Ammonia as a Transportation Fuel and Fertilizer

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Norm Olson –Iowa Energy Center

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)

Oil Experts See Supply Crisis in Five Years

International Energy Agency

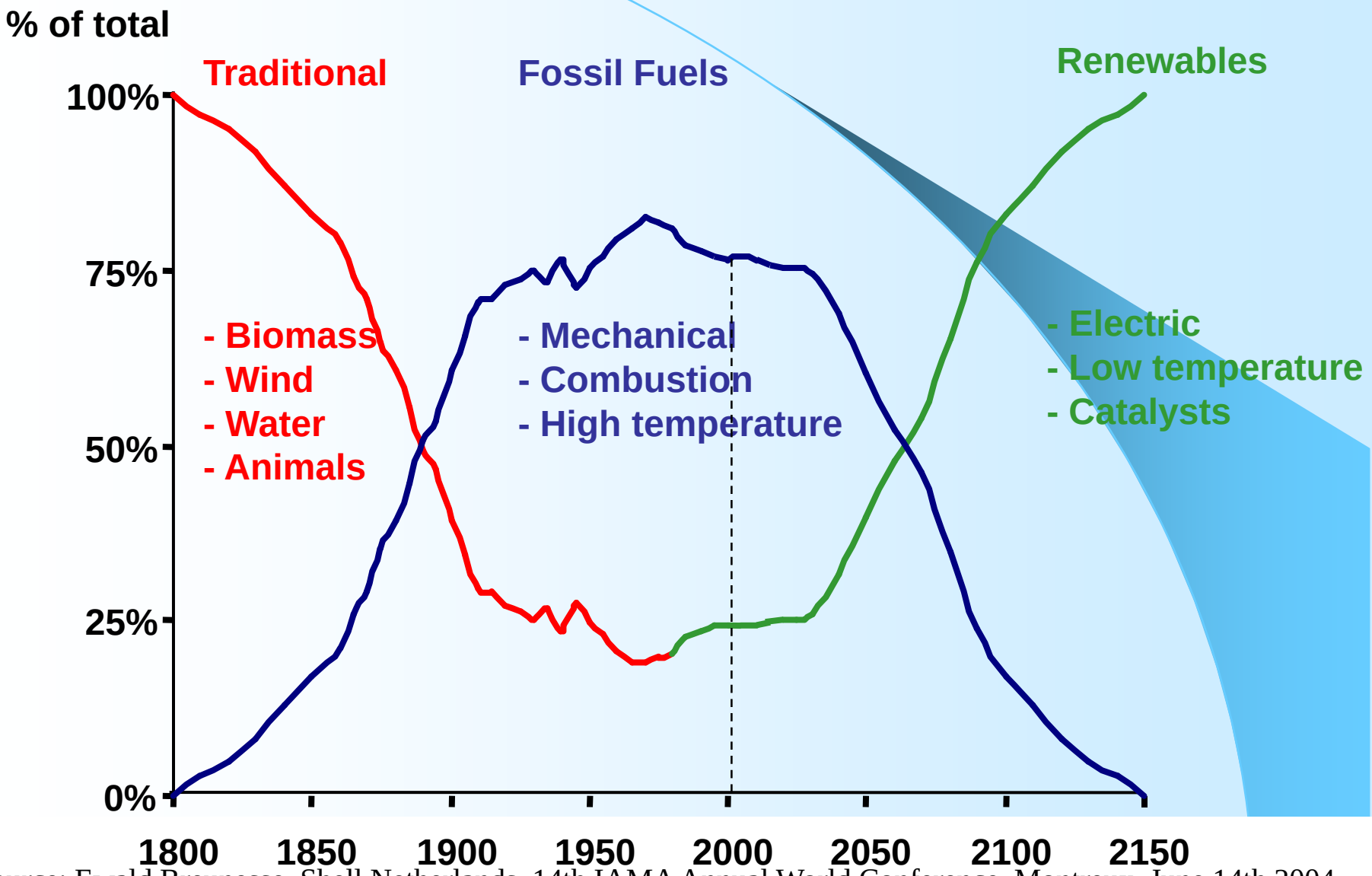
July 10, 2007

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

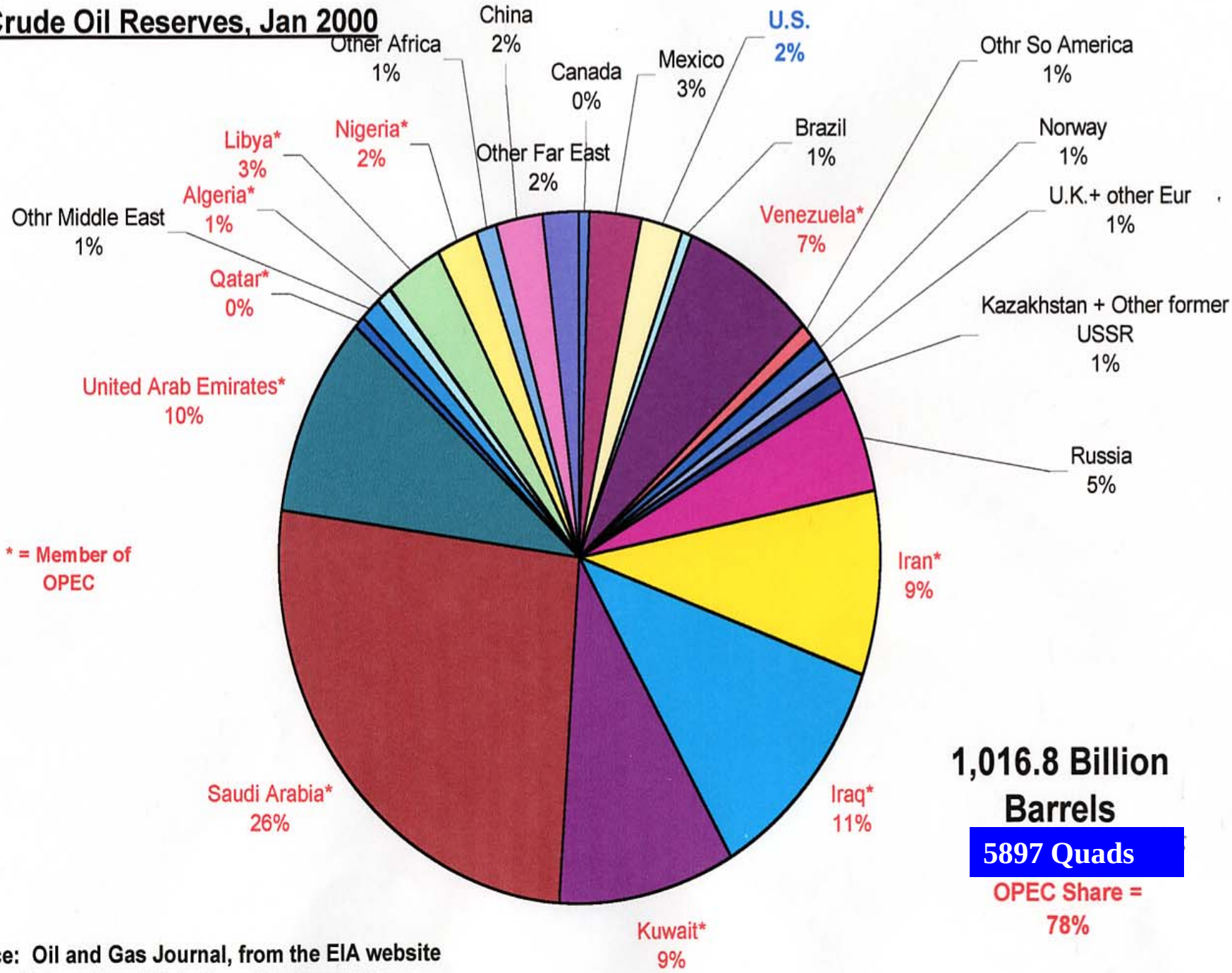
The Fossil Fuel Era



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

Oil Reserves

World Crude Oil Reserves, Jan 2000



1,016.8 Billion Barrels

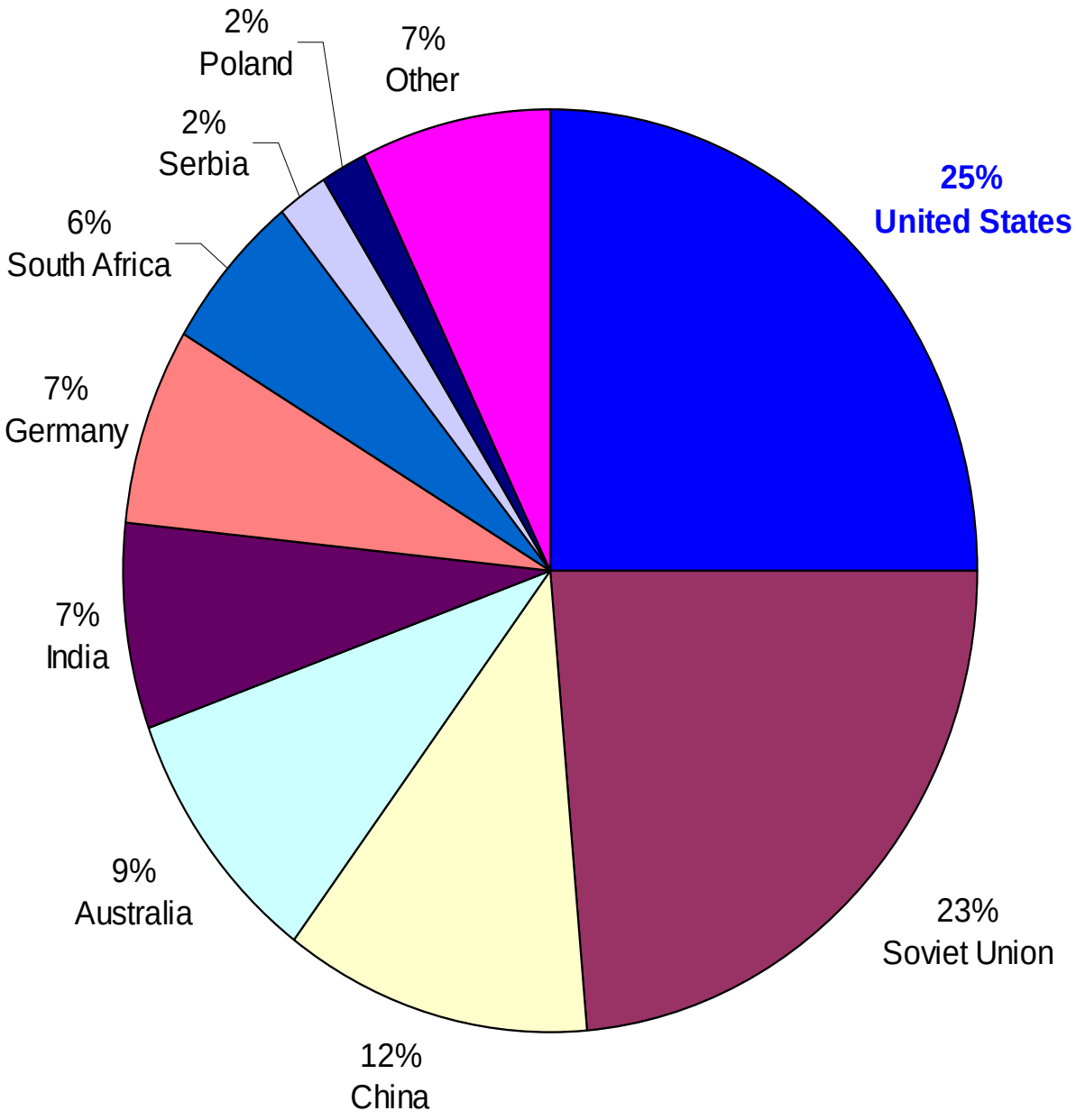
5897 Quads

OPEC Share = 78%

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

Coal Reserves

World Recoverable Coal Reserves - January 1999



The Perfect Transportation Fuel

- Can be produced from any raw energy source (i.e. wind, solar, biomass, coal, nuclear, hydro etc.) **Don't exclude wind, solar, hydro and nuclear energy 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 1

- Ammonia (NH3) can be produced from any raw energy source, including all fossil, renewable and nuclear sources.
- Ammonia is cost competitive with gasoline as a transportation fuel
- Ammonia has extensive, worldwide transportation and storage infrastructure already in place
- Ammonia is very environmentally friendly when used as a transportation fuel and produces only N2 and H20 at the tailpipe with low-cost emissions controls.
- Ammonia has been successfully demonstrated in SI engines, CI engines, and fuel cells.

Ammonia Basics 2

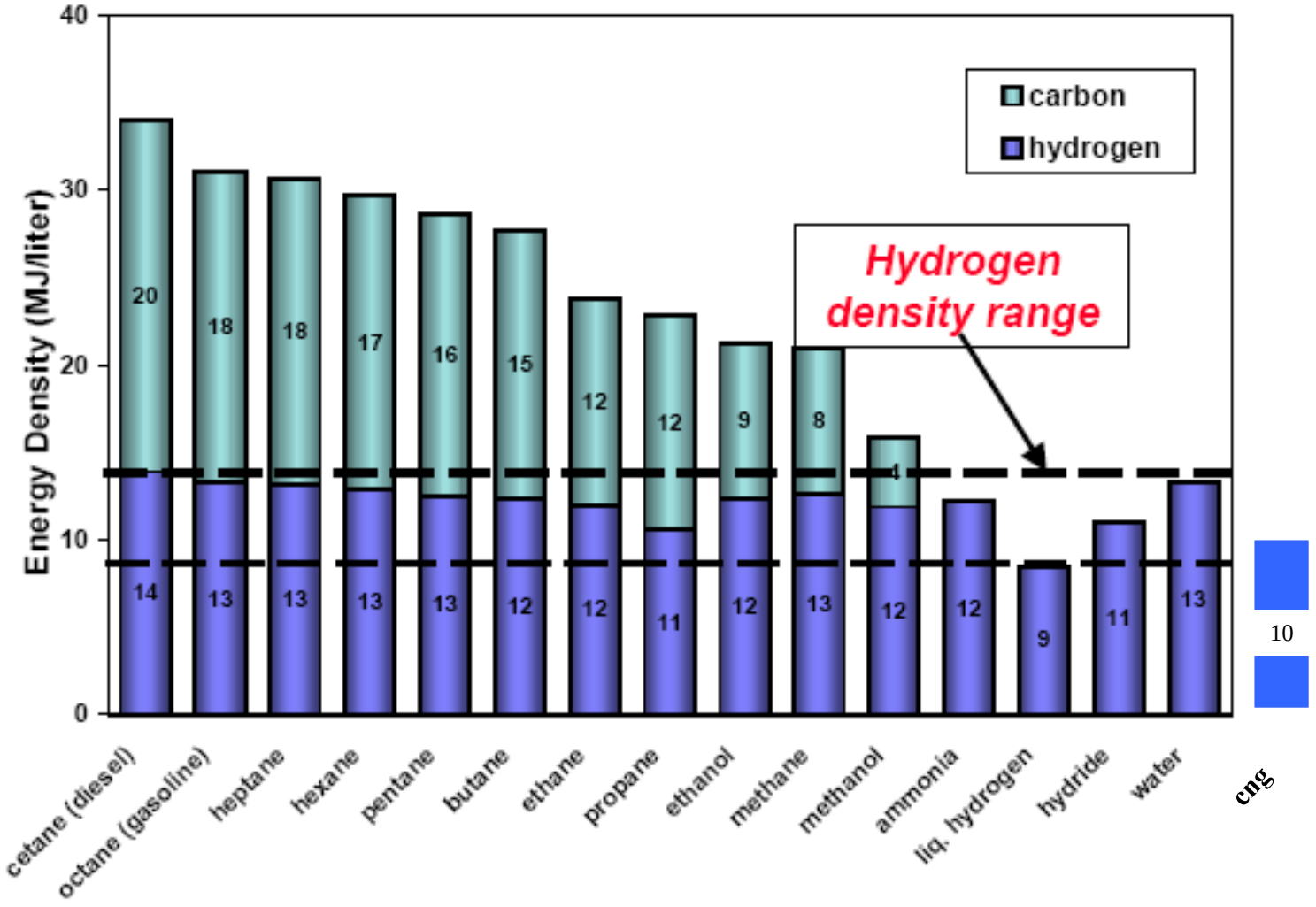
- High U.S. cost is due to high cost of U.S. natural gas
- The U.S. imported over 50% of it's nitrogen fertilizer for the first time in 2004
- Ammonia high cost partially due to highly seasonal nature of use (inefficient use of infrastructure)
- Ammonia has been produced from coal in Beulah, North Dakota for decades. China has huge coal to ammonia capacity.

Dakota Gasification

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

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

Energy densities (LHV) for fuels in liquid state



From George Thomas, BES workshop 5/13/03

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***

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

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

15.3×10^{15} Btu/year = 850 million ton/year ammonia

1250 new plants @ 650,000 ton/year each

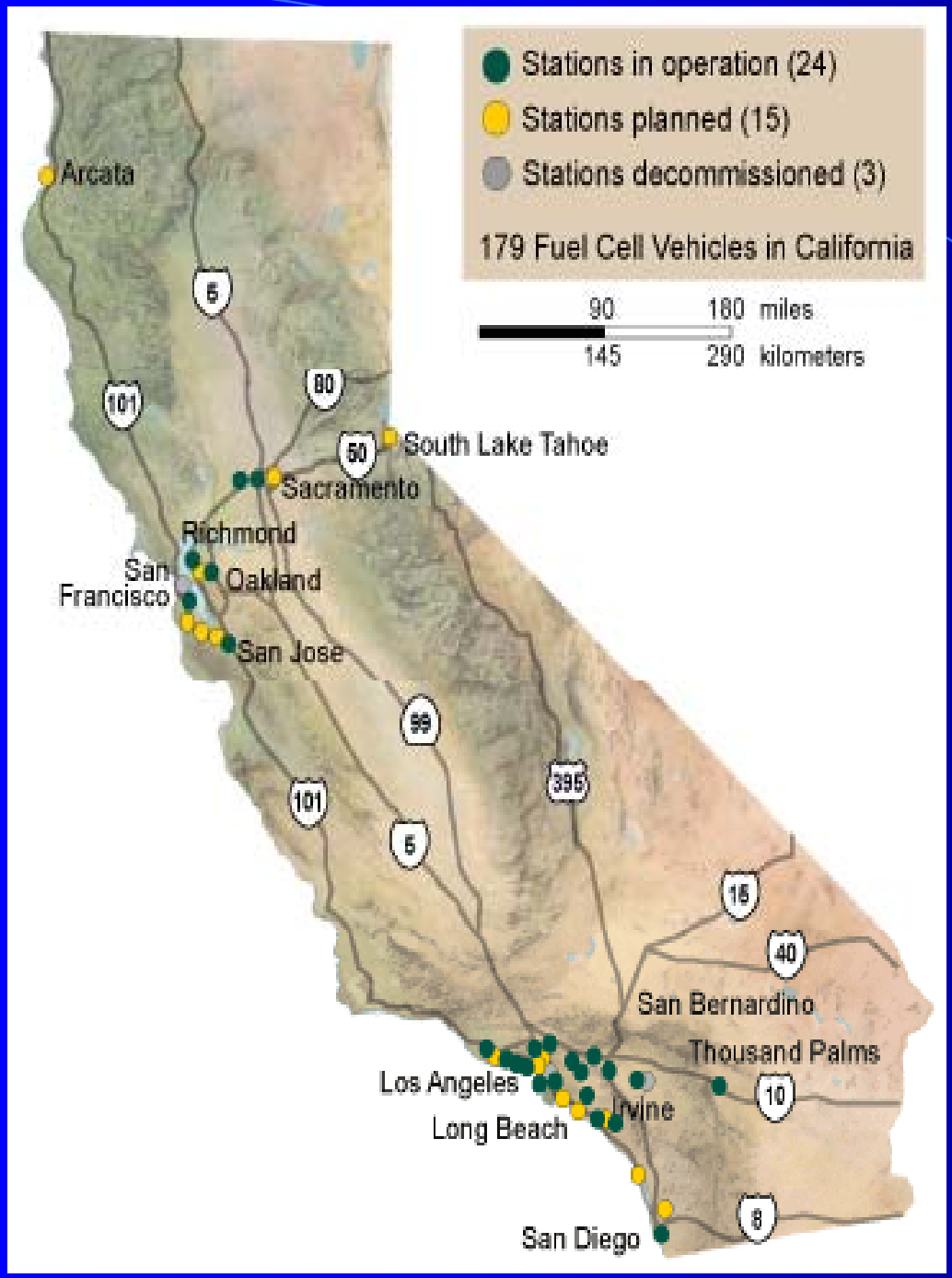
$562 billion investment @$450 million/plant

375,000 new jobs

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

Delivery Infrastructure

California Hydrogen Stations

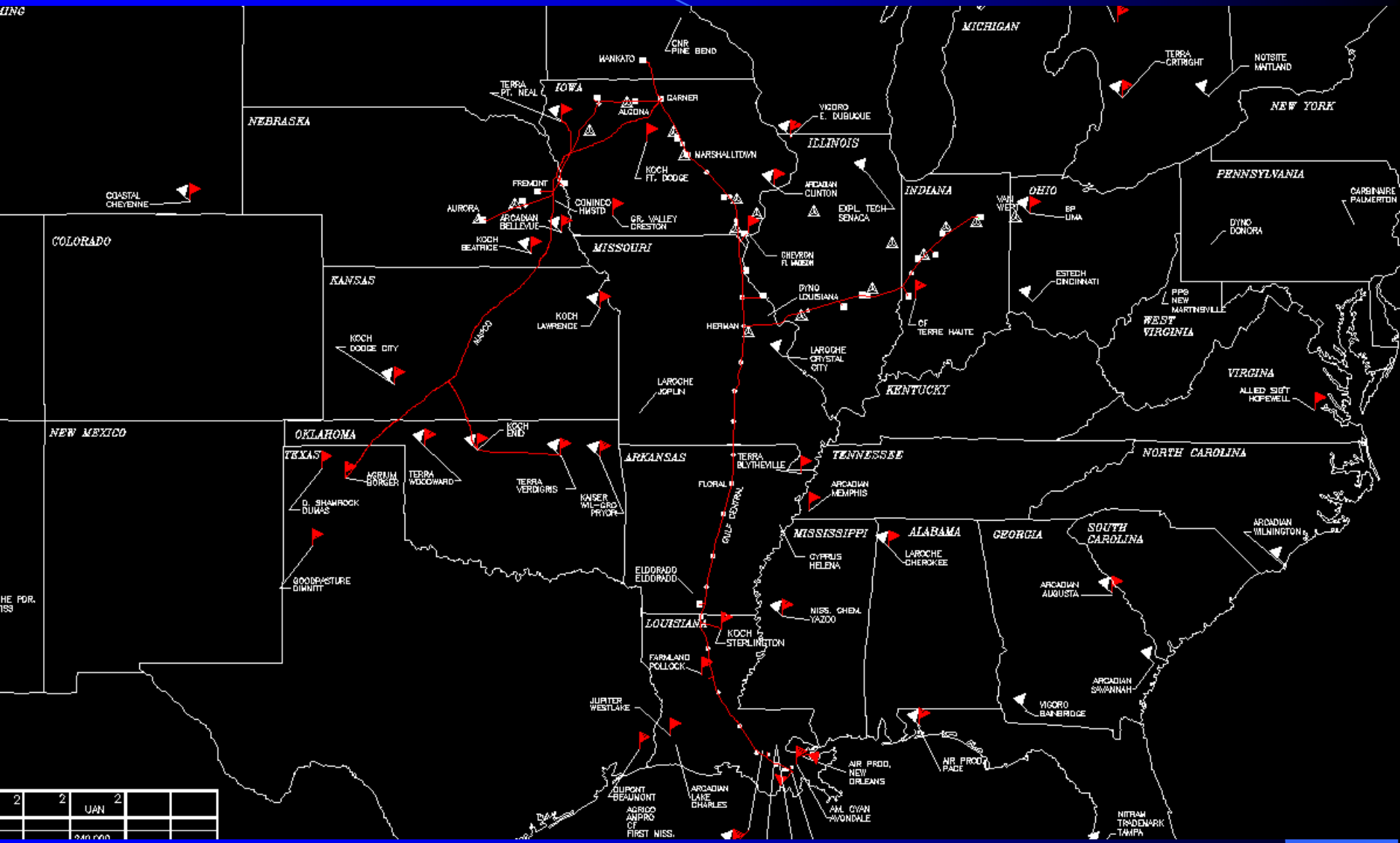


http://www.fuelcellpartnership.org/fuel-vehl_map_print.html

Iowa Hydrogen Refueling Stations

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

Ammonia Pipeline



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	NH_3
Ephedrine and Pseudoephedrine	$C_{10}H_{15}NO$
Methamphetamine	$C_{10}H_{15}N$

VOC's + NOx + O2 + Sunlight = ozone = smog+

NOx + H2O + ammonia = ammonium nitrate = smog-

If the NOx doesn't form ammonium nitrate it goes to ozone (worse)

Fossil fuels (the source of NOx) are the problem, not ammonia

Ammonia is actually used to clean up NOx emmissions at coal plants

Progress

- Irrigation pump demonstration with SI engine
- Over 50% efficiency demonstrated in a SI engine
- Direct ammonia fuel cell
- Wind to ammonia demonstration funded
- 95% ammonia, 5% diesel, full power, LOWER NOx!!! (CI engine)
- New ammonia synthesis technologies
- Ammonia trademarked as “The Other Hydrogen” (HEC)

Summary 1

- **Ammonia meets most 2015 Freedom Car targets today**
- **Ammonia has a very extensive, worldwide transportation and storage infrastructure already in place. Hydrogen infrastructure is negligible and too costly to ever implement.**
- **With relatively minor modifications, existing oil and natural gas pipelines could be converted to transport NH3**
- **Only H2 and NH3 have no tailpipe greenhouse gas emissions**
- **Only H2 and NH3 can be made from electricity and water (+air for NH3)**

Summary 2

- **Ammonia from coal, natural gas and nuclear energy now**
- **Ammonia from renewables in the near future (Including wind, solar and hydro!)**
- **NH3 diesel (CI) and spark-ignition (SI) engines now**
- **Direct NH3 fuel cells in the near future**
- **Ammonia is not a toxic chemical! It is the most commonly used fertilizer in the U.S. and is used on most corn ground.**
- **Any known transportation fuel has some associated safety risks but ammonia is safer than gasoline, propane and hydrogen when used as a transportation fuel.**
- **Ammonia looks very good now and in the future**