NH3 – The Key to Energy Independence, Economic Recovery and National Security

Norm Olson P.E.

NH3 VI

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Kansas City, Missouri

Oil Experts See Supply Crisis in Five Years

International Energy Agency

July 10, 2007

IEA Update

IEA Economist Says World Oil Reserves Less Than Estimated

United Press International 9/7/2009

World oil supplies will pass their peak production sooner than expected, creating conditions for a global energy catastrophe, a French energy economist says. Higher crude prices brought on by sharply growing demand, coupled with a stagnation or decline in supply, could shove any recovery off-course, said Fatih Birol, chief economist at the International Energy Agency in Paris. Birol told The Independent that the public and many governments are ignoring reports that the oil is running out faster than predicted. Birol said global production likely will peak in about a decade, 10 years sooner than most governments have estimated. In an assessment of more than 800 oil fields in the world, Birol found most of the biggest fields already have peaked, and the rate of decline in oil production is running at nearly twice the pace calculated just two years ago, the newspaper said. In addition, chronic under-investment by oil-producing countries likely will result in an "oil crunch" within the next five years, jeopardizing any hope of a recovery from the global economic recession, Birol said. "One day we will run out of oil. It is not today or tomorrow, but one day we will run out of oil and we have to leave oil before oil leaves us, and we have to prepare ourselves for that day," Birol said. "The earlier we start, the better, because all of our economic and social system is based on oil, so to change from that will take a lot of time and a lot of money and we should take this issue very seriously."

Mid East

Petroleum Demand

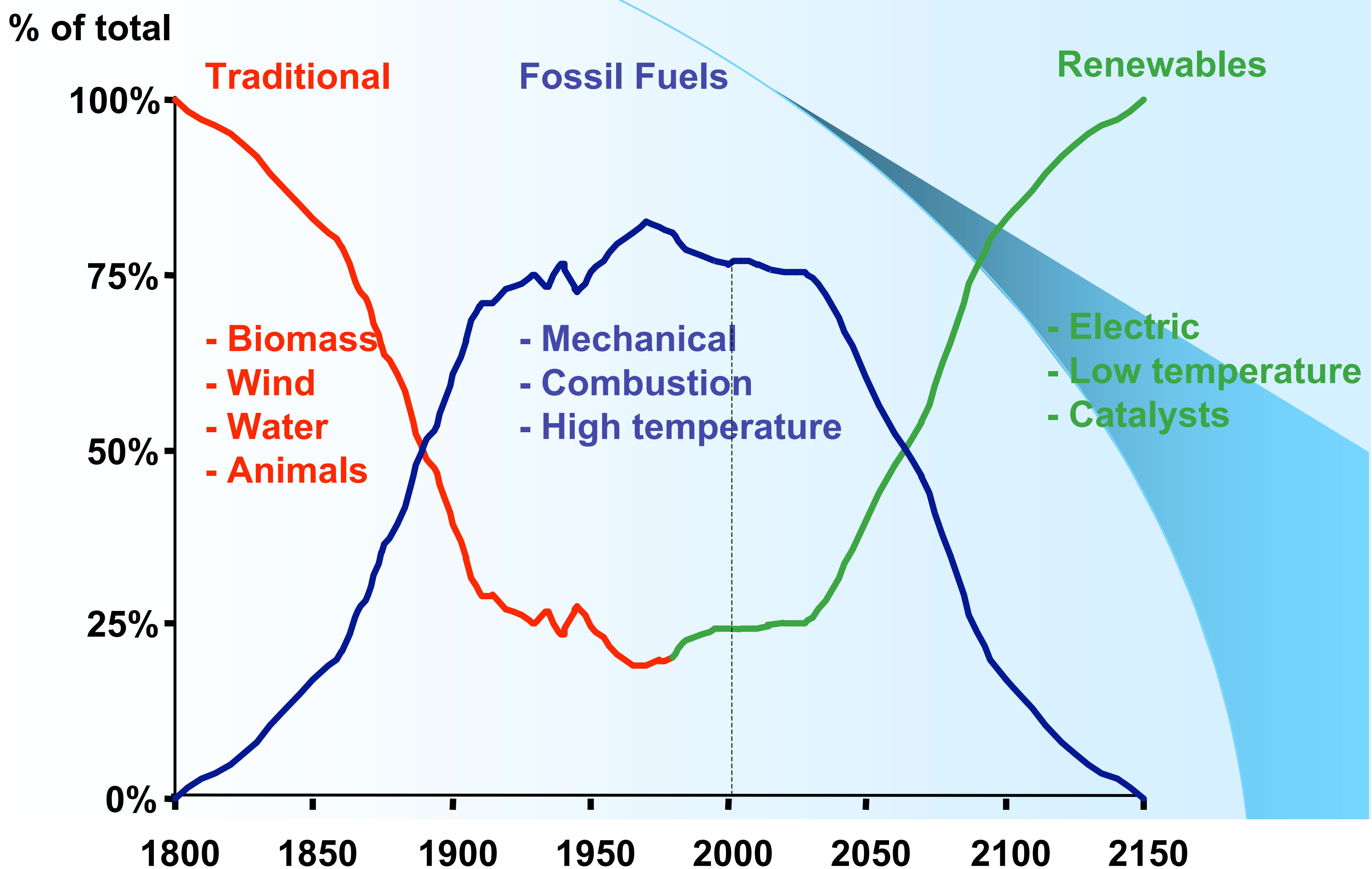
China has been widening its lead over the U.S. as the world's top auto market, with September sales jumping 78 percent over a year earlier, boosted by tax cuts and government stimulus spending. China's total sales hit 9.66 million vehicles in the first nine months of the year, up 34 percent from a year earlier and are forecast to top 12 million units for the year. Previously only Japan and the U.S. have exceeded 10 million vehicles in annual output.

Energy Independence Goals

- Use Local Resources for Local Energy Needs
- Eliminate Petroleum Imports
- Provide a Bridge to Renewable Energy
- Protect the Environment
- Create Local Jobs/Improve Economy
- Eliminate NH3 Imports

Background Information

The Fossil Fuel Era



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

Oil Reserves

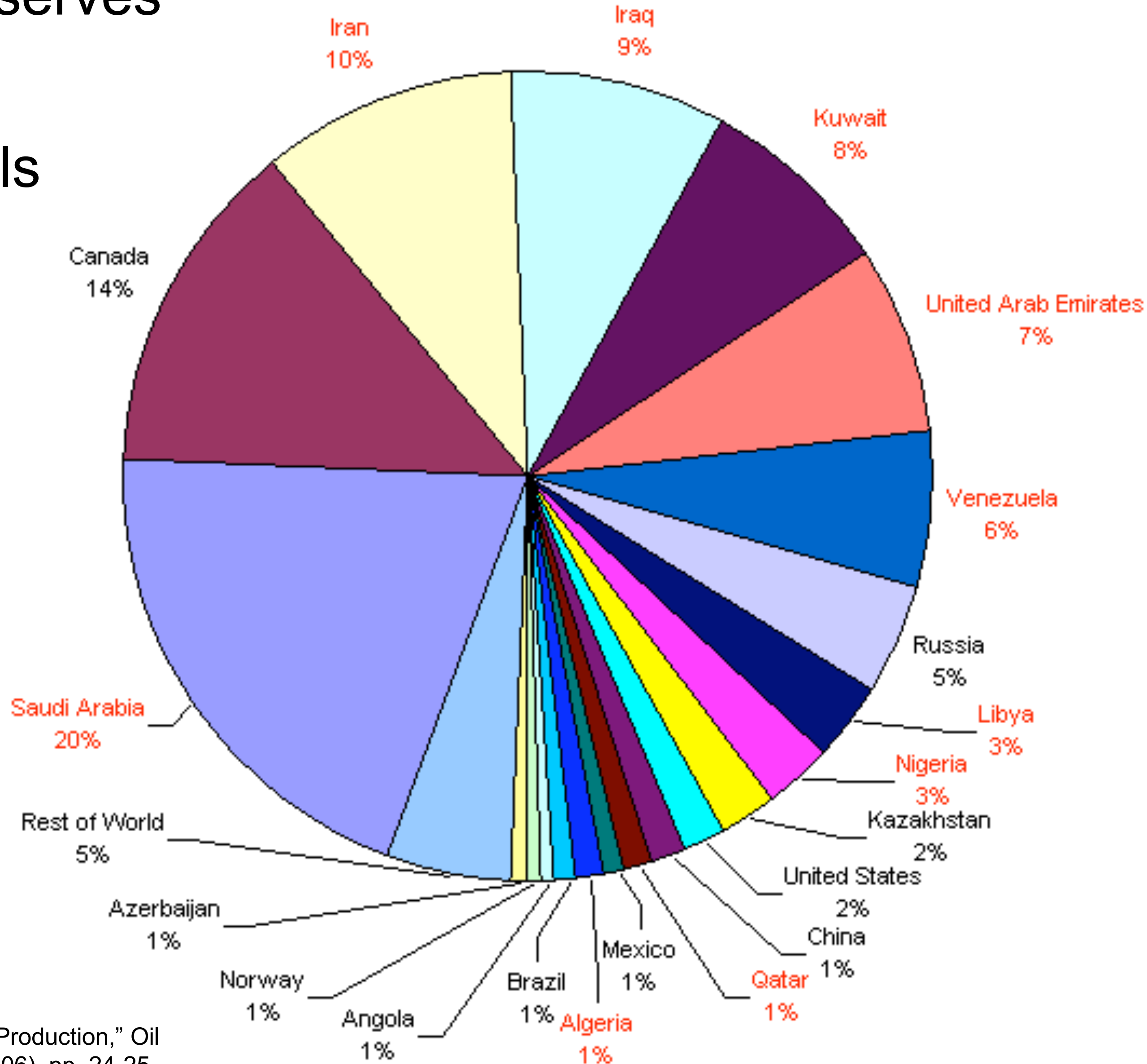
World Crude Oil Reserves
Jan 2007

1,317.4 billion barrels
7,749 quads

(Coal: 22,171 quads)

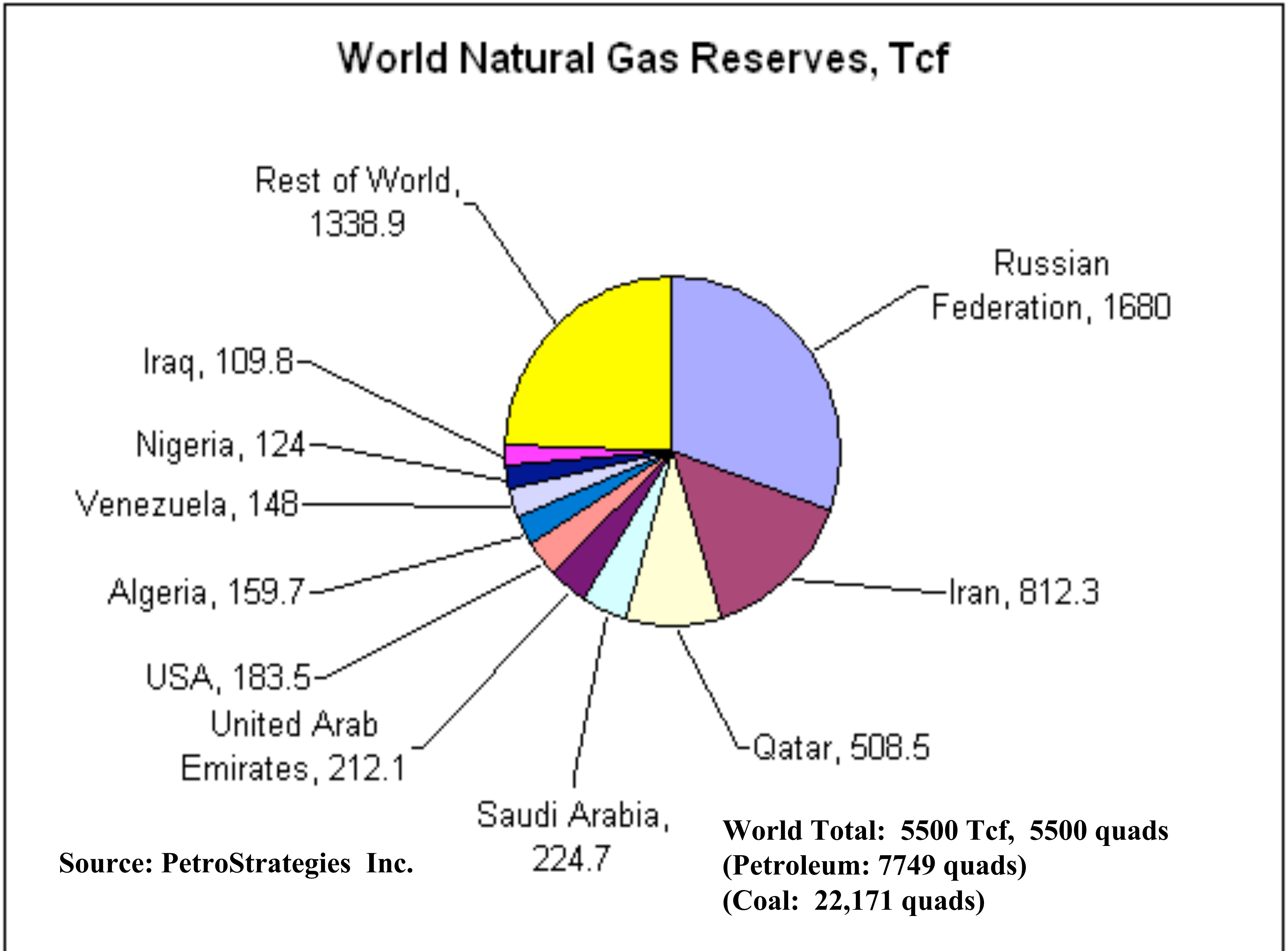
(NG: 5,500 quads)

OPEC Share (68%)



Compiled from "Worldwide Look at Reserves and Production," Oil & Gas Journal, Vol. 104, No. 47 (December 18, 2006), pp. 24-25.

Natural Gas Reserves

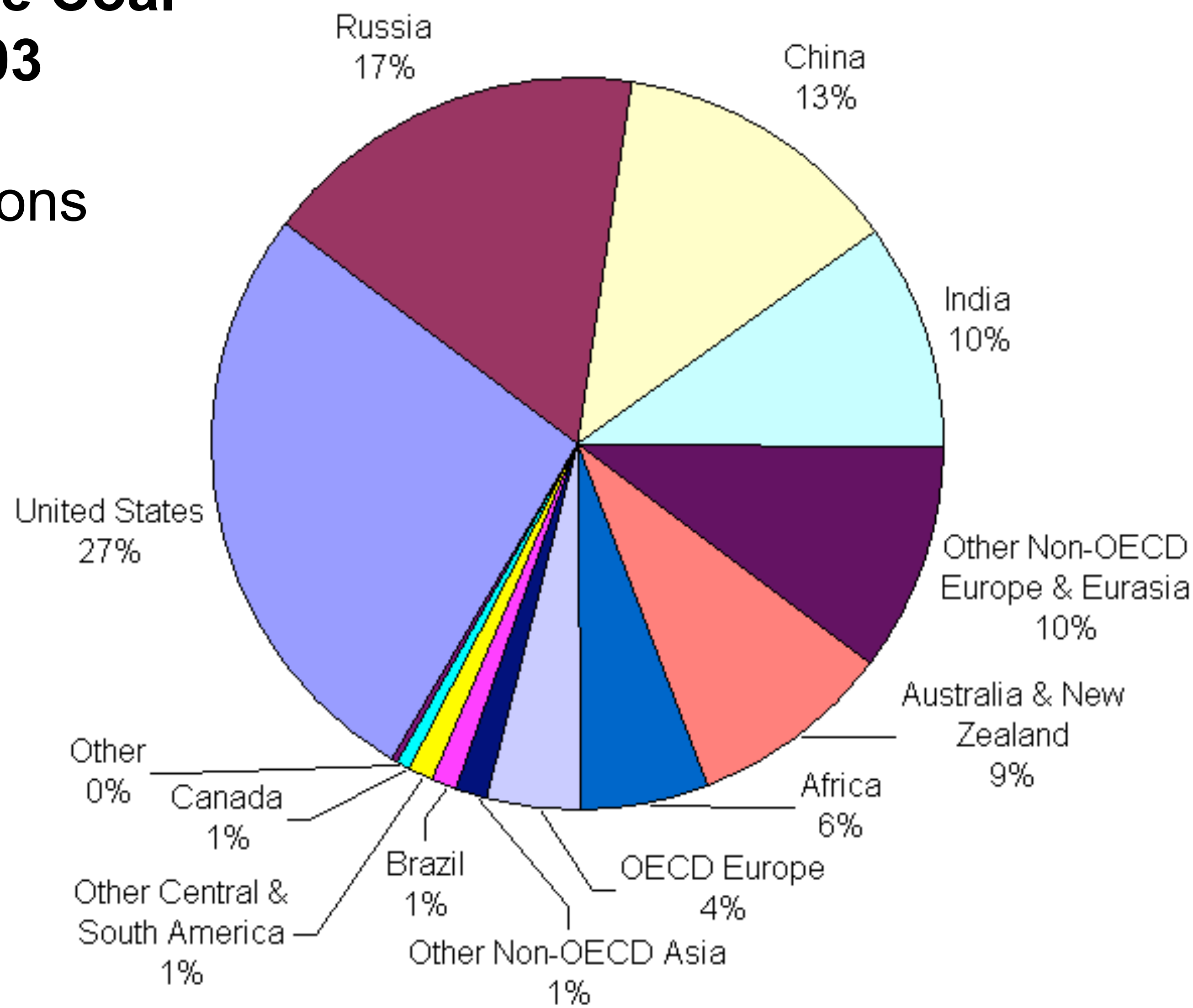

World Natural Gas Reserves, Tcf
Rest of World, 1338.9
Russian Federation, 1680
Iraq, 109.8
Nigeria, 124
Venezuela, 148
Algeria, 159.7
USA, 183.5
United Arab Emirates, 212.1
Saudi Arabia, 224.7
Qatar, 508.5
Iran, 812.3
Source: PetroStrategies Inc.
World Total: 5500 Tcf, 5500 quads
(Petroleum: 7749 quads)
(Coal: 22,171 quads)

Coal Reserves

World Recoverable Coal Reserves, Jan 2003

997.7 billion short tons
22,171 quads

Oil: 7,749 quads
NG: 5,500 quads



USDoE - EIA, unpublished data, Coal Reserves Database (April 2007). World Energy Council, 2004 Survey of Energy Resources, Eds. J. Trinnaman and A. Clarke (London, UK: Elsevier, December 2004).

The Ideal 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 potential transportation fuel sources!!!**
- Is cost effective
- Has significant storage and delivery systems already in place
- Environmentally friendly
- Can be used in any prime mover (i.e. diesel engines, fuel cells, SI engines, gas turbines, etc.)
- Has a proven, acceptable safety record
- Produced in the U.S.

NH3 Basics 1

- **NH3 can be produced from any raw energy source, including all fossil, renewable and nuclear sources.**
- **NH3 is normally cost competitive with gasoline as a transportation fuel**
- **NH3 has extensive, worldwide transportation and storage infrastructure already in place**
- **NH3 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, fuel cells and burners. Ammonia can replace natural gas, propane, gasoline and diesel fuel.**

NH3 Basics 2

- The U.S. imported over 50% of it's nitrogen fertilizer for the first time in 2004 and continues to import increasingly more than it produces domestically
- Ammonia high cost partially due to highly seasonal nature of use (inefficient use of infrastructure)
- NH3 has been produced from coal in Beulah, North Dakota for decades and with CO2 capture since 2000. China has huge coal to NH3 capacity.
- NH3 cost 2009: $125 - $325 per metric tonne

Alternative Fuel Candidates

Algae – will algae-based biodiesel displace all other fuels?

Electric Vehicles – will all-electric vehicles eliminate the need for liquid transportation fuels?

Alcohol Fuels – will cellulosic alcohol fuels meet all of our transportation fuel needs?

Natural gas – Does T. Boone really have the best solution?

Propane – nice fuel, limited quantities.

DME – a dark horse candidate?

NH3 Hydrogen – a formidable candidate

Alternative Fuel Candidates
Biodiesel

Algae – will algae-based biodiesel displace all other fuels? Probably not, especially natural gas, propane, gasoline, nuclear and certainly not coal (with CO_2 sequestration). Algae produces protein (high value), oil (high value), carbohydrates (low value). NH_3 could be made from the low value carbohydrates. Fuel cells run "better" on NH_3 than on biodiesel. All current existing sources of fats, oils, and grease are very small compared to the demand for diesel fuel. Food vs. fuel issues can be a problem if non-algae sources of oil (e.g. soybean oil, canola oil, etc.) are used.

Alternative Fuel Candidates
All Electric Vehicles

Electric Vehicles:

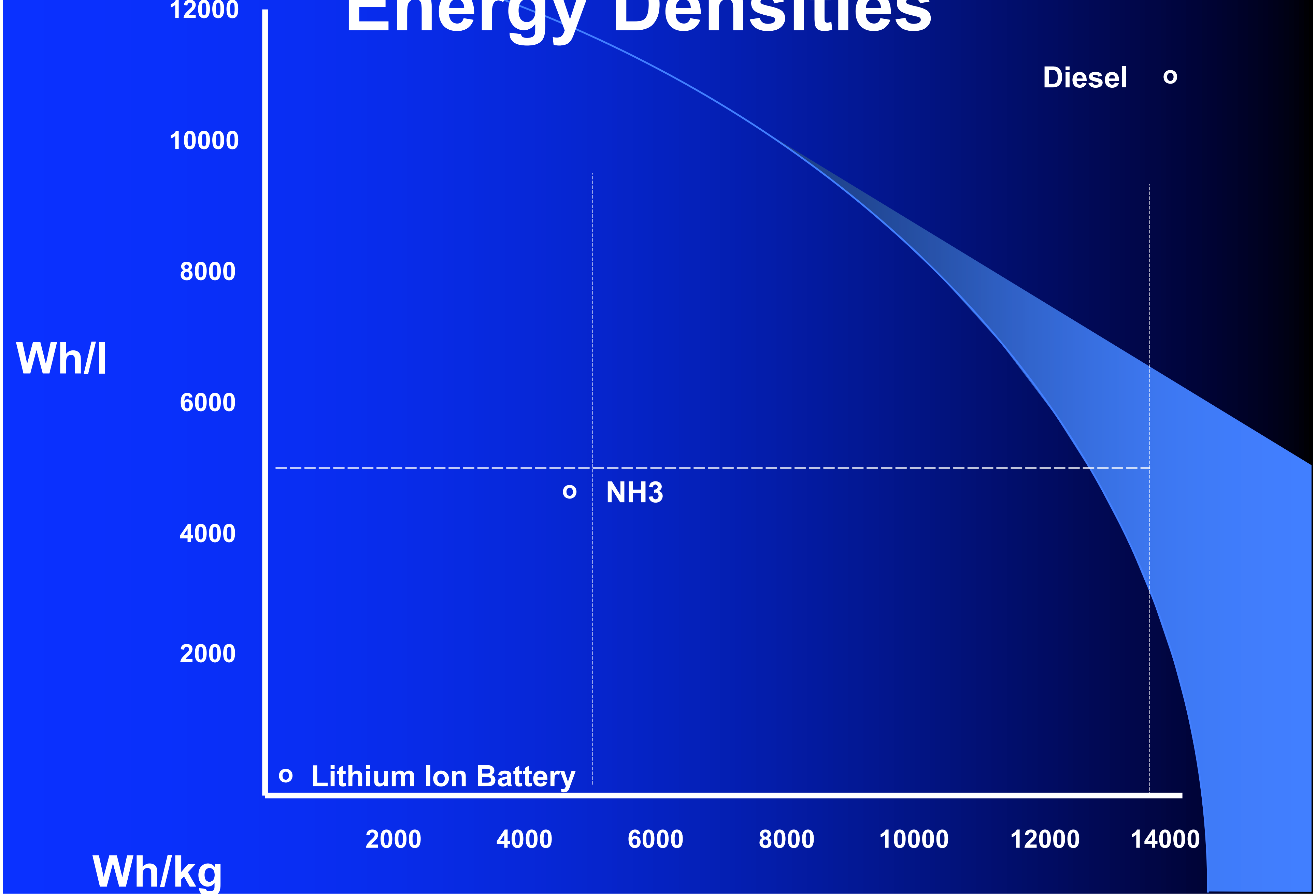
+very efficient use of electricity

-charging infrastructure for quick charge costly (could change out battery pack

-charging time

-energy density, cost and life expectancy problems

Energy Densities



Alternative Fuel Candidates
Alcohols

Alcohols – With the exception of methanol, alcohols are difficult to produce in a cost-effective fashion from cellulose, coal or other carbon/hydrogen sources. Corn to alcohol has some fairly significant opposition due to the "food vs. fuel" issue. Alcohols can not be produced from wind, solar, OTEC, nuclear or other similar important future energy sources. Any land that can produce significant amounts of cellulosic biomass could also produce significant amounts of food.

Alternative Fuel Candidates Natural Gas

Natural Gas - Natural gas can not be produced from wind, solar, OTEC, nuclear or other similar important future energy sources. Can be made with existing, commercially available technologies from cellulosic biomass and coal. Expensive to store and transport (LNG at -278 degrees F). Compared to coal and petroleum, there is not as much natural gas available. Russia has the largest reserves. Extensive pipeline system already in place.

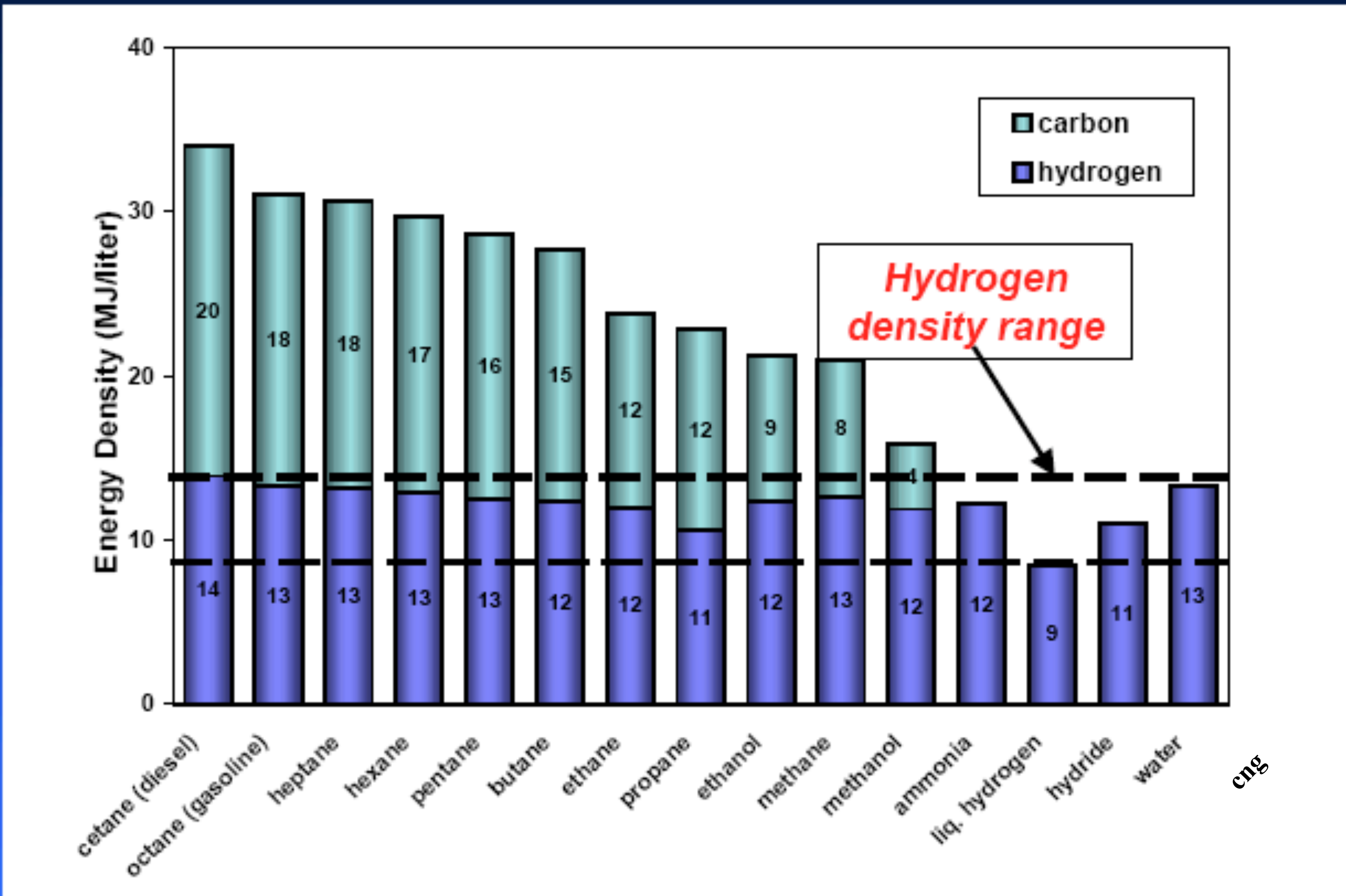
Alternative Fuel Candidates Propane

Propane - Propane can not be produced from wind, solar, OTEC, nuclear or other similar important future energy sources. No commercial production from cellulosic biomass or coal. Stores easily as a liquid. Limited amounts available worldwide. Usually co-produced with natural gas.

Alternative Fuel Candidates
NH3 – "The Other Hydrogen"

NH3 - Unlike all other alternative fuel candidates (except electricity) NH3 can be produced from wind, solar, OTEC, nuclear or other similar important future energy sources. Easily produced from cellulose using commercially available technologies (i.e. thermal gasification, anaerobic digestion) biomass and coal. China has a huge, existing coal to NH3 industry. Stores easily as a liquid at slightly milder conditions than propane. Proven performance in pipelines and natural gas pipelines converted to transport NH3 would gain 50% additional energy shipping capacity. NH3 can perform in all types of engines (with modifications) and direct NH3 fuel cells promise to be low-cost, efficient and robust.

Energy densities (LHV) for fuels in liquid state



 From George Thomas, BES workshop 5/13/03

Freedom Car Targets w/ 2005 NH3 Comparison

Parameter (2005)	Units	2007	2010	2015	NH3
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

	$/MMBtu
Ammonia - $200/metric ton*	$10.01
Methanol - $0.79/gallon*	$13.68
Ammonia - $350/short ton (coal)	$19.26
Gasoline - $2.50/gallon	$21.92
Ethanol - $2.20/gallon	$28.93
Gasoline - $3.50/gallon	$30.69
Wind NH3-$1000/short ton (estimate)	$55.02

*June 2003 Chemical Market Reporter

In Tampa, the January (2009) contract price is expected to be agreed next week with little change from the current level of $125/tonne CFR expected.

NH3 will normally cost less than gasoline (per million BTU) due to the fact that NH3 is currently made from coal and natural gas, both of which cost significantly less than petroleum per million BTU

Wholesale price per million Btu for fuels October 2009: Coal (spot) - $0.52 (PRB), $1.73 (ILB); Natural Gas - $4.90; Gasoline - $17.28

NH3 is a great use for stranded natural gas since NH3 is so cost effective to transport. Much cheaper than LNG and CNG.

Future Compatibility




Hydrogen + Nitrogen

Ammonia

Storage & Delivery – Pipeline, Barge, Truck, Rail

Stationary Power

Fertilizer

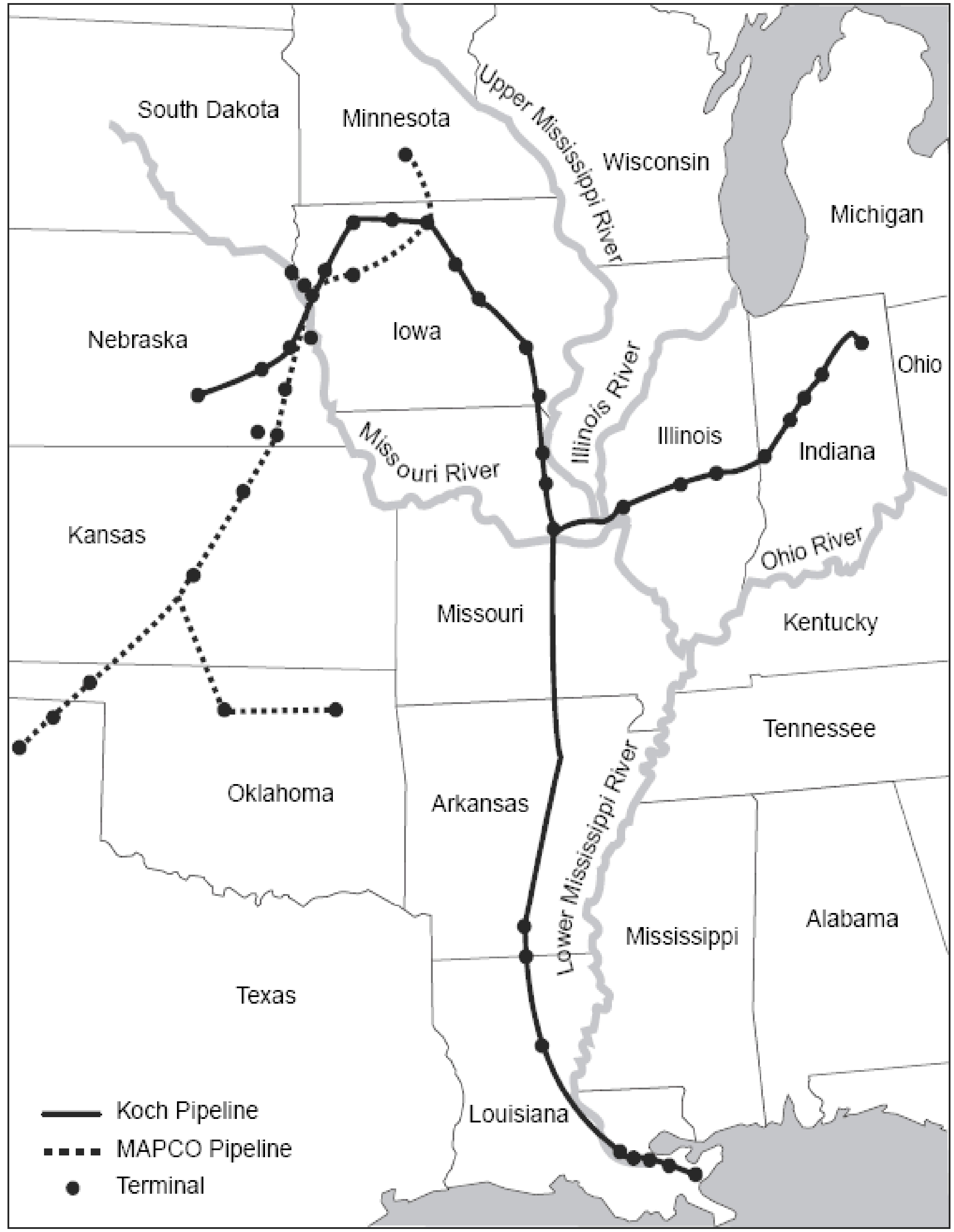
Transportation

Delivery Infrastructure

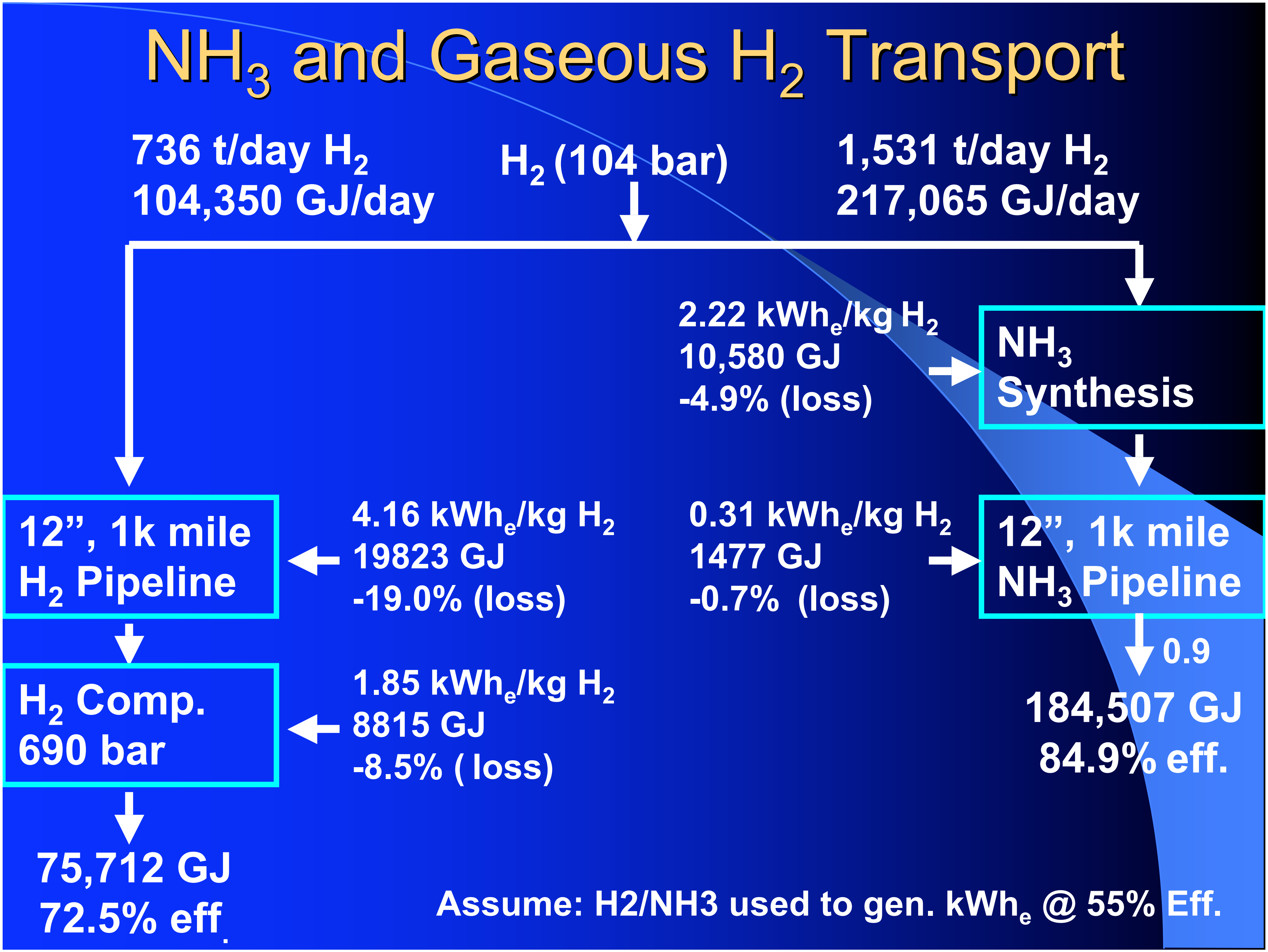
NH_3 is in the top three chemicals shipped worldwide.

Ammonia Storage & Transport

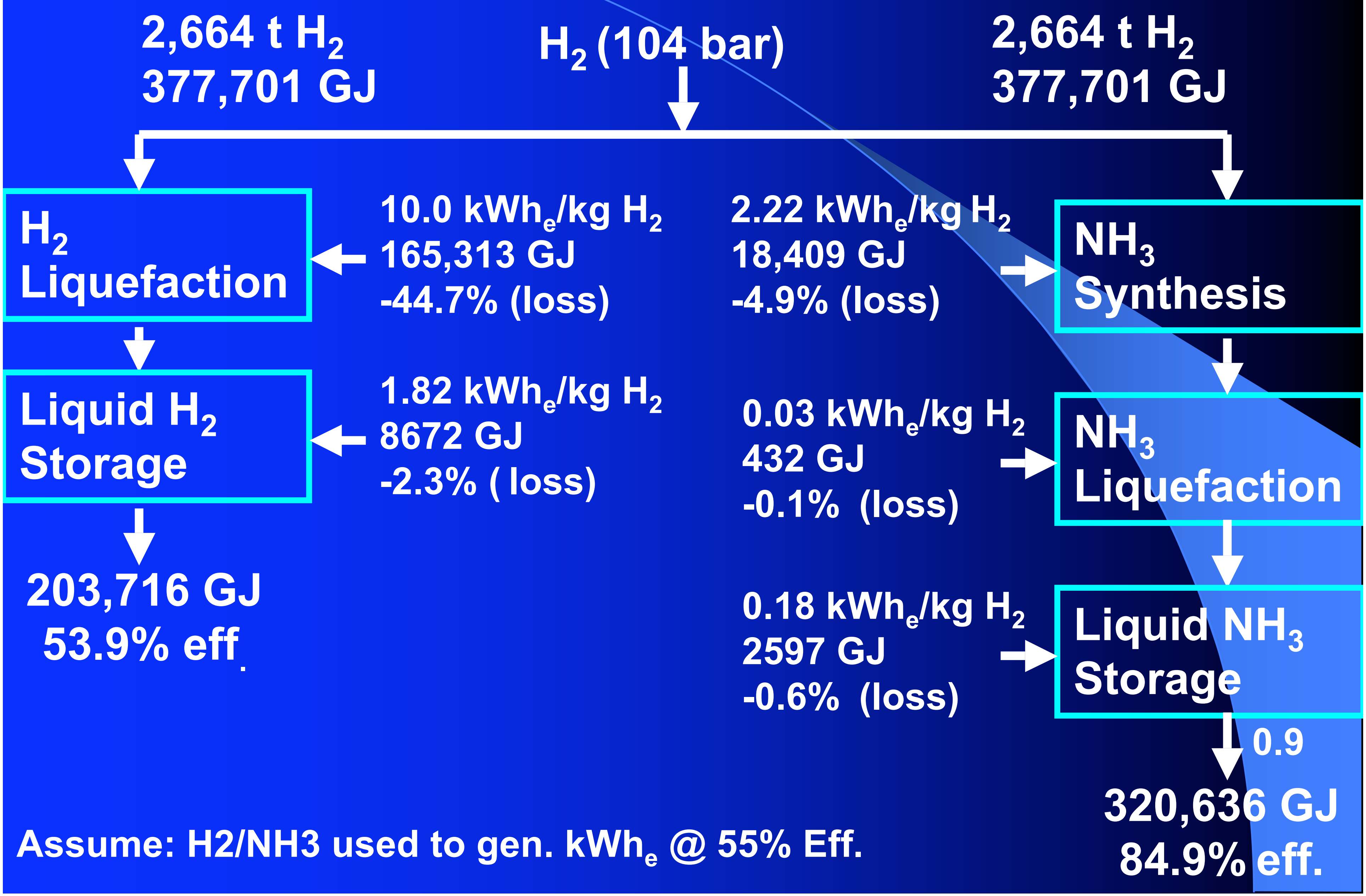
U.S. Ammonia Pipeline



3000 Miles Total


NH3 and Gaseous H2 Transport
736 t/day H2
104,350 GJ/day
H2 (104 bar)
1,531 t/day H2
217,065 GJ/day
2.22 kWhe/kg H2
10,580 GJ
-4.9% (loss)
NH3 Synthesis
12", 1k mile H2 Pipeline
4.16 kWhe/kg H2
19823 GJ
-19.0% (loss)
0.31 kWhe/kg H2
1477 GJ
-0.7% (loss)
12", 1k mile NH3 Pipeline
0.9
184,507 GJ
84.9% eff.
H2 Comp. 690 bar
1.85 kWhe/kg H2
8815 GJ
-8.5% (loss)
75,712 GJ
72.5% eff.
Assume: H2/NH3 used to gen. kWhe @ 55% Eff.

NH_3 and Cryogenic H_2 Storage

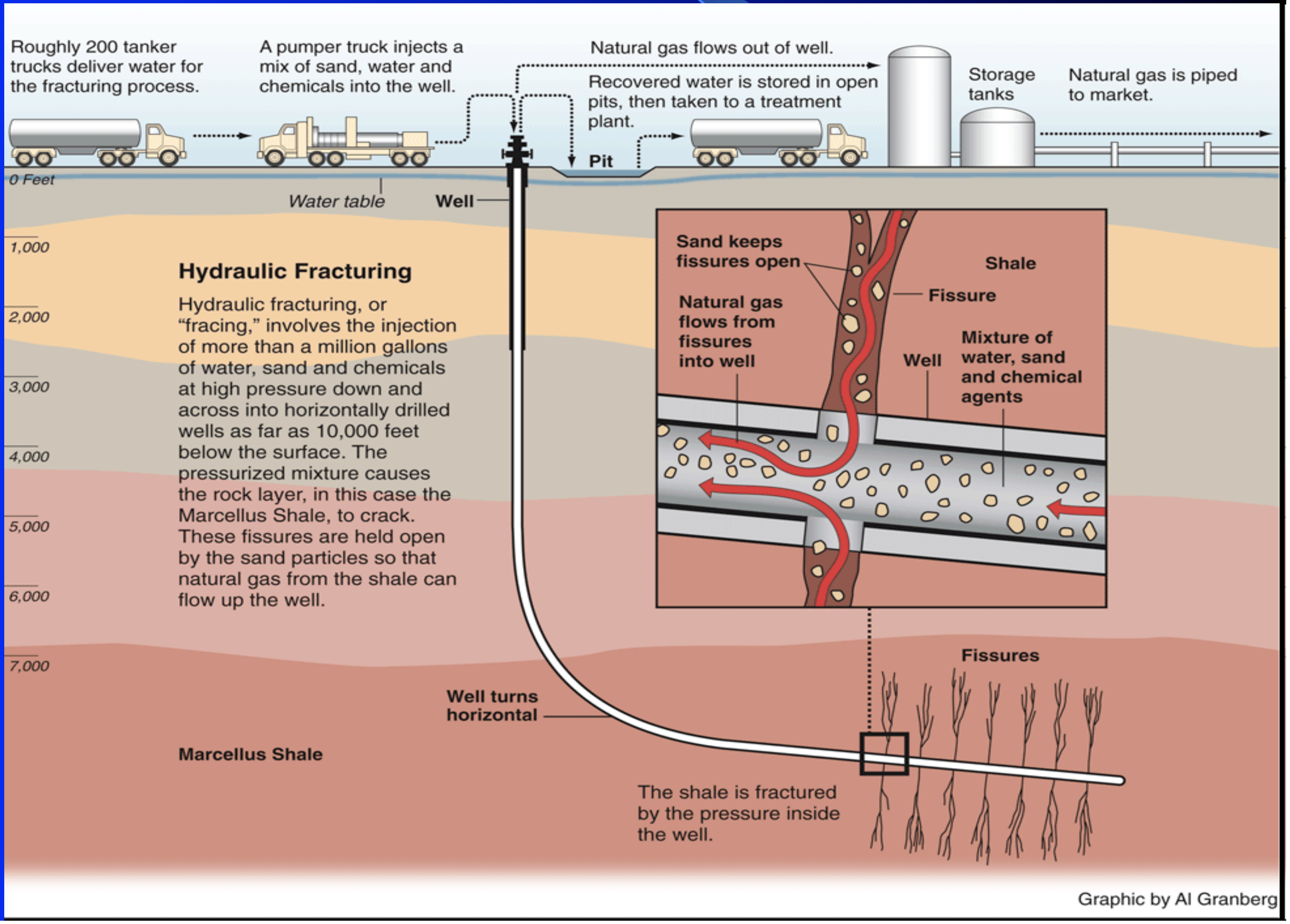


NH_3 vs. Natural Gas

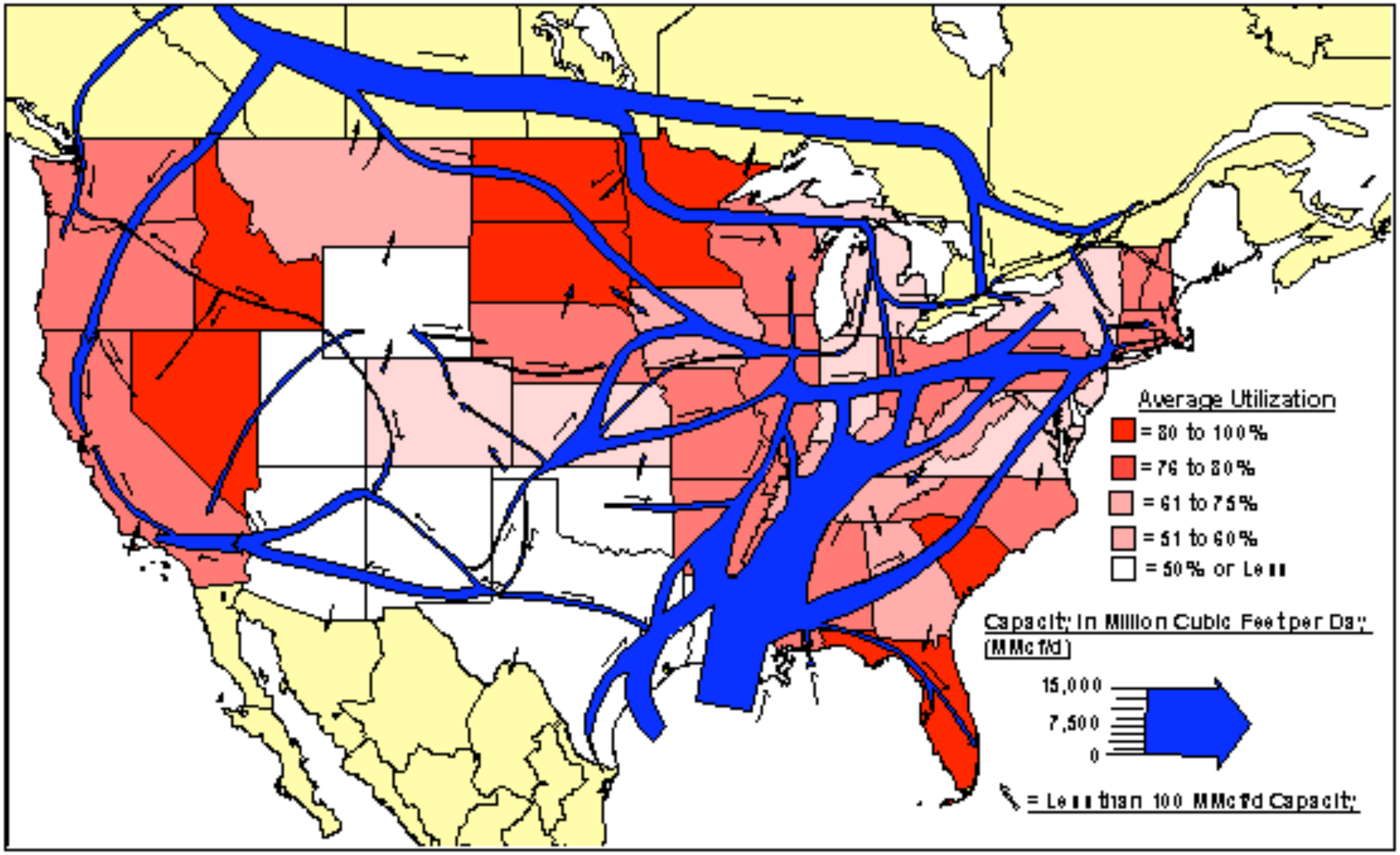
Convert CH4 to NH3 at well head, sequester CO2 in natural gas well to extend well production and use natural gas pipeline (with modifications) to ship NH3

1.5 times more energy capacity when transporting NH3 than CH4 for a given pipeline size

More efficient energy transport

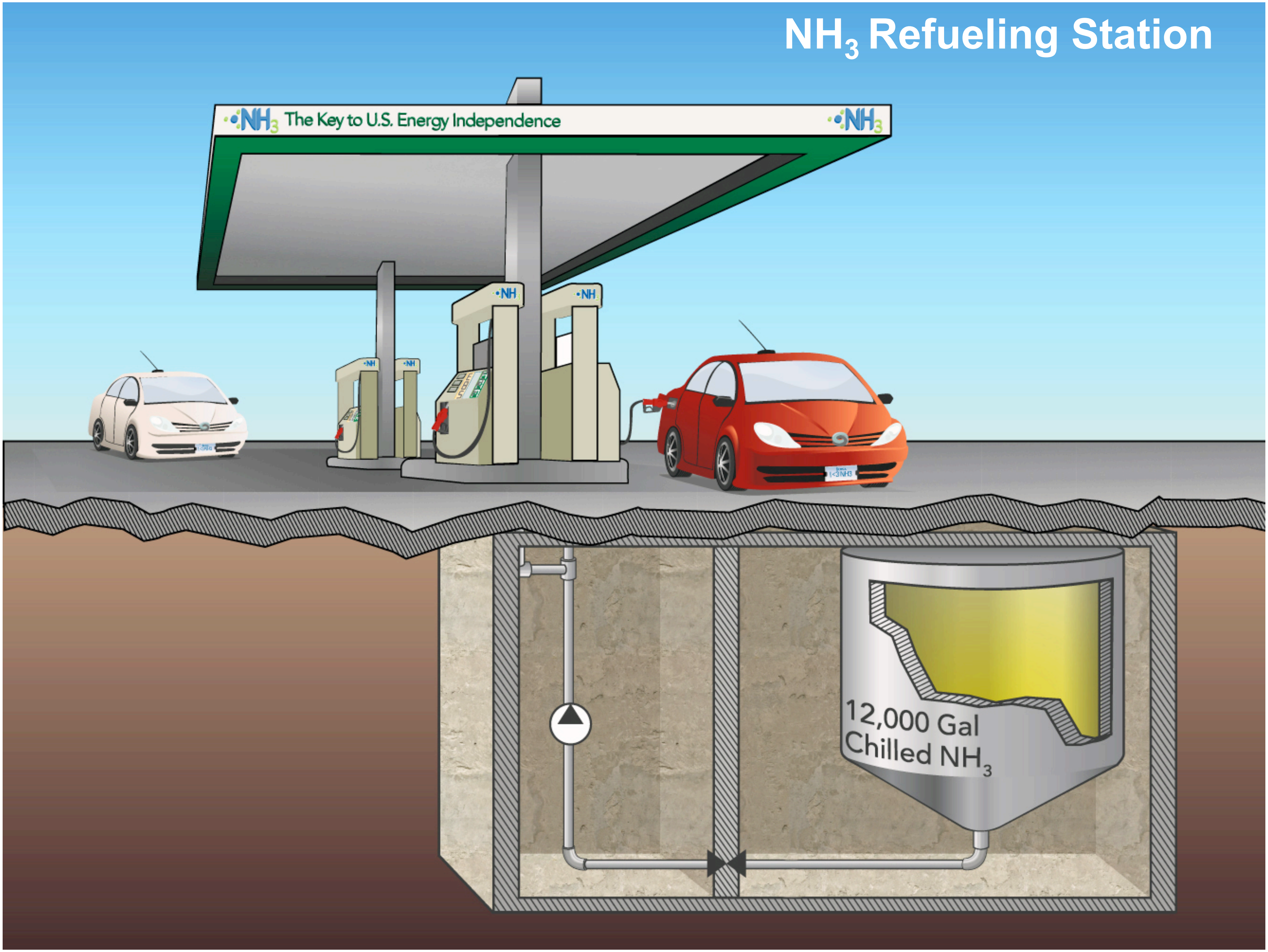


Natural Gas Pipelines



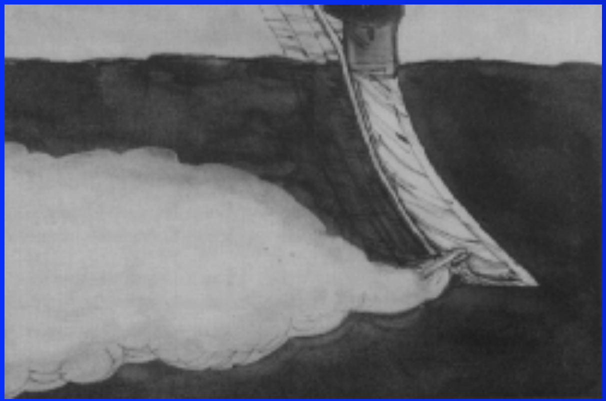
Iowa Hydrogen Refueling Stations

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



NH3 Refueling Station
NH3 The Key to U.S. Energy Independence
NH3
12,000 Gal
Chilled NH3

NH3 Fertilizer 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 and/or DME)
- Direct Ammonia Fuel Cells
- Gas Turbines
- Gas Burners (including residential furnaces)

Economic Impacts

T Boone Pickens – "$700 Billion new U.S. industry."

Using NH3 as the main fuel will allow any country to produce it's own transportation fuel and create a large number of high quality, long-term jobs. The wild price fluctuations that have made long-term investments in energy products will no longer be a problem and allow sound, long-term investments to be made.

Summary 1

- Ammonia meets critical 2015 Freedom Car targets today
- Ammonia has a very extensive, worldwide transportation and storage infrastructure already in place. 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 (with controls)
- Only H2 and NH3 can be made from electricity and water (+air for NH3)
- Ammonia can replace diesel fuel, gasoline, natural gas and propane in most fuel applications
- NH3 is the world's most hydrogen dense chemical by volume, ~50% greater than liquid hydrogen. Results in outstanding green energy storage capability.

Summary 2

- NH3 from coal, natural gas and nuclear energy now
- NH3 from renewables in the near future (Including wind, solar, OTE and hydro!)
- NH3 diesel (CI) and spark-ignition (SI) engines now
- Direct NH3 fuel cells in the near future
- NH3 is not a toxic chemical! It is an very prevalent, naturally occurring chemical
- Any known transportation fuel has some associated safety risks but NH3 is as safe as gasoline and safer than propane when used as a transportation fuel.
- NH3 looks very good now and in the future
- Hydrogen produced stored, delivered and utilized in the form of NH3 is the best choice for cost-effective, near-term energy independence for many countries.