Wrap-Up/An Ammonia Fuel Business Plan

5th Annual Ammonia Fuel Conference

Minneapolis, September 30, 2008

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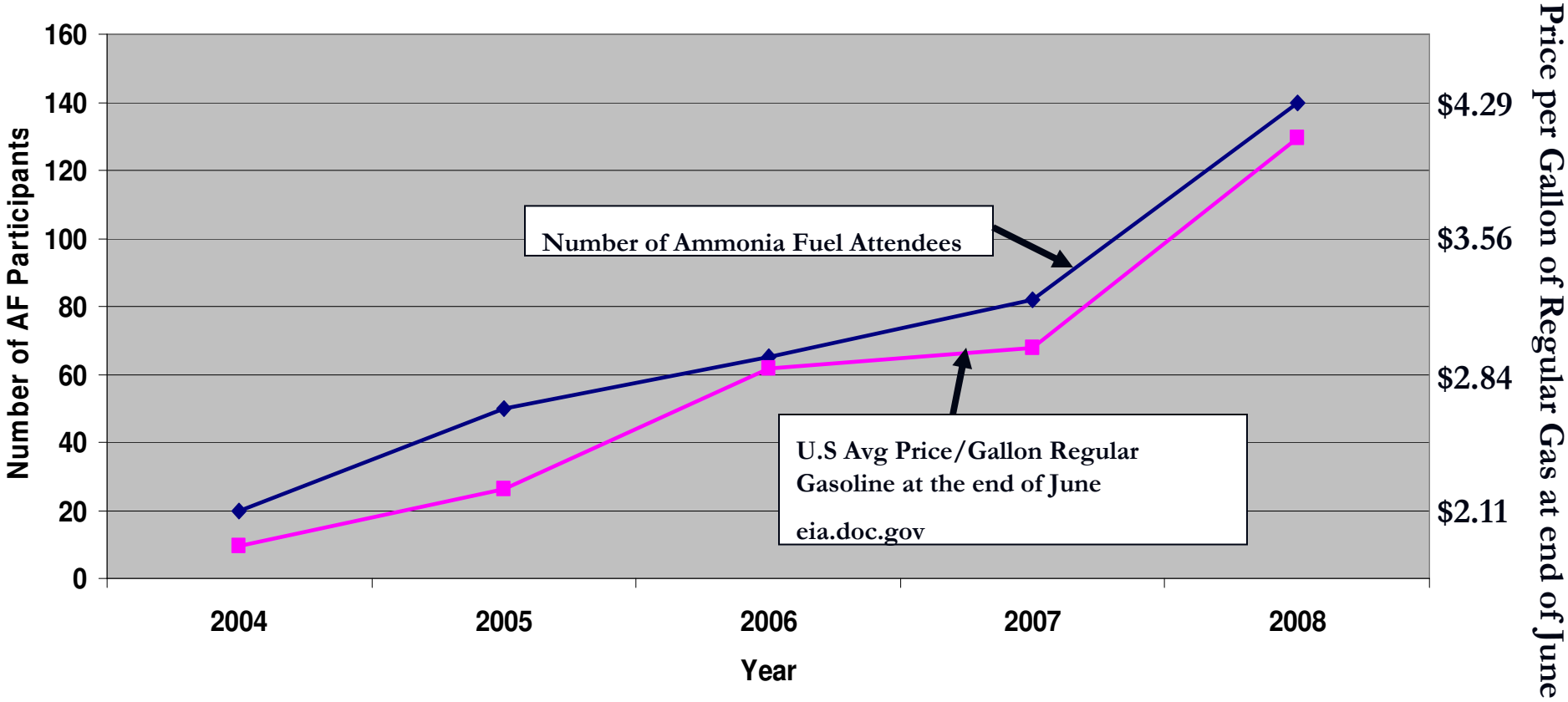
Overview

- Re-cap of meeting
- News
- Ammonia Fuel Network
- An Ammonia Fuel Business Plan

Conference Re-Cap

- Excellent attendance and participation (75% more than 2007)
- Ammonia transport in NG pipelines w/ carbon sequestration
- Validation of low-emission, powerful performance in SI and CI ICEs
- Partial "cracking" to H2 and N2 may offer benefits
- NH3 from OPEC promising
- NH3 is potential excellent energy storage medium for RE, especially stranded RE
- Progress in direct-ammonia fuel cells
- Safety issues with storage and use of NH3 understood, and largely manageable
- Several avenues for clean, high-volume NH3 production, particularly from various RE sources, coal, and nuclear

Ammonia Conference Attendance Driver

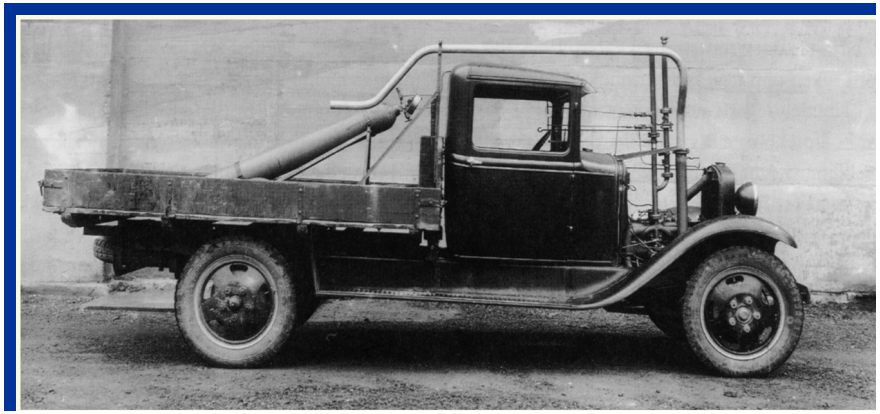


News

- Iowa Energy Center Grants
- Ammonia highlighted in Edwin Black's "*The Plan*"
- Article in thecuttingedgenews.com on ammonia will reach 1.4 million viewers
- Motor Trend article
- Alaska Renewable Energy Fund

Ammonia Fueled Vehicles

Rjukan 1933



Ann Arbor 2007

1959 Fuel Cell Tractor

Ammonia Fuel Network

- Established in WA state in 2007
- Web site www.ammoniafuelnetwork.org – over 2000 visits since July
- Need Board of Directors
- Need By-Laws
- Need to formalize membership
- Need to determine how best to serve membership

Possible Functions of AFN

- Library
- Forum
- News service
- R&D/feasibility
- Political Action
- Education
- Other?

An Ammonia Fuel Business Plan

Relevant quote 1 –

There are three kinds of ball players – those who make something happen, those who watch it happen, and those who wonder what happened.

- Tommy Lasorda, LA Dodgers

Relevant quote 2 –

Mr. Holtz, there are lots of people who don't know what is going on. But, you don't even suspect something is going on.

- High school guidance counseler

To Lou Holtz, future football coach

An Ammonia Fuel Business Plan
Outline

- Mission
- Industry Description
- Market Analysis
- Competitor Analysis
- Marketing Plan
- Management Plan
- Organizational Plan/Operating Plan
- Financial Plan

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AFBP Mission

The ammonia fuel industry will replace 70% of U.S. diesel generators, 80% of farm and industrial diesel and gasoline use, and 19.4% of highway transportation petroleum-based fuels by 2030.

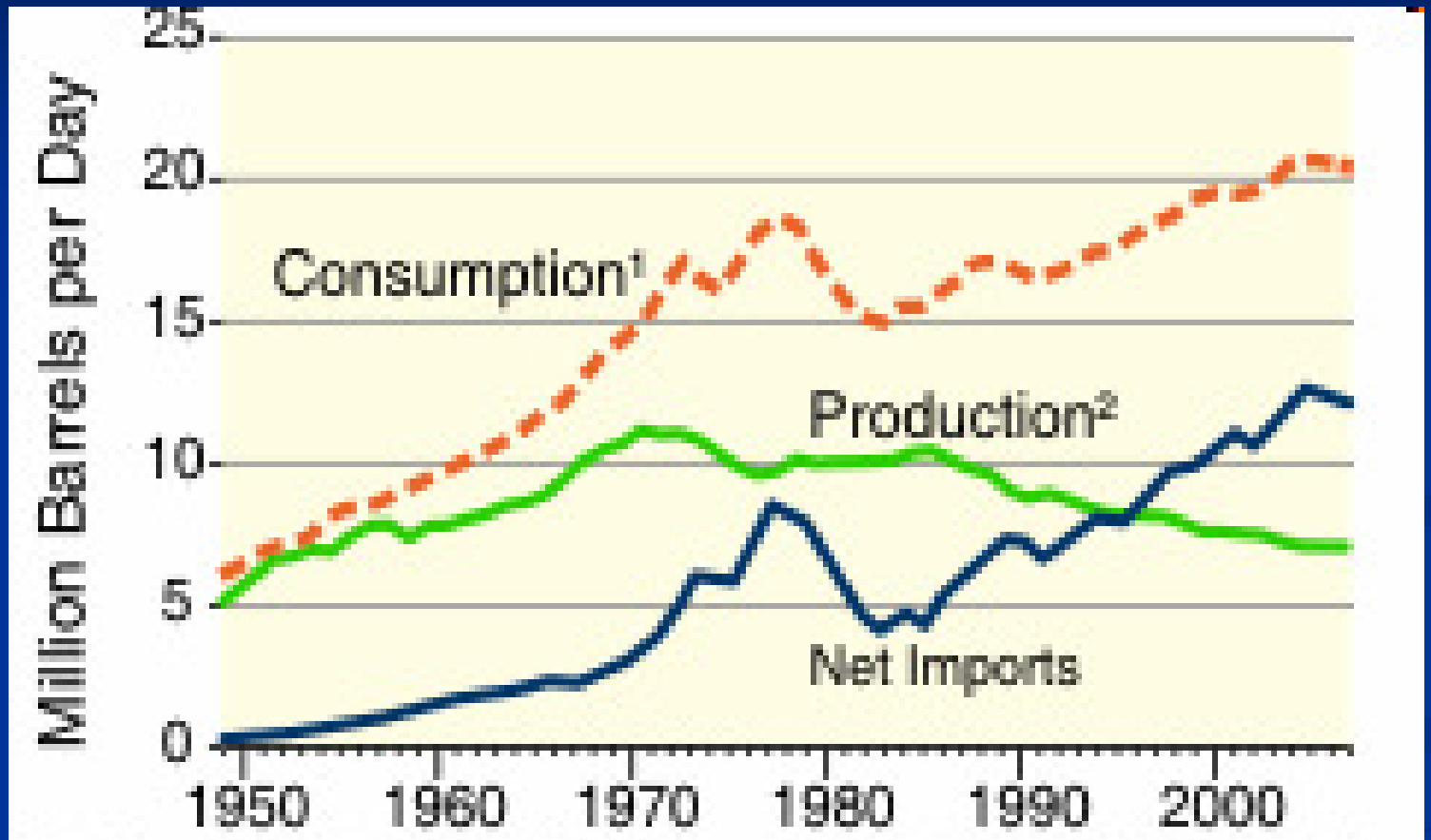
Mission Qualifiers

- The U.S. will not import any additional off-shore, fossil-fuel-based NH3 to accomplish the mission; that would be exchanging an oil dependency for an ammonia dependency.
- The U.S. will cease all foreign oil imports by 2030.
- Green incentives and carbon limits will be in place to incentivize clean alternative fuel production and usage.
- The U.S. will pursue a portfolio approach ("fuel democracy") to solving the fuel problem; numerous fuels, including electricity, will be used to meet the U.S. need. There will be no Fuel King.

Competitor Analysis

- Electric
- Hydrogen
- Biofuels
- CNG
- Coal to Liquids
- Domestic Oil

U.S. Oil Consumption



Petroleum products supplied is used as an approximation for consumption.,
Crude oil and natural gas plant liquids production.
Source: Energy Information Administration, *Annual Energy Review 2007*–
Table 5.1. (June 2008)

Top 5 U.S. Oil Imports

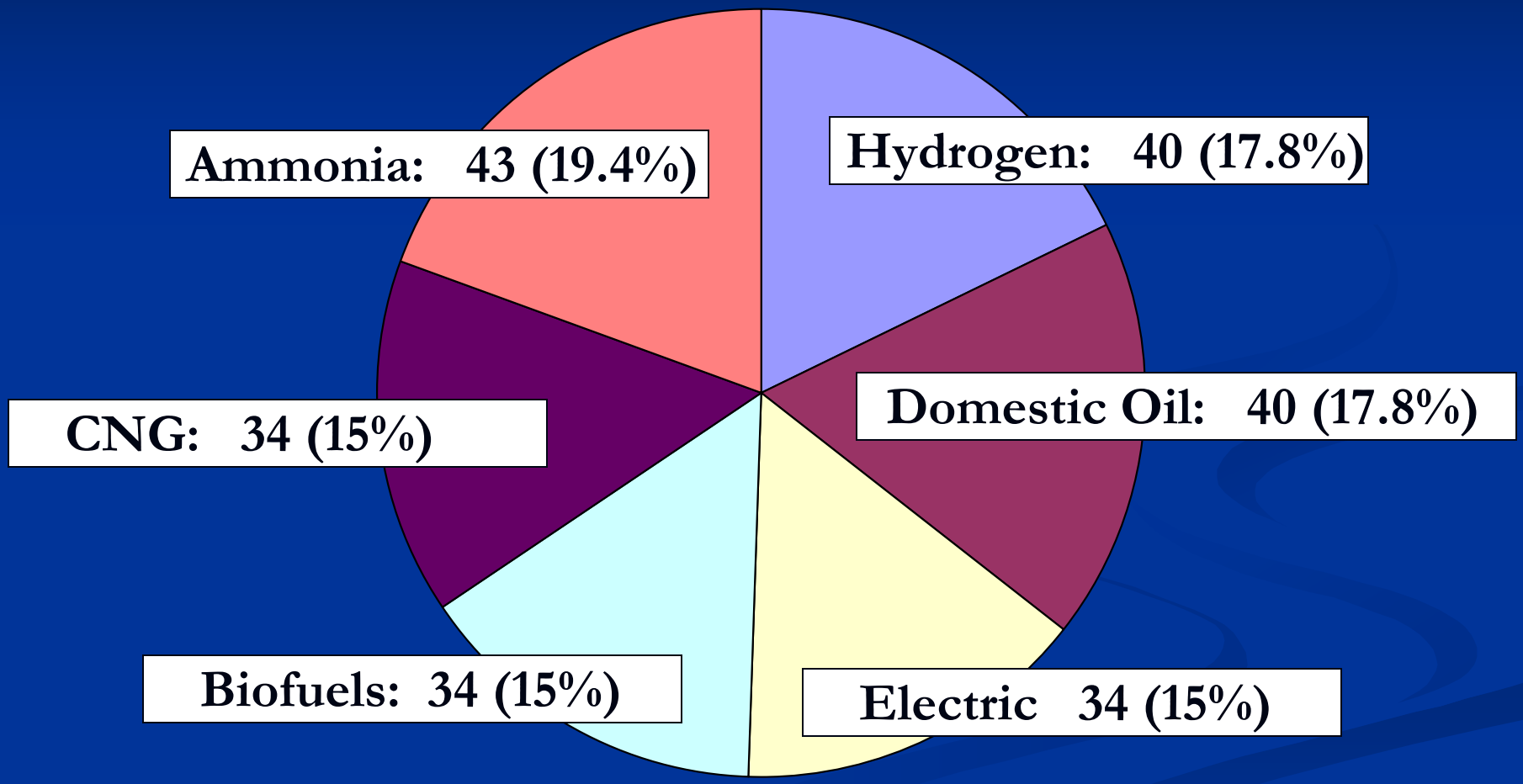
Daily imports (% of U.S. consumption):

1. Canada -- 2 million barrels (9.1%)
2. Saudi Arabia -- 1.5+ million barrels (6.8%)
3. Mexico -- 1.4 million barrels (6.4%)
4. Venezuela – 1.2 million barrels (5.5%)
5. Nigeria -- 1.2 million barrels (5.5%)

2030 Assumptions

- The U.S. will use 25% more total energy for transportation than it does today (180 billion gallons of gasoline and diesel per year)
- CNG, biofuels, and electric energy will each have a 15% share of the transportation energy market
- DOE's goal of 40 MT of hydrogen production/consumption will be achieved
- Domestic U.S. oil production will drop to 5 million barrels per day
- Oil imports will be zero by 2030

2030 Transportation Energy
(in billions of gallons gasoline equivalent)



Total = 225 billion gge

Market Analysis

Successful completion of the mission will require:

- Additional annual U.S. production of ~300 million tons of NH3 (current world production is ~130 million tons)
- Additional renewable or nuclear electric power of 250 to 400 GW to synthesize the NH3 or equivalent amount of natural gas or coal
- ~50 million NH3 vehicle conversions or new NH3 vehicles by 2030 [many of these can be direct ammonia fuel cell vehicles]
- Additional distribution and delivery infrastructure—pipelines, rail, trucks, barges—roughly 50X what currently exists
- Large amounts of water, ~420 gallons for each ton of NH3 produced with electricity [collect water exhaust?]

So, What Will This Cost?

Using Wind-to-Ammonia as an example (i.e. all 19.4% ammonia transportation energy comes from wind energy converted to ammonia):

- Capital costs for wind turbines to produce electricity for NH3 = ~ $700B+.
- Capital equipment costs for domestic wind-powered NH3 synthesis of 300 million tons/year = $160B to $350B
- 50 million vehicle conversions at $5K @ would be ~$250B, or a few dollars less.
- 50X additional delivery infrastructure, figure ~$200 million

Organizational Plan

The ammonia fuel industry will require a concerted and coordinated effort (a subsidized effort?), including:

- Renewable, nuclear, and clean coal/NG sources
- Ammonia production facilities
- Storage and delivery infrastructure
- Converted and new vehicles, farm and commercial equipment, and generators
- Codes and regulations
- Other?

Financial Plan

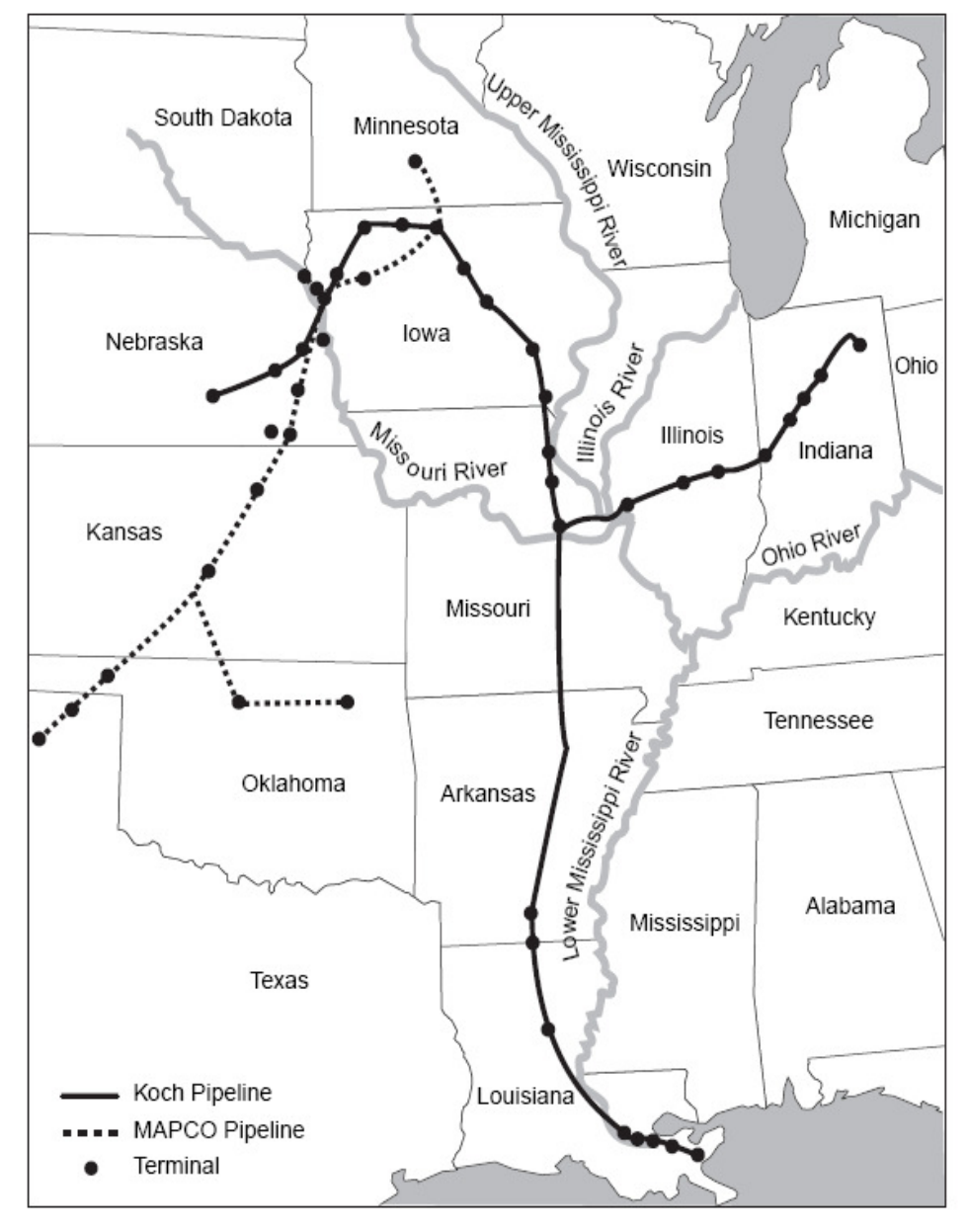
- Who will pay for this?
  - Public
  - Private investors
  - Banks
  - Companies
  - Federal subsidies
- Answer—not sure, at present.
- Comparisons
  - Value of annual 300 million tons NH3 (43 billion gges) is $175B to $300B
  - Annual total oil usage of 22 million tons/day is about $1 trillion
  - Current annual U.S. oil imports ~$700B
- Plenty of opportunity for all.

Thank You

Back-up Slides

U.S. Ammonia Pipeline

3000 Miles Total



Ammonia Is Easy To Store

Ammonia Delivery Infrastructure

Ammonia is easy to crack

	Cracking Reaction to Produce Hydrogen	Energy Lost (or Cost)
Ammonia	$2NH_3 \rightarrow 3H_2+N_2$	12-15%
Methane	$CH_4+2H_2O \rightarrow 4H_2+CO_2$	25-30%
Methanol	$CH_3OH+H_2O \rightarrow 3H_2+CO_2$	~45%
Ethanol	$C_2H_5OH+3H_2O \rightarrow 6H_2+2CO_2$	~60%
Water	$2H_2O \rightarrow 2H_2+O_2$ [electrolysis]	25-35 %