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

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NH3 VIII

September 18 – 21, 2011

Portland, Oregon

K.I.S.S

N – Nitrogen
78% of earths atmosphere

+

H – Hydrogen
Most abundant element
In the universe

NH3 – best choice for a practical, sustainable alternative fuel

Alternative Fuels or Petroleum Forever?

Oil Experts See Supply Crisis in Five Years

International Energy Agency

July 10, 2007

BP's Deepwater Horizon – One of many unacceptable risks associated with petroleum.

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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

Many Sources, Same Message

US military warns oil output may dip causing massive shortages by 2015

- **Shortfall could reach 10m barrels a day, report says**

Terry Macalister , guardian.co.uk,
Sunday 11 April 2010 18.47 BST

Surplus oil production capacity could disappear by 2012 a report from US Joint Forces Command, says. **Photograph: Katja Buchholz/Getty Images**

Petroleum Demand

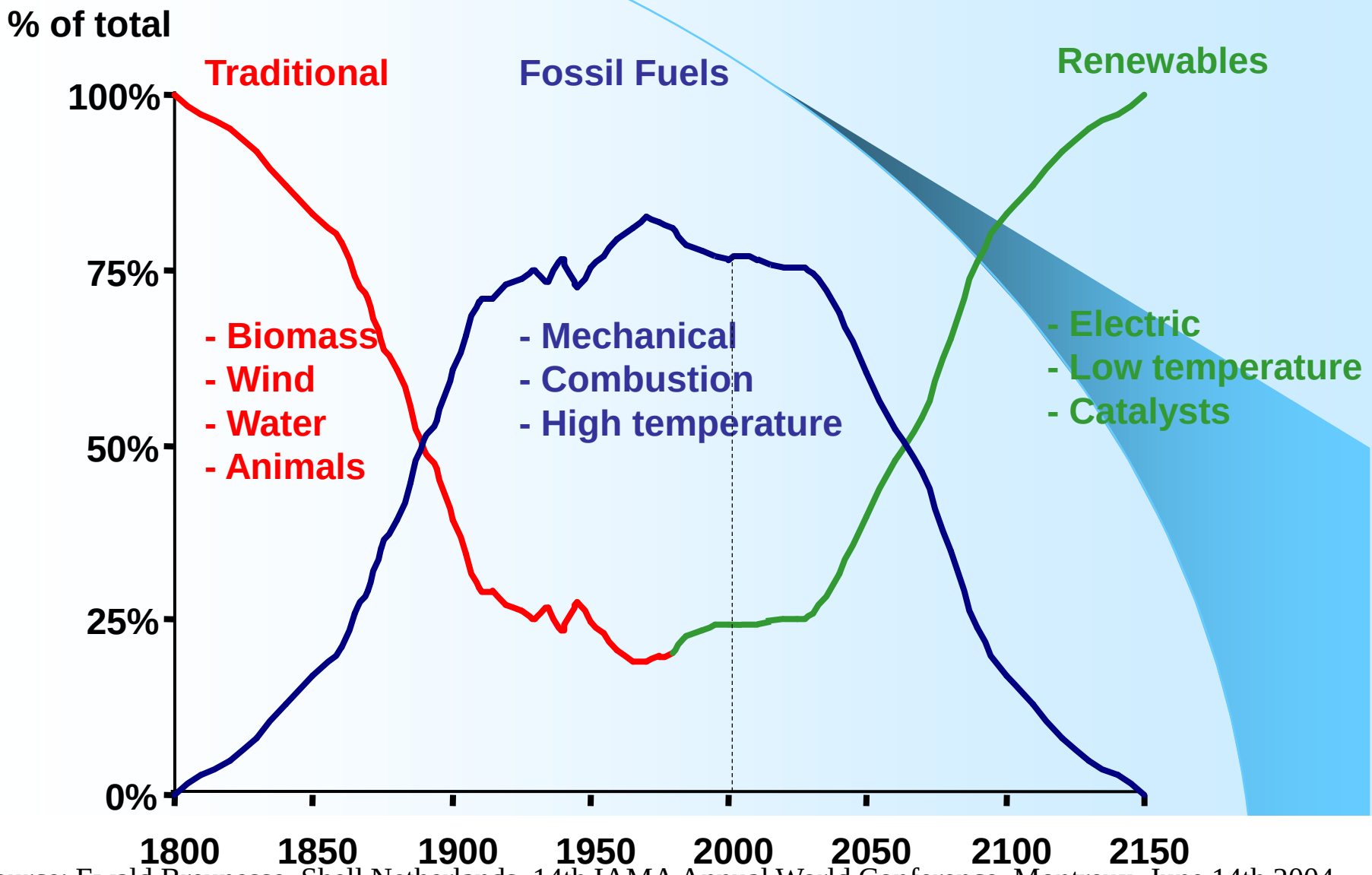
China has been widening its lead over the U.S. as the world's top auto market, with September sales jumping 78 percent over a year earlier, boosted by tax cuts and government stimulus spending. China's total sales hit 9.66 million vehicles in the first nine months of the year, up 34 percent from a year 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.

Risks Associated with Petroleum

- **Peak Oil**
- **Terrorism**
- **War/Regional Conflict**
- **Natural disasters**
- **Equipment/human failure**
- **Supply – demand**
- **Environmental degradation**
- **Economic recession/depression**

Background Information

The Fossil Fuel Era



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

BP Statistical Review of World Energy – June 2011

World Resource	Oil	Nat. Gas	Coal
BB Oil Equiv.	1383	1234	3092

Oil Proved Reserves (2010): OPEC – 70% (inc. Canadian oil sands)

U.S. Reserves to Production (R/P) ratio:

- **Oil – 11.3 years**
- **Natural Gas – 12.6 years**
- **Coal – 241 years**

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**

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 2010/2011 from $200 - $400 MT**

Alternative Fuel Candidates Major Considerations

Coal (converted to liquid or gaseous fuel) is the only U.S. fossil resource abundant enough to replace all petroleum transportation fuels. NH3 is one of the most profitable, high-volume chemicals that can be produced using coal. China produces huge quantities of low-cost NH3 from coal.

We have to decide if carbon is a major issue or not? If it is, hydrogen delivered as NH3 is the only practical transportation fuel choice.

Solar and nuclear energy will become major future energy sources and potentially sooner than many people think. It will be very foolish if we don't plan to use these major, future primary-energy resources to help meet transportation fuel needs. NH3 is the only practical transportation fuel which can be produced from all of these sources.

Alternative Fuel Candidates

Biodiesel – significant new sources of FOG's will be needed

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?

Drop-in replacements – no delivery infrastructure or engine modifications required.

DME – a dark horse candidate?

Methanol – may be a good choice.

NH3 – a formidable candidate

Alternative Fuel Candidates
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. Scale-up issues associated with algae production have been difficult to overcome.

Alternative Fuel Candidates
All Electric Vehicles

Electric Vehicles

+ very efficient use of electricity

- charging infrastructure for quick charge

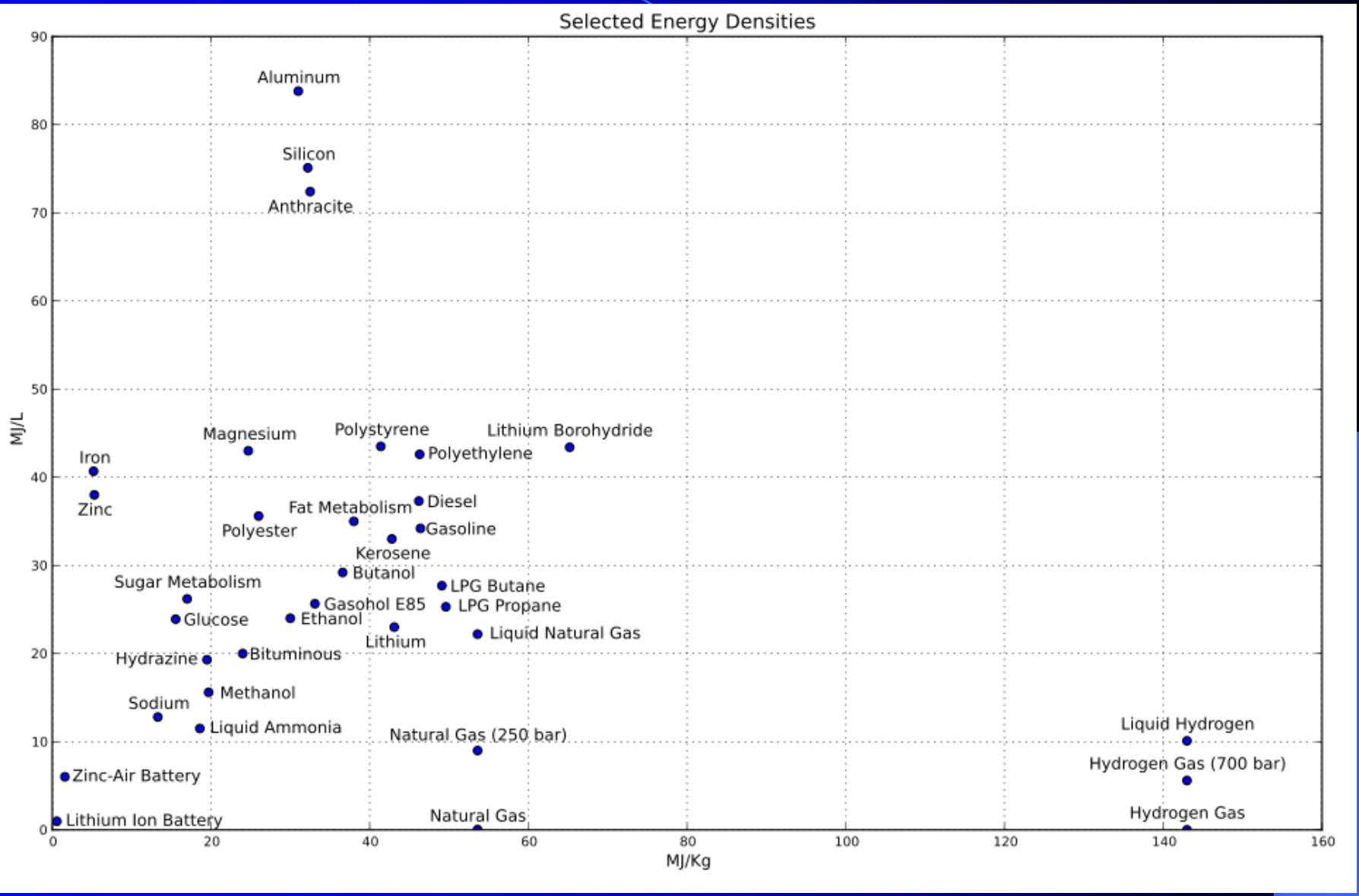
- energy density

- cost

The barriers associated with cost-effective, long-range, quick-charge electric vehicles are at least as challenging as those associated with hydrogen (Chu's 4 miracles)

"It's Time to Kill the Electric Car, Drive a Stake Through Its Heart and Burn the Corpse", John Peterson, August 25, 2011. Suggested reading.

Energy Densities



Alternative Fuel Candidates
Alcohols

Alcohols – With the exception of methanol, alcohols are difficult to produce cost-effectively 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. It can be made with existing, commercially available technologies from cellulosic biomass and coal. Expensive to store and transport via ship, LNG at -278 degrees F. Compared to coal and petroleum, there is not as much natural gas available. Russia has the largest natural gas reserves.

+ Extensive pipeline systems already in place.

+ Improved fracking and new discoveries are making natural gas a more attractive alternative transportation fuel.

Alternative Fuel Candidates
Drop–in Replacements

Drop-in Replacements - F/T fuels (both diesel and gasoline substitutes) and other direct gasoline and diesel fuel replacements can be made from coal, natural gas and biomass.

- Can't be produced from wind, solar, ocean, hydro or nuclear resources.

+ Compatible with existing infrastructure and end use applications.

Alternative Fuel Candidates
NH3 – "The Other Hydrogen"

NH3 - Unlike all other alternative fuel candidates, NH3 can be produced from wind, solar, OTEC, nuclear or other similar important future energy sources. Easily produced using commercially available technologies (i.e. thermal gasification, anaerobic digestion) from cellulosic biomass and coal. China has a huge, existing coal to NH3 industry. Stores easily as a liquid at milder conditions (i.e. lower pressure, higher temperature) than propane. Proven performance in pipelines. Natural gas pipelines converted to transport NH3 would gain 50% additional energy shipping capacity. NH3 can perform well (with modifications) in all prime movers. NH3 is safer than propane and as safe as gasoline in transportation fuel applications.

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

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

The production of NH3 is a great use for stranded natural gas since NH3 can be shipped at a relatively low cost compared to LNG. NH3 is much cheaper to store than LNG, CNG and especially hydrogen.

Future Compatibility




Hydrogen + Nitrogen

Ammonia

Storage & Delivery – Pipeline, Barge, Truck, Rail

Stationary Power

Fertilizer

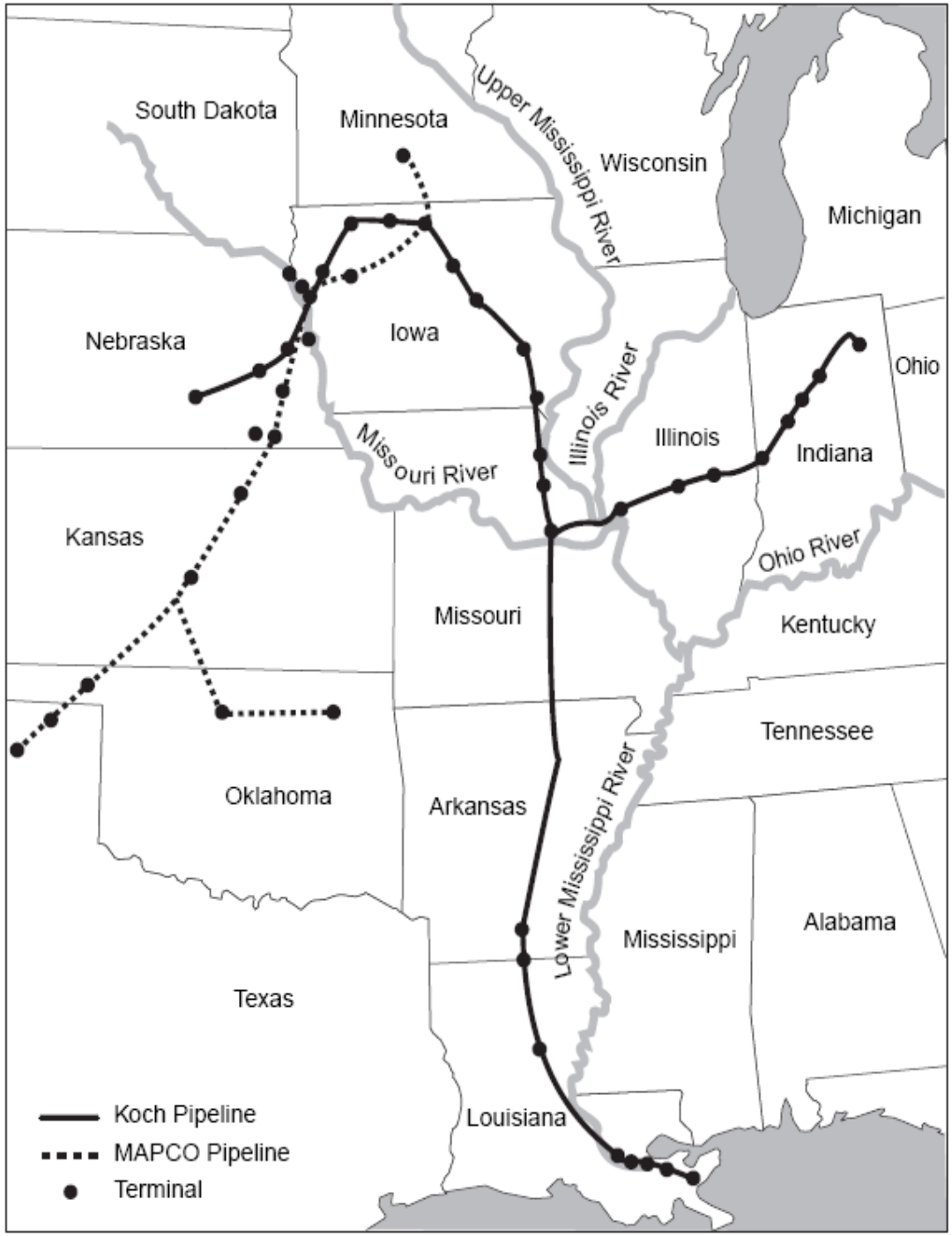
Transportation

Delivery Infrastructure

NH3 is in the top three chemicals shipped worldwide.

Ammonia Storage & Transport

U.S. Ammonia Pipeline

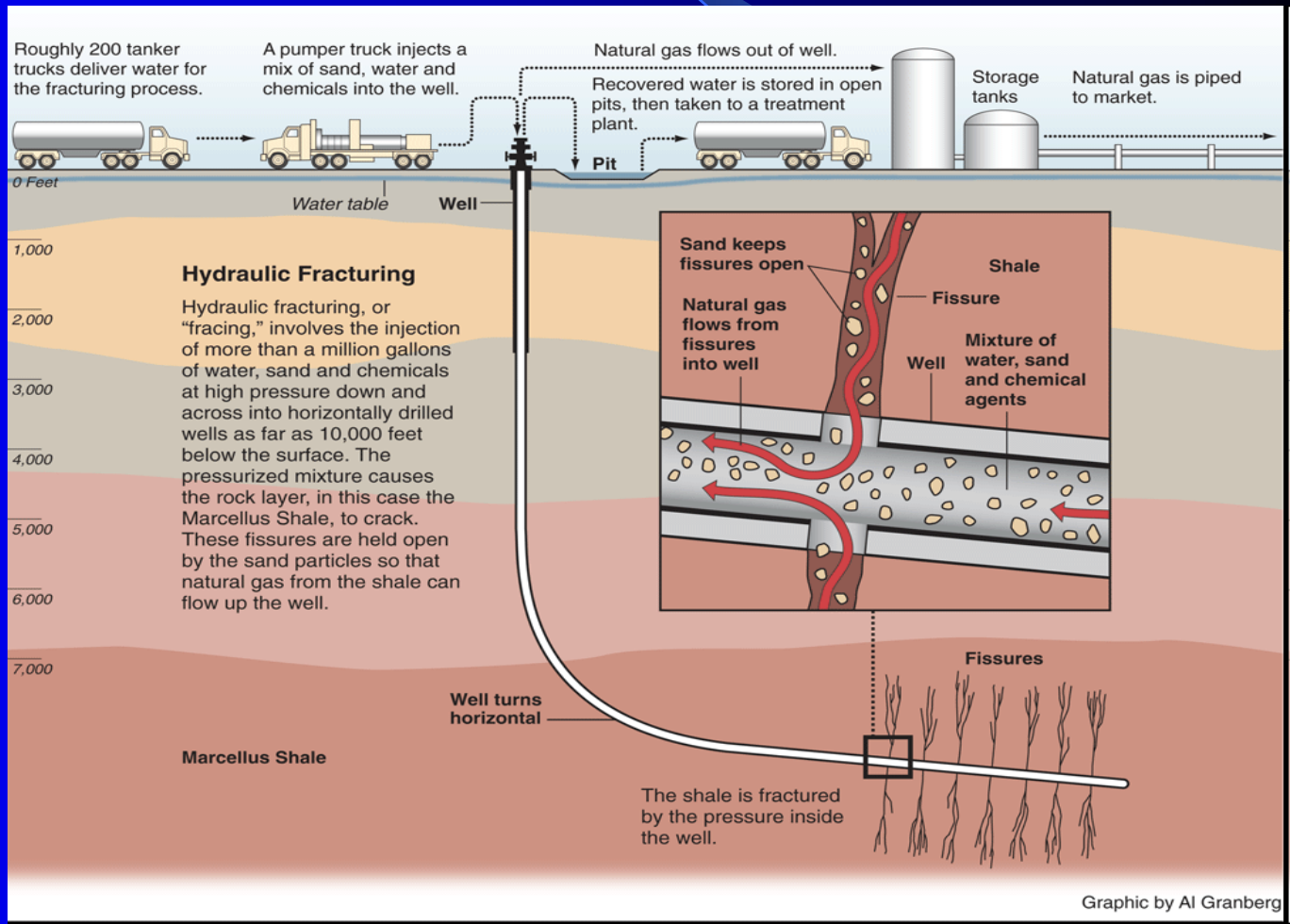


Nearly
3000 Miles
Total

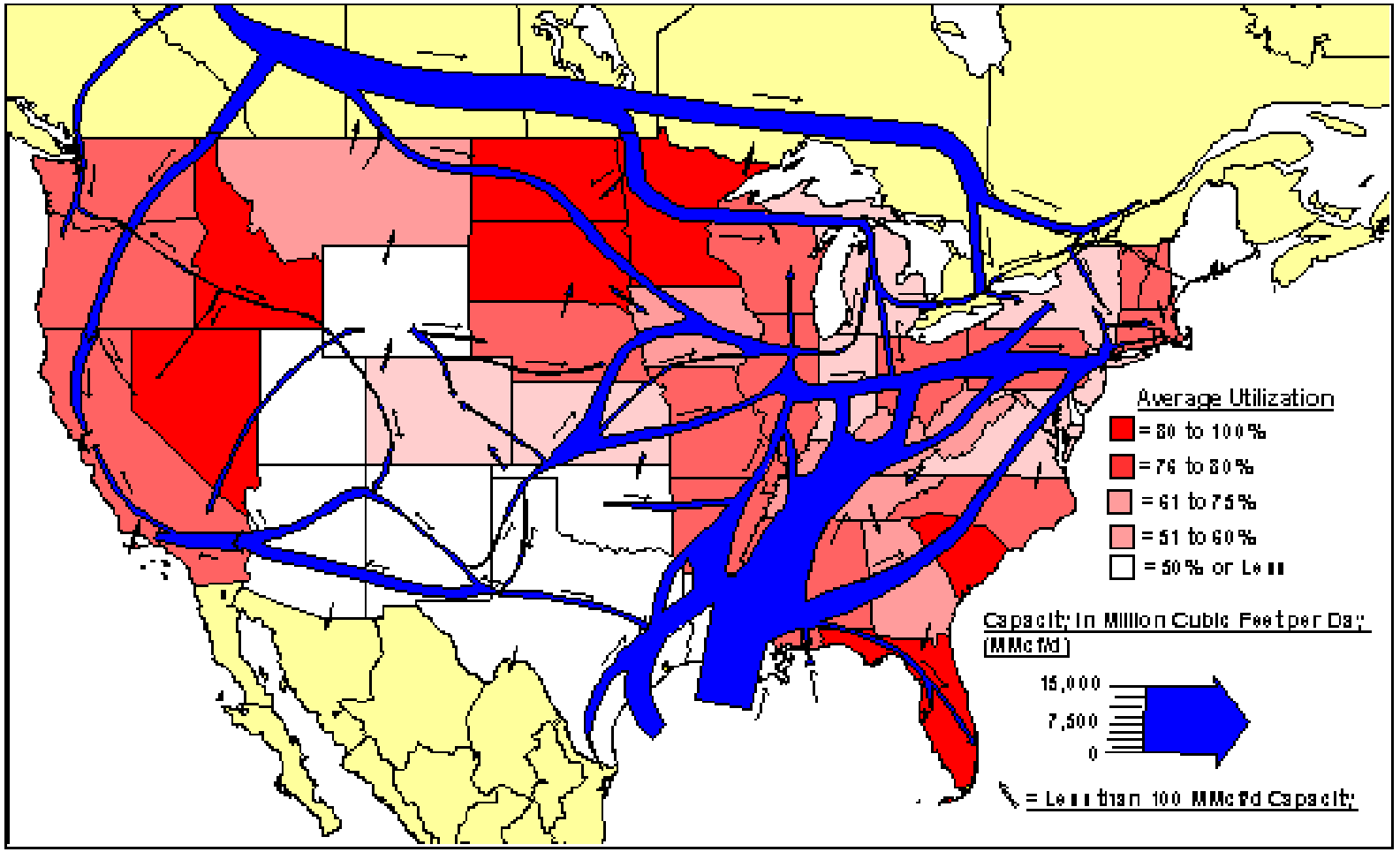
NH_3 vs. Natural Gas

Convert CH4 to NH3 at well head, sequester CO2 in natural gas well to extend well production. Use natural gas pipeline (with modifications) to deliver NH3.

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



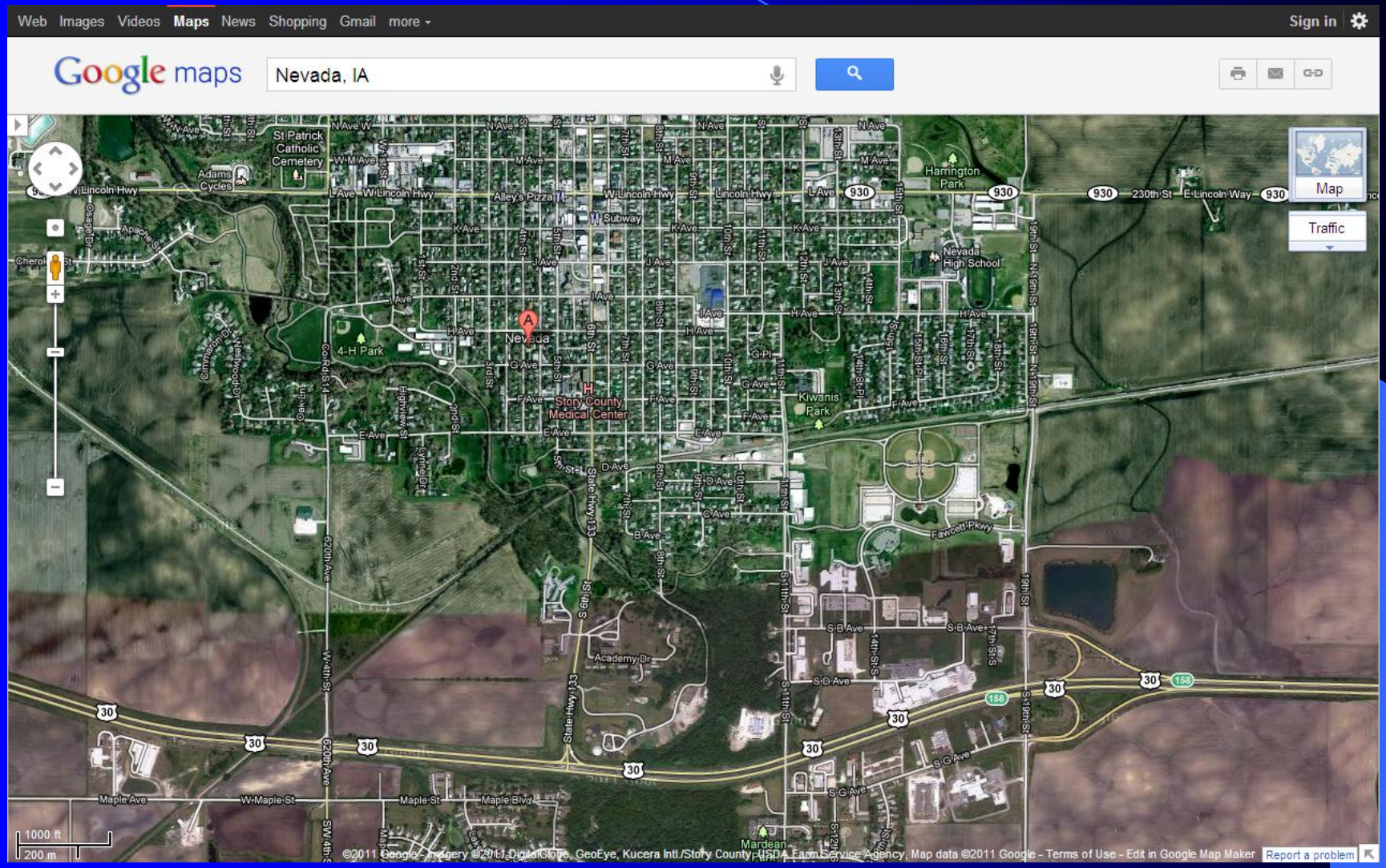
Natural Gas Pipelines



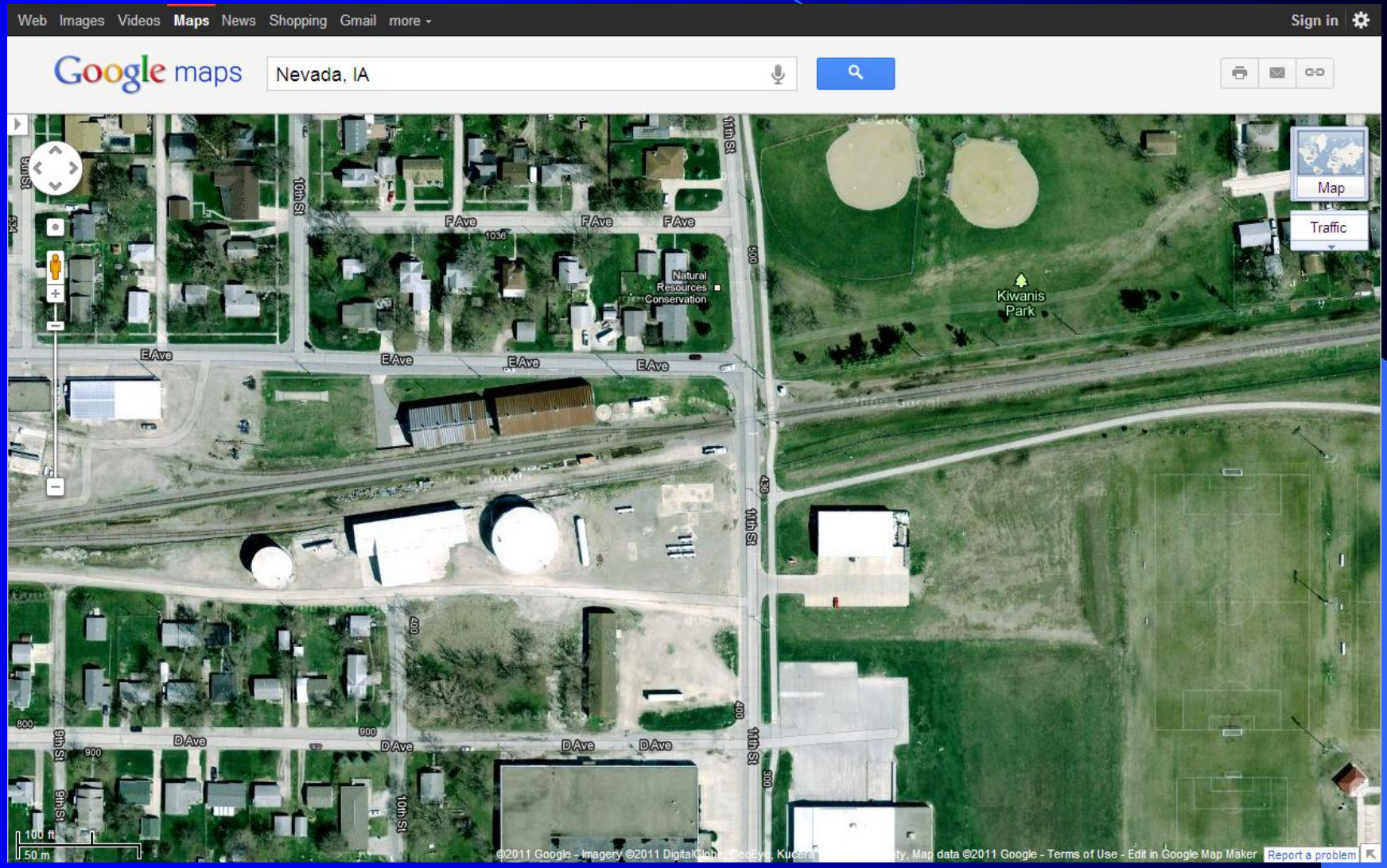
Iowa “Hydrogen” Refueling Stations

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

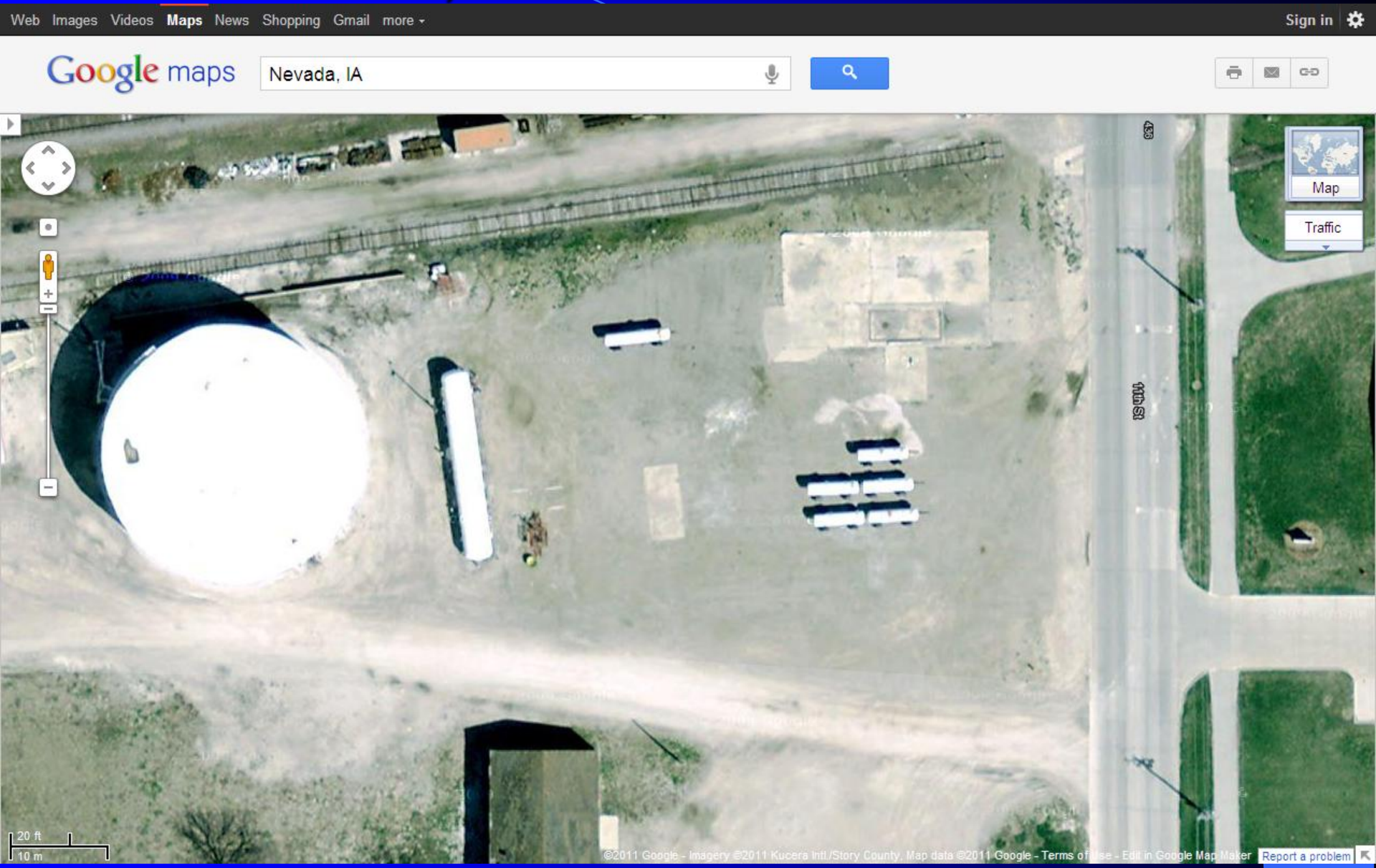
Nevada, Iowa Retail NH3 Outlet



Nevada, Iowa NH3 Retail Outlet

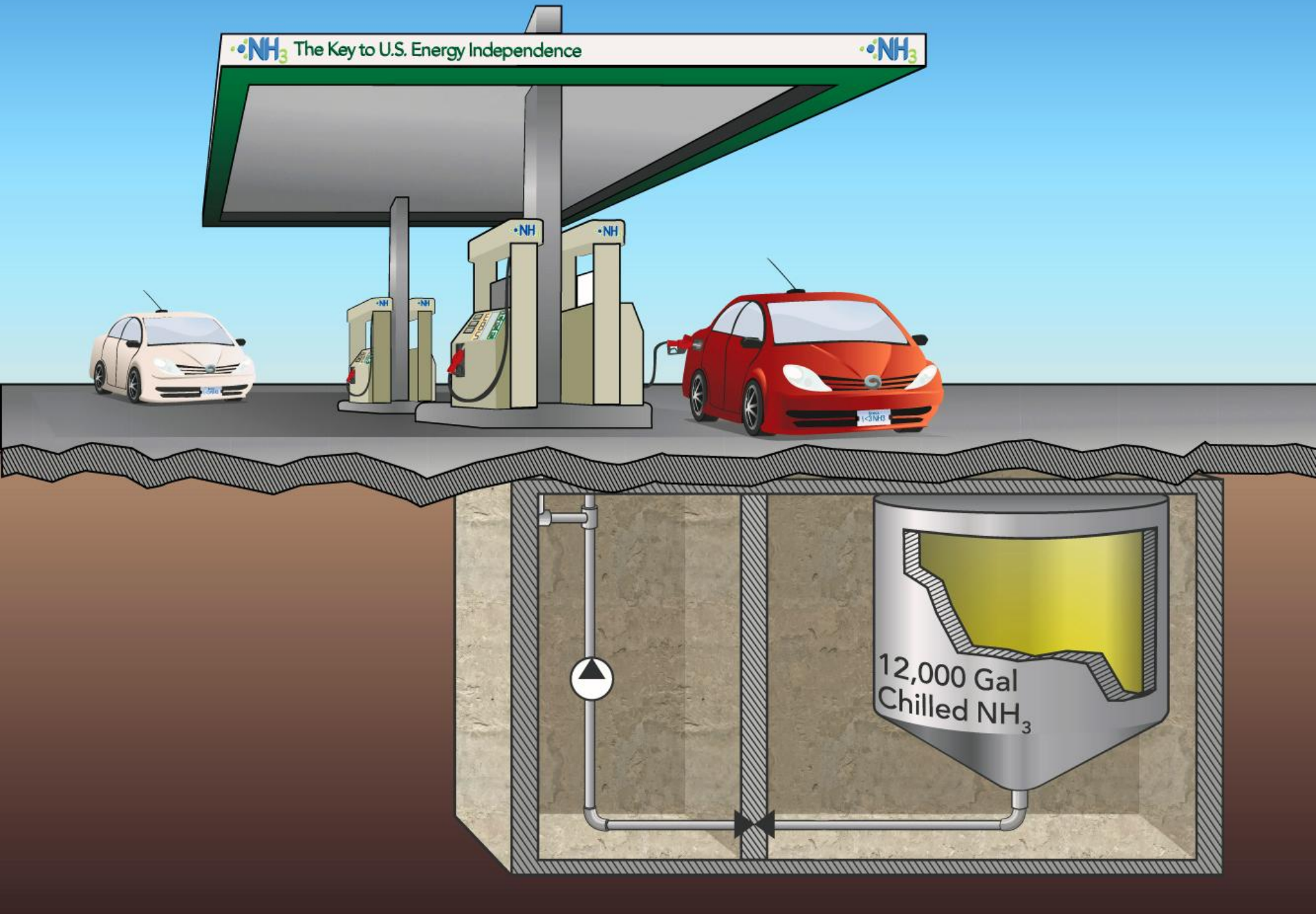


Nevada, Iowa NH3 Retail Outlet



Nevada, Iowa NH3 Retail Outlet

NH_3 Refueling Station



Safety

- NH3 is a common, naturally occurring chemical found in all animal life forms. It is not a carcinogen and is not a greenhouse gas.
- NH3 is safer than propane and as safe as gasoline when used as a transportation fuel.
- Iowa Energy Center funded comparative quantitative risk assessment (CQRA) study completed by March 2009, Quest Consultants Inc., Norman, Oklahoma
- “Safety assessment of NH3 as a transportation fuel”, Nijs Jan Duijm, Frank Markert, Jette Lundtang Paulsen, Riso National Laboratory, Denmark, February 2005
- NH3 plant operators
- NH3 safety is an engineering issue. It can be made to be as safe as is necessary.
- NH3 is classified by DOT as a non-flammable liquid and an inhalation hazard (not a poison)

Vehicle On-Board Storage

Properly designed, pressurized (250 psi rating) NH3 vehicle fuel tanks can meet all international requirements for acceptable safety.

Scapegoat?

NH3 **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 + NH3 = 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, <u>not</u> NH3

NH3 is actually used to clean up NOx emmissions at coal plants

NH3 Fertilizer Application

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

See Clip

End Use Applications

- **Spark-Ignition Internal-Combustion Engines**
- **Diesel Engines**
- **Direct Ammonia Fuel Cells**
- **Gas Turbines**
- **Gas Burners (including residential furnaces)**

Economic Impacts

In 2008 U.S. gasoline prices were as low as $1.50 per gallon. Current prices of over $3.50 per gallon combined with annual transportation fuel consumption of approximately 200 billion gallons creates a current economic drain of $400 billion from the non-transportation portion of the U.S. economy. The $400 billion is equivalent to the combined annual sales of GM, Ford, Chrysler and all fast food in the U.S. This economic drain and the housing crisis are primary reasons for the current U.S. recession.

Summary 1

- **Ammonia meets critical DOE 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 ~zero tailpipe greenhouse gas emissions (with existing control technologies)**
- **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-related applications**
- **NH3 is a very hydrogen dense chemical, ~2x greater (volume basis) than 10k psi hydrogen. This results in outstanding green energy storage capability.**

Summary 2

- NH3 from coal and natural gas now
- NH3 from renewables and nuclear 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 poison! It is an very prevalent, naturally occurring chemical
- Any transportation fuel has associated safety risks but NH3 is as safe as gasoline and safer than propane according to two, highly-credible studies.
- NH3 looks very good now and in the future
- Hydrogen stored, delivered and utilized in the form of NH3 is the best choice for sustainable, cost-effective, near-term alternative transportation fuel.