

# Ammonia as a Transportation Fuel and Fertilizer

Des Moines

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[www.energy.iastate.edu](http://www.energy.iastate.edu)

# Iowa Energy Center

- Created by the Iowa Energy Act of 1990
- Conduct and sponsor research, demonstrations, training and educational programs in the areas of energy efficiency and renewable energy
- Main facilities/programs – Biomass Energy CONversion (BECON) Facility, Energy Resource Station (ERS), Alternative Energy Revolving Loan Program (AERLP)

# The Perfect Transportation Fuel

- Can be produced from any raw energy source (i.e. wind, solar, biomass, coal, nuclear, hydro etc.) Don't leave wind and solar behind as transportation fuel sources!
- Is cost effective
- Has significant storage and delivery systems already in place
- Is environmentally friendly
- Can be used in any prime mover (i.e. diesel engines, fuel cells, SI engines, gas turbines, etc.)

# Ammonia Basics

- High U.S. cost is due to high cost of U.S. natural gas
- The U.S. imported over 50% of its nitrogen fertilizer for the first time in 2005
- Ammonia high cost partially due to highly seasonal nature of use
- Ammonia has been produced from coal in Beulah, North Dakota for decades. China has huge coal to ammonia capacity.



GETTY

# Oil Experts See Supply Crisis in Five Years

International  
Energy  
Agency

July 10, 2007

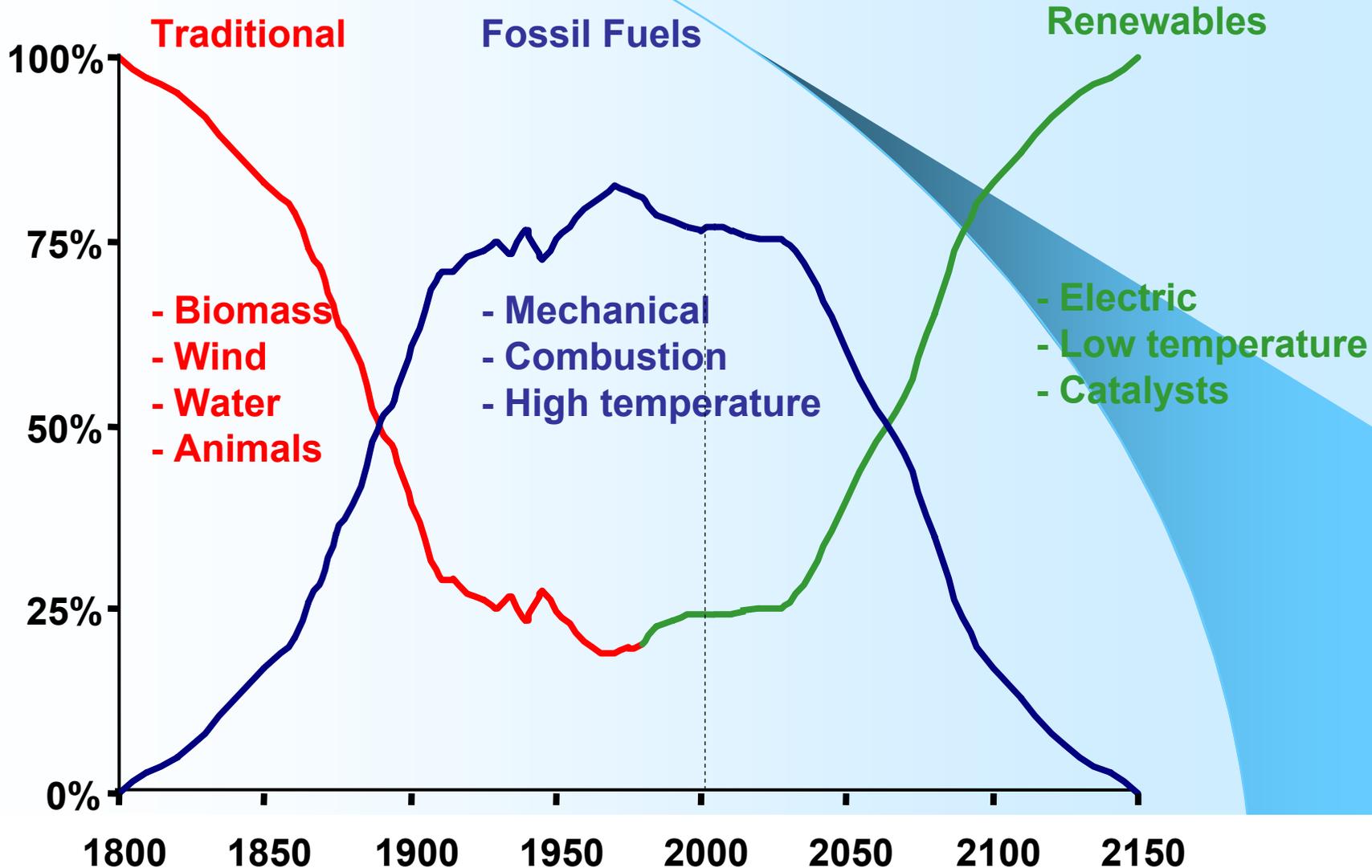
# Energy Independence Goals

- Use U.S. Resources for U.S. Energy Needs
- Eliminate Petroleum Imports
- Provide a Bridge to Renewable Energy
- Protect the Environment
- Create U.S. Jobs/Improve Economy
- Eliminate Ammonia Imports

# Background Information

# The Fossil Fuel Era

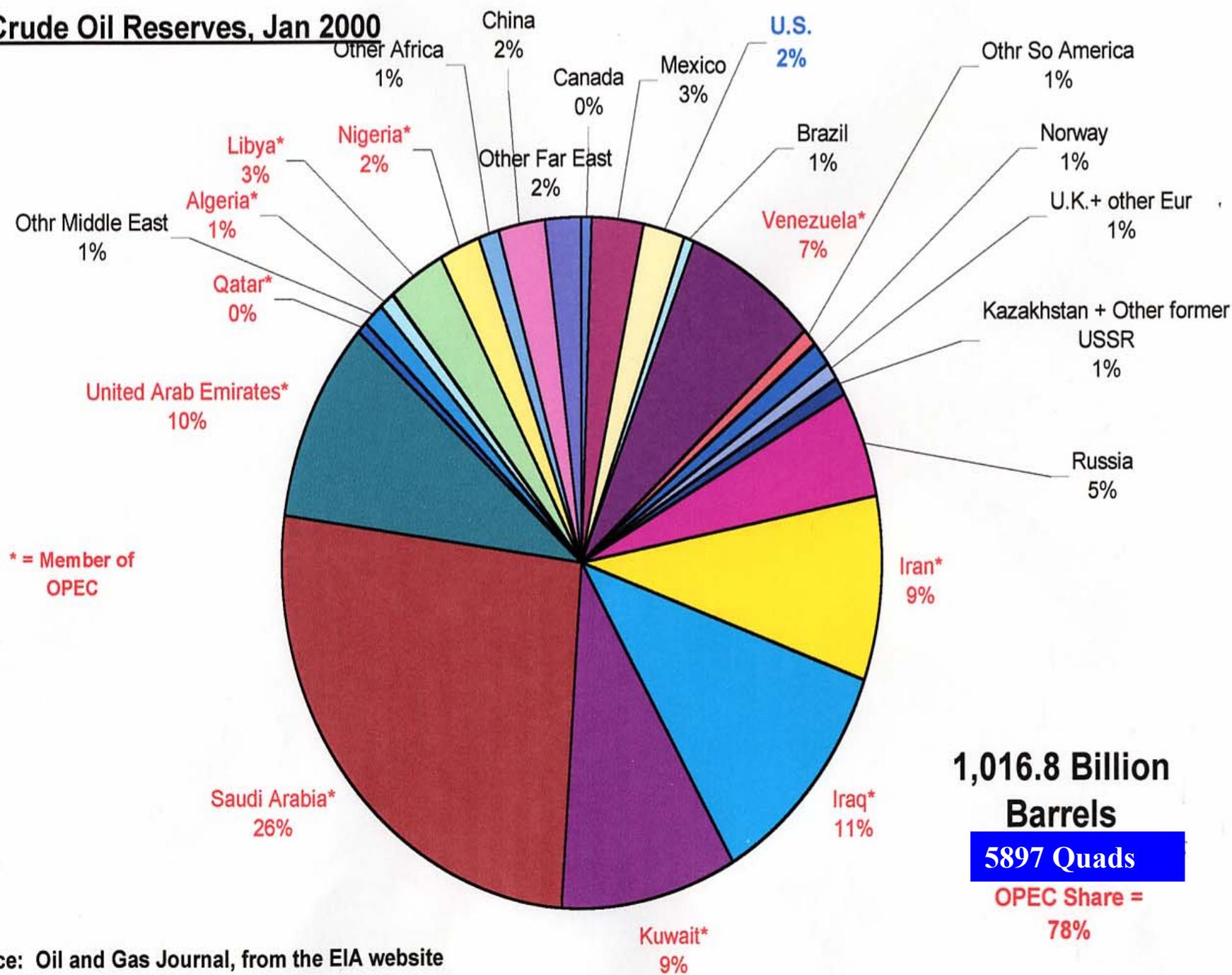
% of total



Source: Ewald Breunese, Shell Netherlands, 14th IAMA Annual World Conference, Montreux, June 14th 2004

# Oil Reserves

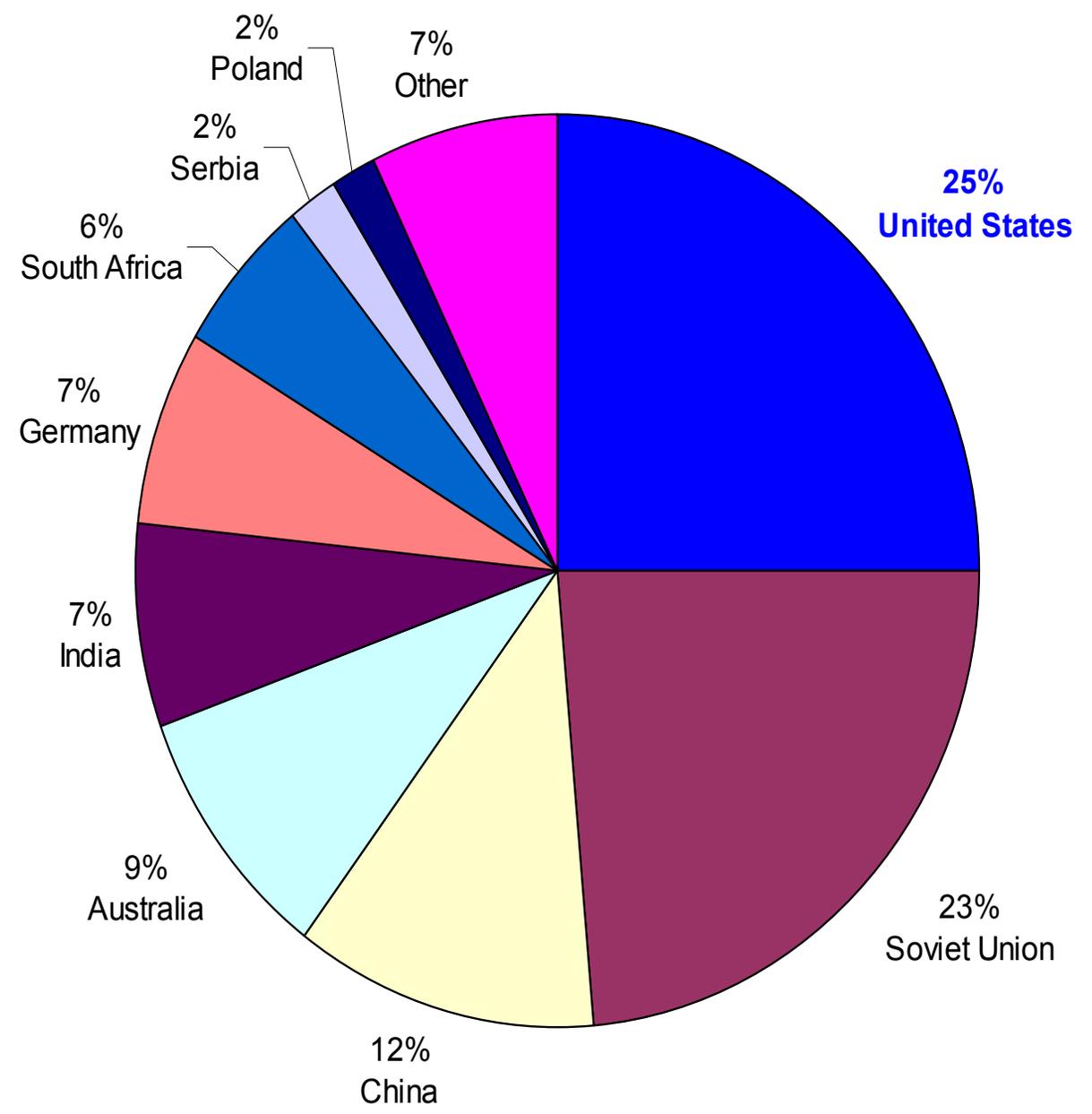
# World Crude Oil Reserves, Jan 2000



Source: Oil and Gas Journal, from the EIA website on International Petroleum Consumption

# Coal Reserves

# World Recoverable Coal Reserves - January 1999



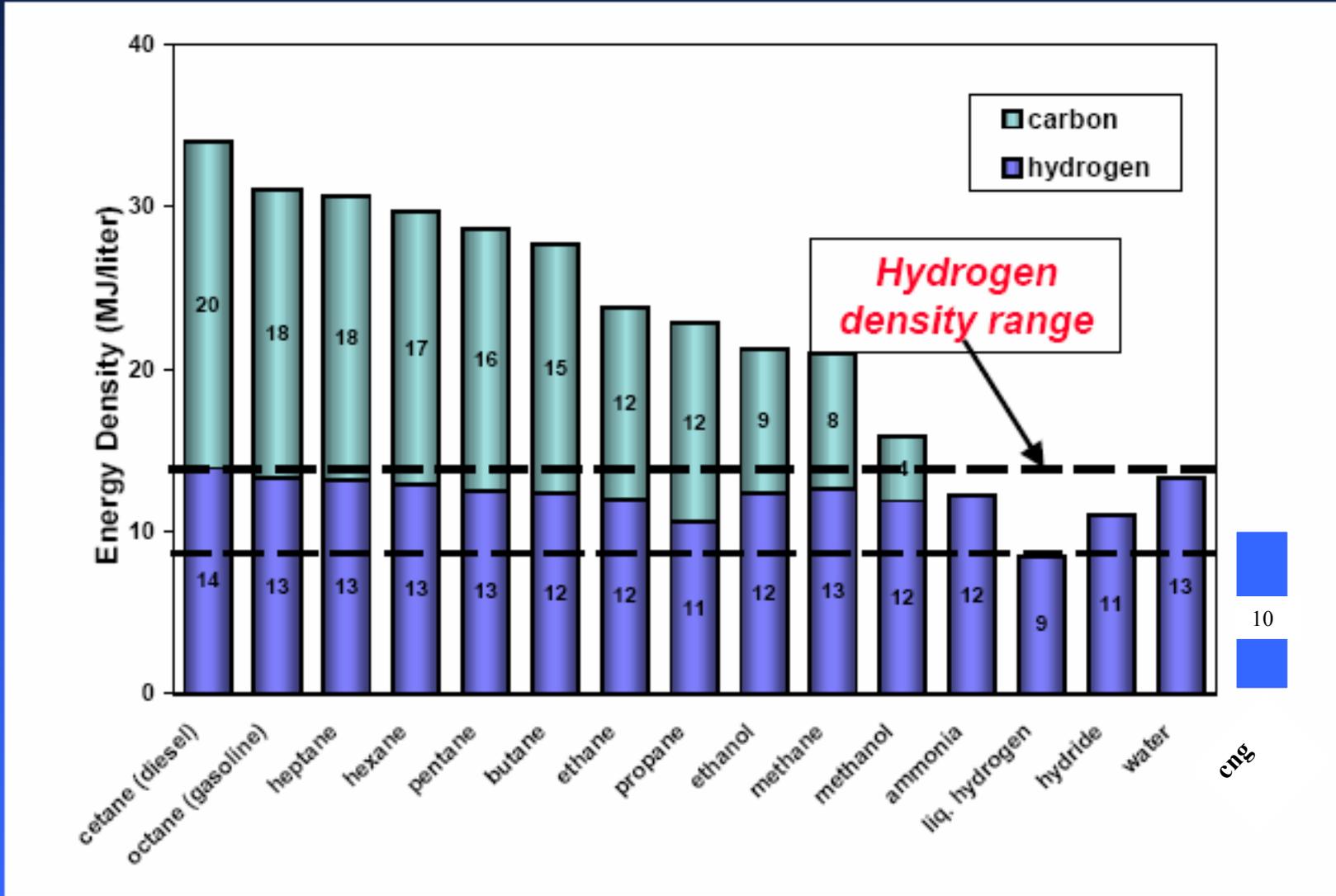
# Dakota Gasification



Over 20 years of producing natural gas, ammonia and other valuable chemicals from US coal.

At Lukes - \$4.50 Nat. Gas from new coal gasification plants.

# Energy densities (LHV) for fuels in liquid state



# Freedom Car Targets w/ 2005 NH3 Comparison

Parameter	Units	2007	2010	2015	NH3 (2005)
Spec. Energy	kWh/kg	1.5	2	3	3.0
Energy Density	kWh/L	1.2	1.5	2.7	2.7
Storage Cost	\$/kWh	6	4	2	2.1
Fuel Cost	\$/gal. Gas equiv	3	1.5	1.5	1.7*

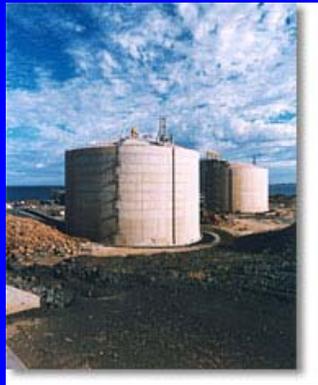
\*\$280/ton ammonia

# Fuel Costs

- **June 2003 Chemical Market Reporter\***

	<b>\$/MMBtu</b>
● <b>Ammonia - \$200/metric ton*</b>	<b>\$10.01</b>
● <b>Gasoline - \$1.20/gallon</b>	<b>\$10.52</b>
● <b>Methanol - \$0.79/gallon*</b>	<b>\$13.68</b>
● <b>Ammonia - \$270/short ton</b>	<b>\$14.86</b>
● <b>Ethanol - \$1.25/gallon* (\$2.70, 9/05)</b>	<b>\$16.44</b>
● <b>Gasoline - \$2.00/gallon</b>	<b>\$17.54</b>
● <b>Wind - \$0.035/kwh x 2 (electrolyzer)</b>	<b>\$20.51</b>
● <b>Gasoline - \$2.50/gallon</b>	<b>\$21.92</b>
● <b>Ethanol - \$2.70/gallon (9/05)</b>	<b>\$35.51</b>

# Future Compatibility



Hydrogen + Nitrogen

Ammonia

Storage & Delivery – Pipeline, Barge, Truck, Rail

Stationary Power

Fertilizer

Transportation

# Economic Impacts

2003 Petroleum Imports: ~ 13 million bpd

= \$228 billion @ \$48/bbl, \$456 billion @ \$96/bbl

2003 Gasoline Consumption – 8,756,000 bbl/day

$15.3 \times 10^{15}$  Btu/year = 850 million ton/year ammonia

1250 new plants @ 650,000 ton/year each

\$562 billion investment @\$450 million/plant

375,000 new jobs

\$5 billion annual new tax revenue/year (employees only)

# Delivery Infrastructure

# California Hydrogen Stations



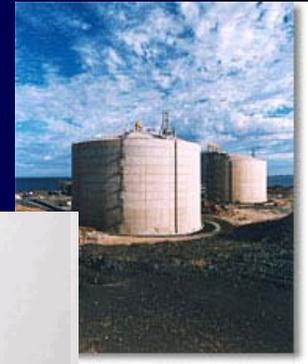
[http://www.fuelcellpartnership.org/fuel-vehl\\_map\\_print.html](http://www.fuelcellpartnership.org/fuel-vehl_map_print.html)

# Iowa Hydrogen Refueling Stations

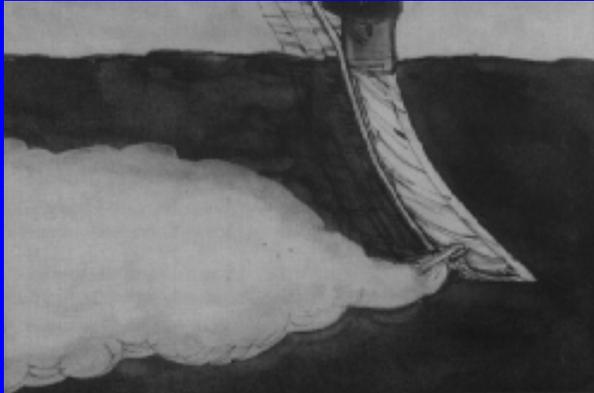
Over 800 retail ammonia (the “Other Hydrogen”) outlets currently exist in Iowa.



# Ammonia Storage & Transport



# Anhydrous Application



**Anhydrous ammonia expands into a gas as it is injected into the soil where it rapidly combines with soil moisture.**



# End Use Applications

- Spark-Ignition Internal-Combustion Engines (w/ethanol)
- Diesel Engines (w/biodiesel)
- Direct Ammonia Fuel Cells
- Gas Turbines
- Gas Burners

# Health And Safety

- “Safety assessment of ammonia as a transportation fuel”, Nijs Jan Duijm, Frank Markert, Jette Lundtang Paulsen, Riso National Laboratory, Denmark, February 2005

# Scapegoat?

Ammonia



Ephedrine and Pseudoephedrine



Methamphetamine



VOC's + NO<sub>x</sub> + O<sub>2</sub> + Sunlight = ozone = smog+

NO<sub>x</sub> + H<sub>2</sub>O + ammonia = ammonium nitrate = smog-

If the NO<sub>x</sub> doesn't form ammonium nitrate it goes to ozone (worse)

Fossil fuels (the source of NO<sub>x</sub> ) are the problem, not ammonia

Ammonia is actually used to clean up NO<sub>x</sub> emissions at coal plants

# Progress

- Irrigation pump demonstration with SI engine
- Over 50% efficiency demonstrated in an IC engine
- Direct ammonia fuel cell
- Wind to ammonia demonstration funded
- 95% ammonia, 5% diesel, full power, LOWER NO<sub>x</sub>!!!
- New ammonia synthesis technologies

# Summary

- **Ammonia Meets Most 2015 Freedom Car Targets Today**
- **Ammonia Has a Very Extensive, Worldwide Delivery and Storage Infrastructure Already in Place**
- **Only H<sub>2</sub> and NH<sub>3</sub> Have No Tailpipe Greenhouse Gas Emissions**
- **Only H<sub>2</sub> and NH<sub>3</sub> Can be Made From Electricity and Water (+air for NH<sub>3</sub>)**
- **Ammonia From Fossil Fuels Now**
- **Ammonia From Renewables in the Near Future**
- **Diesel and Spark-Ignition IC Engines Now**
- **Fuel Cells in the Future**
- **Ammonia Looks Very Good Now and in the Future**
- **Ammonia is Safer Than Gasoline, Propane and Hydrogen**