH3) Research Initiative Proposed Bill Language

- ***Task Force:***
  - ***Within 90 days***
  - ***< 15 members***
  - ***Consult USDOE***
- ***Identify key technical and economic barriers***
- ***Produce commercial-scale quantities of nitrogen fertilizer***
- ***From renewable energy sources***
- ***Produce Research Report:***
  - ***18 months from first meeting***
  - ***Recommend research, development, demonstration and commercialization projects***
  - ***Approximate public-private sector budget***
  - ***Sec'y Ag: review, report to Congress, implementation plan***
- ***$ 950 K authorization request***

"Renewable Nitrogen Fertilizer" (RE-NH3) Research Initiative Proposed Bill Language

Address critical needs of the industry:

1. **Efficiency improvements, each production process component**
2. **Additional technical challenges impeding commercialization**
3. **Determine GHG benefits**
4. **Develop chemical process, business, commercialization models**
5. **Draft RFP or RFQ for pilot plant**
6. **Identify > 10 US counties, low-cost production**
7. **Quantify econ + environ impacts on:**
   - **Jobs**
   - **Investment**
   - **Reduced nitrogen fertilizer imports**

"Renewable Nitrogen Fertilizer" (RE-NH3) Research Initiative Proposed Bill Language

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"Renewable Nitrogen Fertilizer" (RE-NH3) Research Initiative Proposed Bill Language

2. Identify technical challenges impeding commercialization:

- ***Cost competition from NH3 from natural gas and coal***
- ***Modifications or expansion needed:***
  - ***Extant NH3 pipeline and storage tank system***
  - ***Interconnection of on-farm RE-NH3 systems***
- ***Impacts on:***
  - ***Safety regs***
  - ***NH3 transportation infrastructure***
  - ***Domestic water supplies, for NH3 production***
- ***Supply of competitively-priced renewable electricity (?)***

"Renewable Nitrogen Fertilizer" (RE-NH3) Research Initiative Proposed Bill Language

Nothing prevents RE-NH3 for Fuel

Fertilizer to Fuel : the '07 US Farm Bill

- Research Initiatives proposed for Title VII:
  1. Renewable Nitrogen Fertilizer
  2. Renewable Hydrogen Transmission Demonstration Facility (pipeline system)
- Related:
  - Hydrogen
  - Transmission
  - Firming storage
- "Firming": Energy storage reduced by diverse renewables synergy
- Neither in House Ag Committee bill: July
- Senate Ag Committee bill soon: Oct - Nov

Renewable Nitrogen Fertilizer

- Wind, solar, geothermal → electricity
- Electricity + H_2O + N_2 → NH_3
- Other paths to H_2
- Good Farm Bill fit:
  - New ag crops: energy
  - Localized production, consumption
  - New “farm-to-market road system” for exports
  - Fertilizer + ag equipment fuel
- Proposed $1M Task Force: commercialize

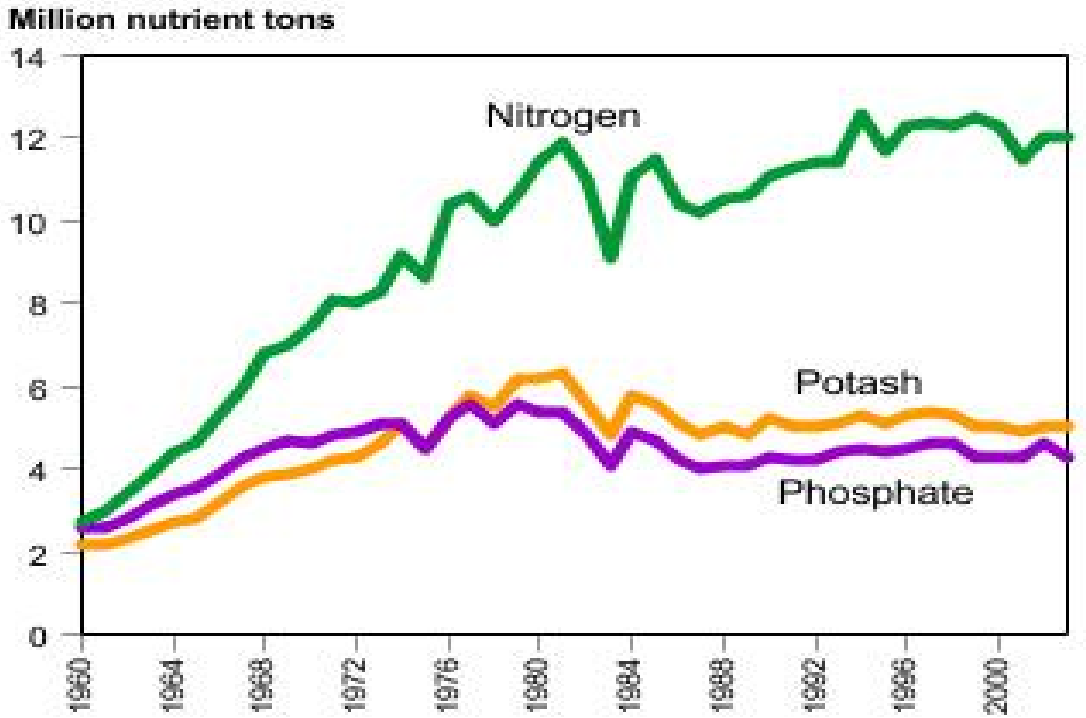
RE-NH3 Fuel

- No Bill restrictions on NH3 use
- Senator Harkin requested briefing from Eldon Boes, ASME Congressional Fellow, Senate Ag Committee
- Expand appeal to Congress
- Hydrogen Engine Center, Algona, IA
  - ICE, spark-ignited
  - CompRatio = 30, Efficiency = 50%
  - Prototype(s): CA water pumping

Challenge 1

N-Fertilizer consumption expected to rise

Figure 4.4.2--Consumption of primary plant nutrients, 1960-2003



Source: ERS, USDA.

ERS

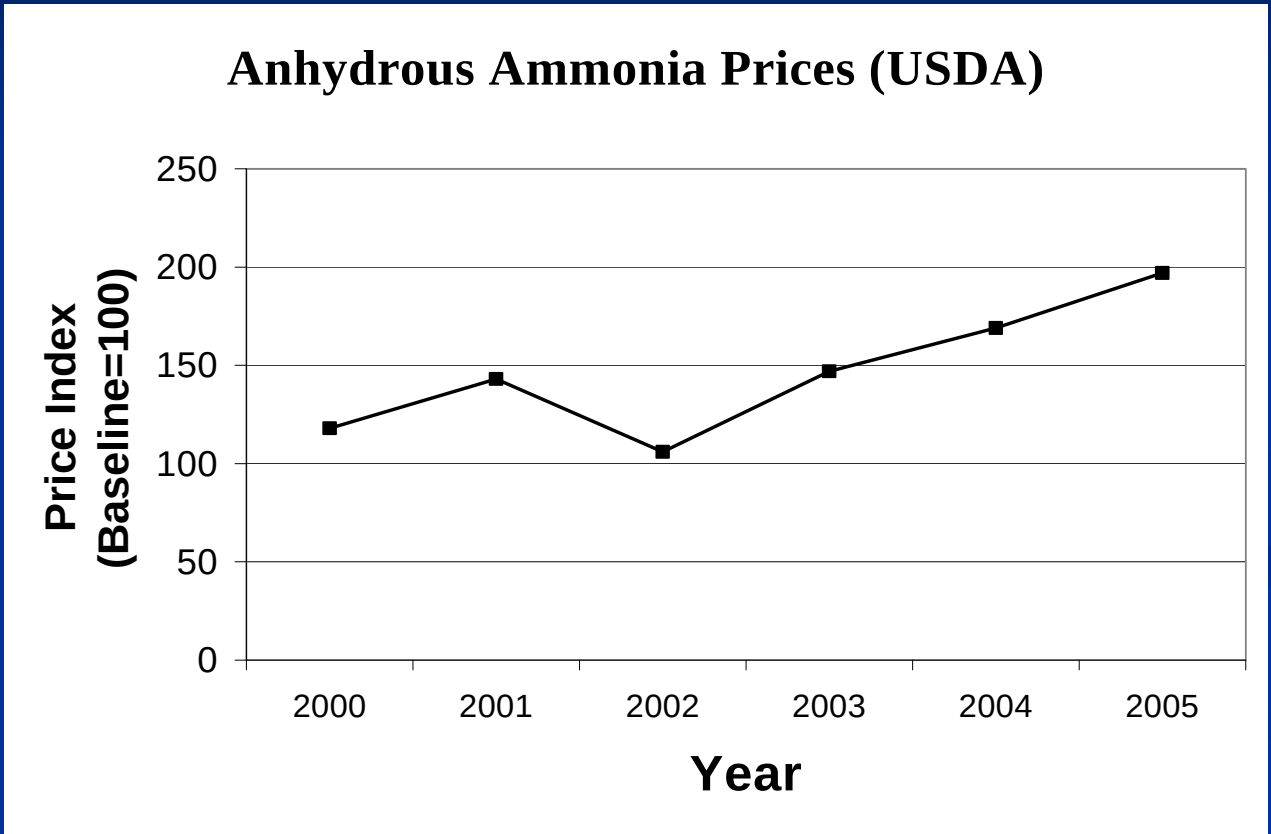
Challenge 1

N-Fertilizer consumption expected to rise

- NH3 Imports growing:
  - Now 60%
  - Trade balance damage
  - Potential U.S. jobs:
    - Not created
    - Exported, lost
- Hurts energy security
- Increases GHG emissions
- USA railroads to shun Ammonia: liability
- Therefore need for NH3:
  - Indigenous production
  - Distributed production
  - From renewable energy sources
  - More pipelines and tanks

Challenge 2

Fertilizer prices expected to continue rising

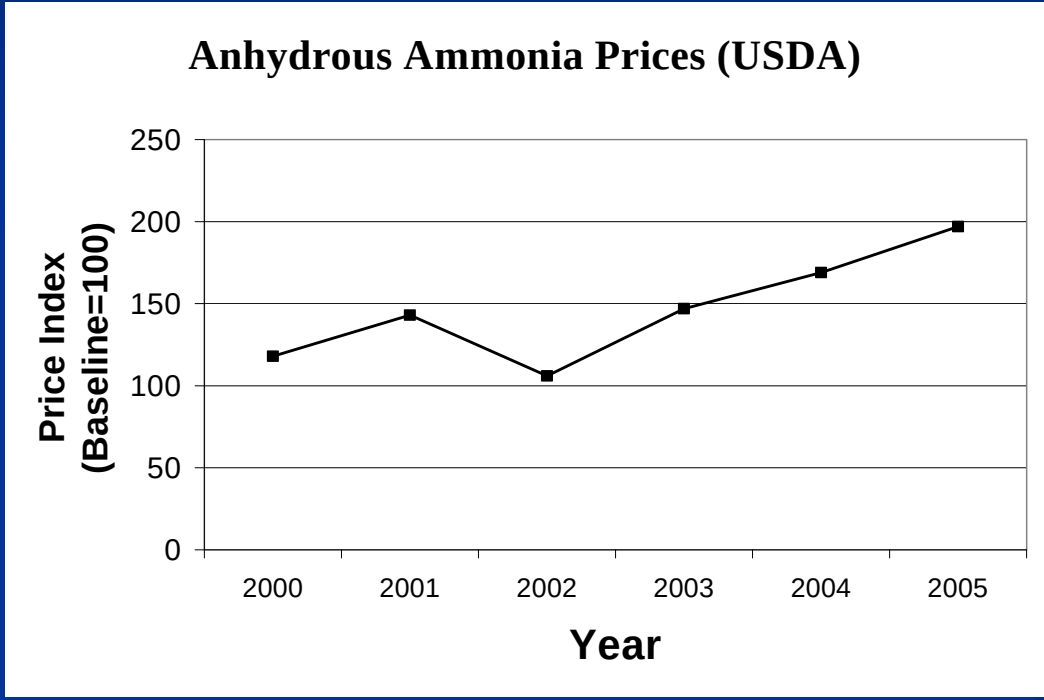


2006 (Mt, average): New Orleans = $

Corn Belt Wholesale Terminal= $

Corn Belt Retail (farmer) = $

Challenge 2
Fertilizer prices expected to continue rising



- Increasing cost pressure on farmers, especially corn, wheat
- Rising corn-ethanol demand → rising N-fertilizer prices

Challenge 3

"Stranded" Slows Renewable Resources Production

- Production
- Transmission
- Delivery
- Sales
- Displacement; penetration

Challenge 4

Energy Conversion System

- Capital equipment costs
- Renewables:
  - Inherent time-varying output
  - Seconds to years, decades
  - Except geothermal
- Low capacity factor of renewable sources: ~ 40%
- Poor “turndown”, dynamic range, of plant components
- Low energy conversion efficiency
- Optimum capacity may be small: 1-5 MWe input
- Poor off-shelf component availability, warranty
- Technical risk; bankability

Challenge 5

Competition: price, cost

Anhydrous ammonia (NH3) (short ton)

- Today's prices (15 Oct 07):
  - Tampa $ 277
  - New Orleans (NOLA) $ 282
  - Corn Belt terminal (CBT) $ 498
  - Corn Belt farmer (CBT +25%) $ 620
- Coal-source:
  - Plant gate cost $
  - Plant gate price $
  - Transportation, delivery cost $
  - Carbon tax cost (CCS ?) $
  - Corn Belt terminal price (CBT) $
  - Corn Belt farmer price (CBT + 25%) $
  - Firm supply ?
- Will new coal → NH3 plants reduce prices ?
- Beyond N-fertilizer: Fuel supply, demand, price

Solution

- Combine the fertilizer + renewable electricity sectors
  - Integrated production, co-location
  - Synergy, efficiency
  - Byproduct marketing
- Now separate: no business case
- Incentive: RE-NH3
  - Renewable-source electricity (wind, solar, biomass) +
  - Hydrogen (from electrolysis of H2O) +
  - Nitrogen (ASU) → NH3 (anhydrous ammonia)

Economic + Environmental Benefits

1. U.S. energy security: reduced imports:
   - NH3
   - Crude oil for ag equipment
2. Food security:
   - Indigenous production
   - Lowers GHG emissions
3. Rural economic development: new income, investment, employment
4. No CO2 emissions from SMR plants and liquid NH3 tankers
5. US trade balance: keep $ x billion at home, via increased competition for offshore NH3 suppliers

Economic + Environmental Benefits

1. Wind energy industry:
   - New product
   - New market
   - New transmission
   - New storage
2. Creates an emissions-free fuel
3. Reduces cost pressure on domestic and imported natural gas

Move to Commercialization: Federal Boost Needed Now

- Accept high risk of innovation
- Public perception of ammonia hazards
- Investor perception of fertilizer industry
  - conventional
  - RE-NH3
- Successful independent business models
- Few, if any, dealings between wind and fertilizer businesses
- Univ MN Morris exception
- “Peak” natural gas
- Market entry barriers to capital investment
- Need R+D and demonstrations
- Need regulations

Path to Commercialization: Wind

- Lowest-cost renewable -- NOW
- Project Developers
  - PPM
  - Abengoa
  - FPL
  - enXco
  - Deere Credit
  - Others
- Only one tool → electricity grid → requires:
  - PPA
  - Transmission
  - Grid integration
  - Turbines
  - Land
  - Finance

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 H2 @ 80% electrolysis efficiency	**16**	**390**	**142,350**
As NH3 @ 70% conversion efficiency	**97**	**2,321**	**847,321**
10” NH3 pipeline capacity as H2	**11**	**264**	**96,360**
10” NH3 pipeline capacity as NH3	**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] $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

Fertilizer → Fuel

- Farm Bill language silent on “fuel”, so OK
- July: Sen Harkin briefed on “fuel” by Eldon Boes, ASME Congressional Fellow, Senate Ag Committee
- Prepare for Senate Farm Bill success
- Business case:
  - Market size, share:
    - 15 MT / yr ag fertilizer
    - 5 MT / yr other
    - **? MT / yr NH3 fuel**
    - **Ag diesel gallons / year ?**
  - Compete with coal, imports
  - Supply: cost
  - Demand: price
  - Interest, orchestrate

Fertilizer → Fuel

Anhydrous ammonia (NH3)

Market size, share today:

- 15 MT / yr ag fertilizer
- 5 MT / yr other
- ? MT / yr fuel

Future market size, share ?

- Ag diesel: gallons / year → tons / year
- Other ag energy
- Non-ag energy

"Ammonia Nation ?"

Anhydrous ammonia (NH3)

- Transportation fuel
- Stationary generation, CHP
- Total USA annual energy '02 - 06
  - 100 quads
  - 10,000 TWh
- More renewables than coal
- Coal limits:
  - Only 200 year supply ?
  - CCS limits: where to put the CO2 ?

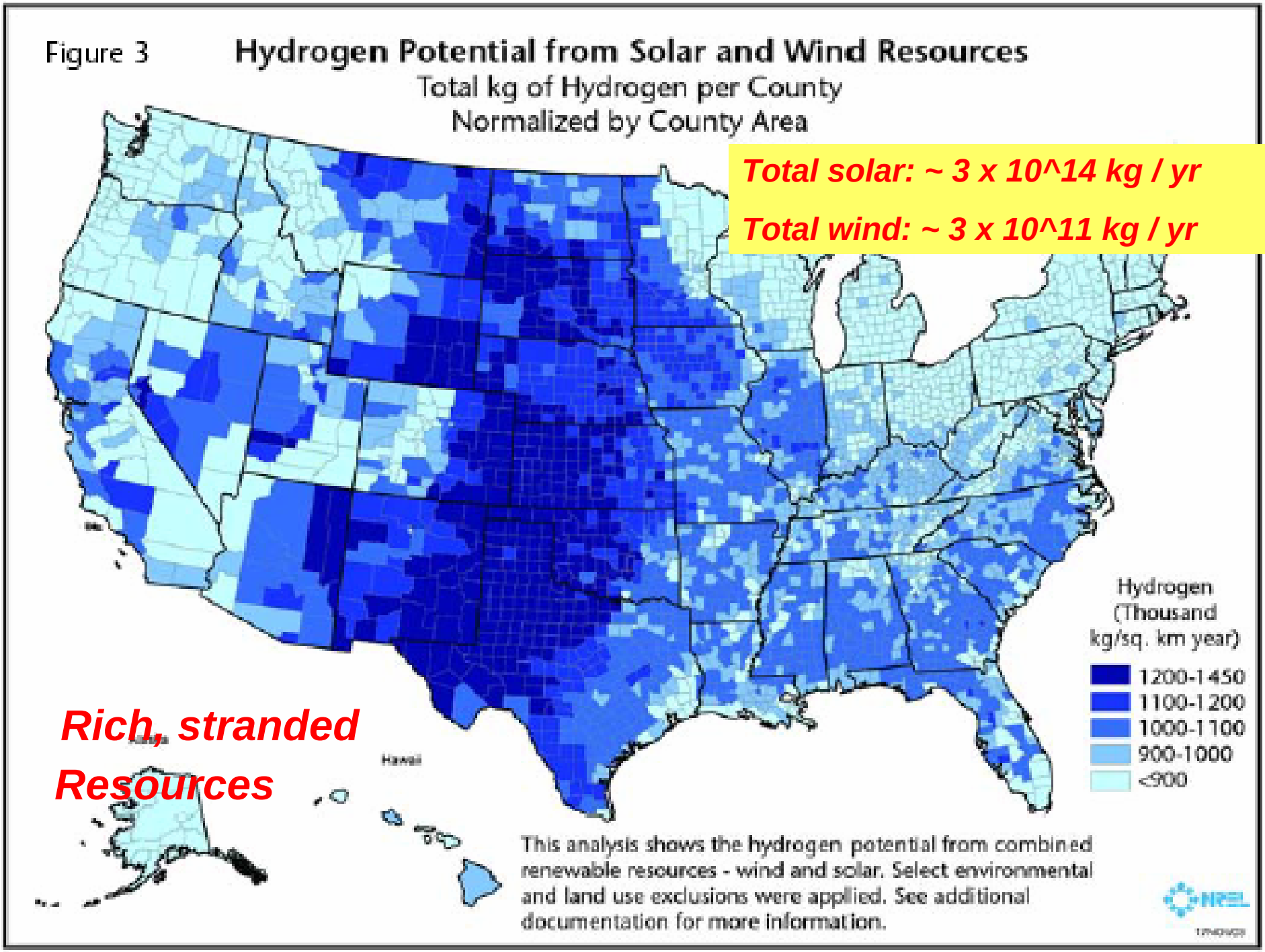
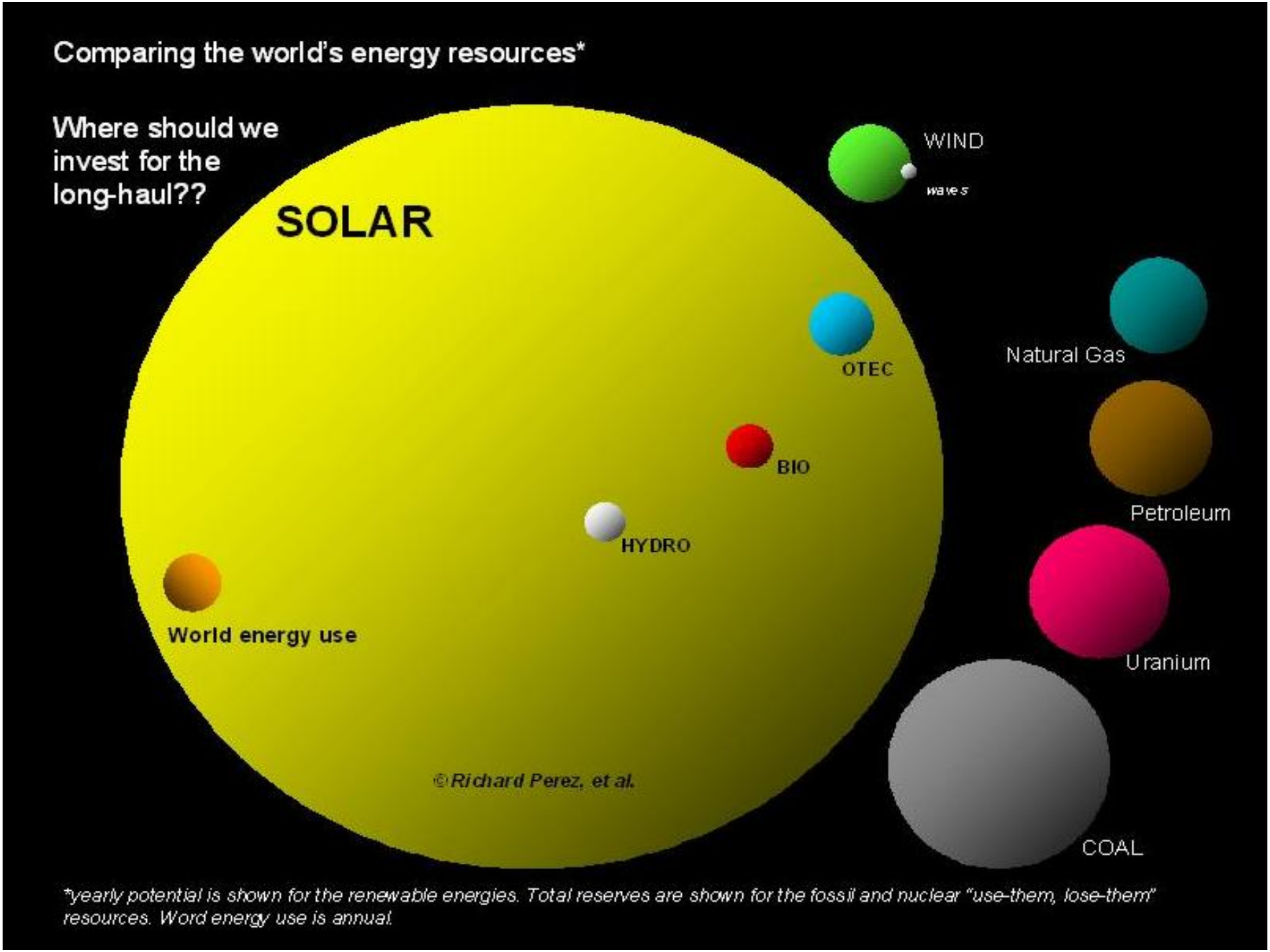
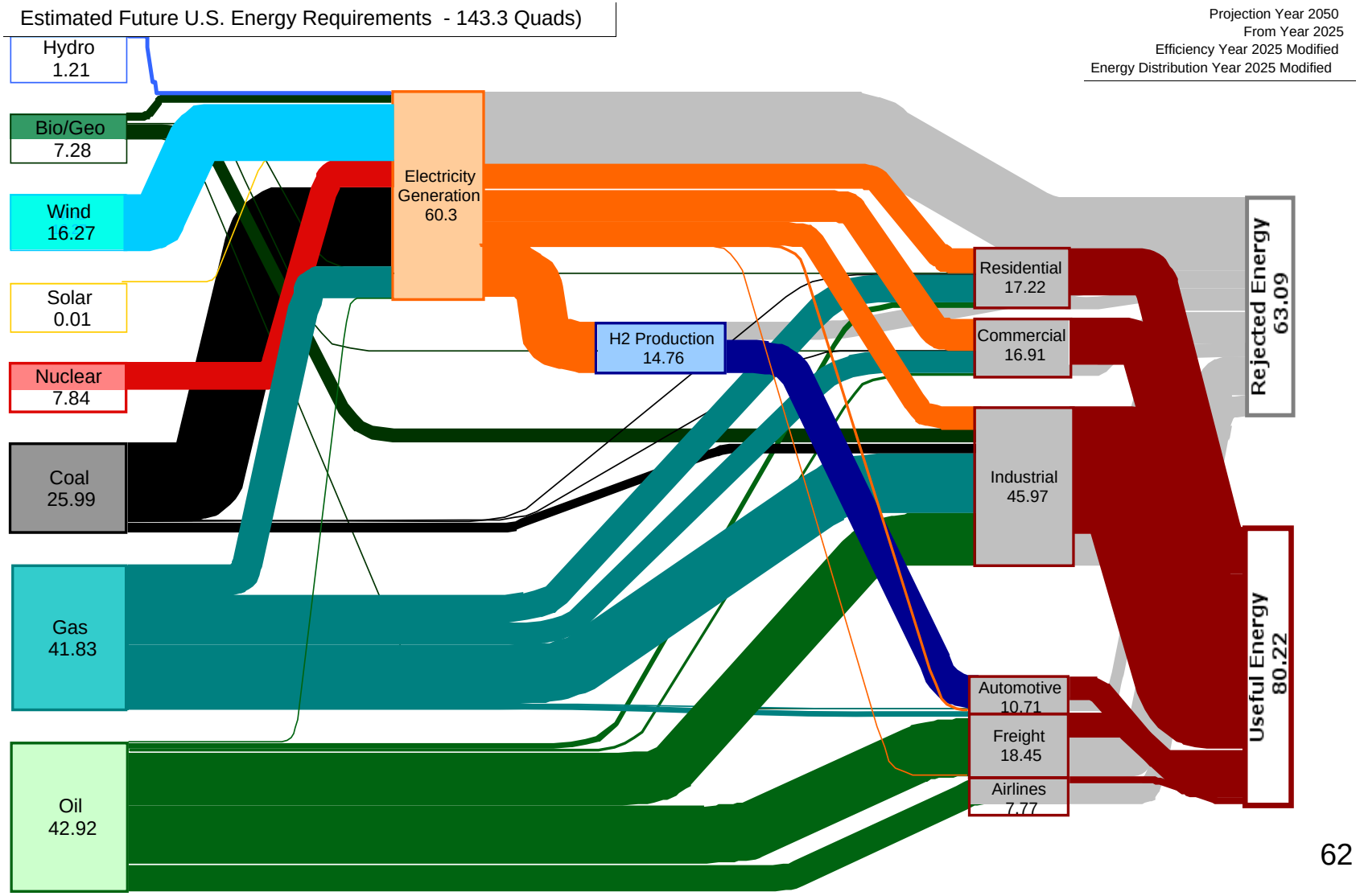


Figure 3
Hydrogen Potential from Solar and Wind Resources
Total kg of Hydrogen per County
Normalized by County Area
Total solar: ~ 3 x 10^14 kg / yr
Total wind: ~ 3 x 10^11 kg / yr
Rich, stranded Resources
Hydrogen (Thousand kg/sq. km year)
1200-1450
1100-1200
1000-1100
900-1000
<900
Hawaii
This analysis shows the hydrogen potential from combined renewable resources - wind and solar. Select environmental and land use exclusions were applied. See additional documentation for more information.
NREL


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

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



"Ammonia Nation ?"

USDOE, Energy Information Administration (EIA), 2050 scenario

Quad = quadrillion BTU

Realistic? Must we do better with renewables ?

Role for anhydrous ammonia, NH3 ?

Sources: total 145 quads (76% fossil)

- Hydro 2
- Wind 16
- Bio – geo 8
- Solar 0
- Nuclear 8
- Coal 26
- Natural gas 42
- Oil 43


The Great Plains Wind Resource
PACIFIC OCEAN
ATLANTIC OCEAN
Gulf of Mexico

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

What if successful: in Farm Bill ?

- Cachet, credibility, attention
- Leverage resources: collaborative
  - Industry
  - USDOE, National Labs
  - Academia
- Recommend to Secretary Ag:
  - Task force members
  - Agenda
  - Budget $950K +

What to do with $950 K
Farm Bill appropriation request

- Secretary of Ag responsible
- Match, collaborate with DOE
- Task force
- Propose scope of work detail, process
- Propose budget
- next ?
- next ?

Call Your Senator to Support

- Energy security
- Renewable Energy development
- Rural economic development
- New “farm-to-market road system”
- Annual-scale firming storage
- Global warming prevention
- Low-cost: $950 K may jump start
  a dynamic new sector

More Information

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- John Holbrook: john.holbrook@charter.net
- Jesse Kharbanda: jkharbanda@elpc.org
- www.agriculture.senate.gov

Optimist

“ You can always count on Americans to do the right thing – after they've tried everything else.”

Winston Churchill

- Opportunities for “Ammonia Fuel Network”
- Systems engineering, analysis required
- Prove NH3 fuel “the right thing”

Fertilizer to Fuel : the '07 US Farm Bill

N- Fertilizer from Renewable Energy

"Ammonia: a Sustainable, Emission-free Fuel"

Rev: 28 Oct 07

October 15, 2007
San Francisco

Bill Leighty
Director, The Leighty Foundation
wleighty@earthlink.net

End 15 Oct 07 presentation

The following slides are supplemental

Bill Leighty

wleighty@earthlink.net

REV: 28 Oct 07

From: Farm Bill, “Chairman’s Mark”, as passed by Senate Ag Committee 25 Oct 07
Viewed 27 Oct 07 at www.agriculture.senate.gov

"SEC. 9018. RURAL NITROGEN FERTILIZER STUDY.

“(a) PURPOSES. --- The purposes of this section are- ---

"(1) to assess the feasibility of producing nitrogen fertilizer from renewable energy resources in rural areas; and

"(2) to formulate recommendations for a program to promote rural nitrogen fertilizer production from renewable energy resources in the future.

"(b) STUDY.--- The Secretary shall---

"(1) conduct a study to assess and summarize the current state of knowledge regarding the potential for the production of nitrogen fertilizer from renewable energy sources in rural areas;

"(2) identify the critical challenges to commercialization of rural production of nitrogen fertilizer from renewables; and

"(3) not later than 270 days after the date of enactment of this section, submit to the Committee on Agriculture of the House of Representatives and the Committee on Agriculture, Nutrition, and Forestry of the Senate a report that summarizes the results of the activities described in paragraphs (1) and (2).

"(c) NEEDS.----

"(1) IN GENERAL. --- Based on the results of the study described in subsection (b), the Secretary shall identify the critical needs to commercializing the rural production of nitrogen fertilizer from renewables, including- ---

"(A) identifying alternative processes for renewables-to-nitrogen fertilizer production;

"(B) identifying efficiency improvements that are necessary for each component of renewables-to-nitrogen fertilizer production processes to produce cost-competitive nitrogen fertilizer;

"(C) identifying research and technology priorities for the most promising technologies;

"(D) identifying economic analyses needed to better understand the commercial potential of rural nitrogen production from renewables;

"(E) identifying additional challenges impeding commercialization, including-

"(i) cost competition from nitrogen fertilizer produced using natural gas and coal;

"(ii) modifications or expansion needed to the currently-installed nitrogen fertilizer (anhydrous ammonia) pipeline and storage tank system to enable interconnection of on-farm or rural renewables-to-nitrogen fertilizer systems;

"(iii) impact on nitrogen fertilizer (anhydrous ammonia) transportation infrastructure and safety regulations;

“(iv) supply of competitively-priced renewable electricity; and

"(v) impacts on domestic water supplies; and

"(F) determining greenhouse gas reduction benefits of producing nitrogen fertilizer from renewable energy.

"(d) PROGRAM RECOMMENDATIONS.--- As part of the report described in subsection (b)(3) and based on the needs identified in subsection (c), the Secretary shall provide recommendations on- ---

“(1) the establishment of a research, development, and demonstration program to support commercialization of rural nitrogen production using renewables;

"(2) the appropriate contents of the program;

"(3) the appropriate approach to implementing the program, including participants and funding plans; and

"(4) legislation to support commercialization of rural nitrogen production using renewables.

"(e) AUTHORIZATION OF APPROPRIATIONS.--- There is authorized to be appropriated to carry out this section $1,000,000 for fiscal year 2008.

AMMONIA PRODUCER CAPACITY (Thousands of metric tons per year, anhydrous ammonia (NH3))

Agrium US: Borger, TX; Kenai, AK	1,650
Air Products: Pace, FL	50
CF Industries: Donaldsonville, LA (4 units)	1,910
Chevron: El Segundo, CA; Richmond, CA	20
Dakota Gasification: Beulah, ND	390
El Paso Refining and Chemical: Cheyenne, WY; Freeport, TX; St. Helens, OR	570
Farmland Industries: Beatrice, NE; Coffeyville, KS; Dodge City, KS; Enid, OK (2 units); Ft. Dodge, IA; Lawrence, KS	2,490
Green Valley: Creston, IA	30
Honeywell: Hopewell, VA	500
IMC-Agrico: Faustina, LA	510
J.R.Simplot: Pocatello, ID	90
Koch Nitrogen: Sterlington, LA (2 units)	1,095
LaRoche: Cherokee, AL	160
MissChem Nitrogen: Yazoo City, MS (2 units)	645
Nitromite Fertilizer: Dumas, TX (2 units)	120
PCS: Augusta, GA; Geismar, LA; Lima, OH; Memphis, TN	2,040
Royster-Clark: East Dubuque, IL	275
Terra Industries: Beaumont, TX.; Blytheville, AR.; Sergeant Bluff, IA; Verdigris, OK (2 units); Woodward, OK	2,385
Triad Nitrogen: Donaldsonville, LA (2 units)	950
Total	**15,880**

Following slides are from Bill Leighty's presentation at "Ammonia '06 …" conference 9-10 Oct, Denver, CO

The following slides are for suggested analytical framework only, and do not represent valid or accurate analyses.

Many more cases need to be formulated, analyzed, and reviewed to prepare to respond the the '07 Farm Bill Section 9018 opportunity.

Case 3a: Annual costs, no firming
Hydrogen energy equivalent
Elec → GH2 → NH3 → Liquid Pipeline → City gate

- **Capital costs @ 15% CRF @ $ 2,268 M** **$ 340 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**

Total annual costs **$ 504 M**

Annual cost per Mt H2 = $ 2,572

Annual cost per kg H2 = $ 2.57

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