Title
Hydrogen Supply: Pathways and Strategies

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Publication Date
2005

Peer reviewed
Hydrogen Supply: Pathways and Strategies

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Presented to
The Hydrogen and Fuel Cell Caucus
Washington, DC
January 11, 2005
H₂ is one of the only long-term fuels that allows radical reductions in greenhouse gases, air pollutants and oil use.

H₂ and fuel cells could enable innovative energy products and services.
H₂ SUPPLY PATHWAYS

Like electricity, hydrogen is an energy carrier produced from primary energy resources.

- Wind
- Solar
- Biomass
- Coal w/CO2 Sequestration
- Natural Gas
- Nuclear
LONG-TERM VISIONS OF H₂ SUPPLY AND CHALLENGES

- **H₂ from renewables** (wind or solar electrolysis, biomass gasification), issue is cost rather than technical feasibility or resources.

- **Nuclear H₂** issues are cost (electrolytic H₂), technical feasibility (water splitting systems powered by nuclear heat). Same waste and proliferation issues as nuclear power.

- **Fossil H₂ with CO₂ capture and sequestration** near zero emissions, relatively low cost, assuming nearby CO₂ disposal sites, and large scale hydrogen production. Much unknown about potential environmental impacts and feasibility of CO₂ sequestration.
FULL FUEL CYCLE GREENHOUSE GAS EMISSIONS
(Normalized to Adv. Lightweight 46 mpg Gasoline ICEV)

DEBATE ABOUT H₂ SUPPLY: I (greenhouse gas emissions)

- Myth: Using natural gas to make hydrogen for vehicles would increase emissions of CO₂ compared to gasoline vehicles.

Studies by ITS-Davis, Argonne and NAS show 10-40% well to wheels reduction of CO₂.
DEBATE ABOUT $H_2$ SUPPLY: II (carbon “efficiency”)

- Myth: It is “carbon-inefficient” to use NG or renewables to make hydrogen for vehicles, when those resources could be used to displace coal fired electricity.

Only valid if resources strictly constrained (not true) AND if CO$_2$ reduction is the only goal (not true).

Use of primary resources for electricity and fuels will be determined by economics, end-use needs, resource availability, other factors
HYDROGEN DEMAND IN FOUR SCENARIOS

Million Metric Tonnes H₂/y

(Energy ~ Billion gallons gasoline/y)

2015 2020 2025 2030 2035 2040 2045 2050

H₂ vehicle Fraction

100%

50%

Uncertainties (technology, policy, market pull) => difficult to project future H₂ demands
Hydrogen Demand in Four Scenarios

**100 million H₂ vehicles w/ 2-3 X today’s gasoline vehicle fuel economy**

**PRIMARY ENERGY TO MEET H₂ DEMAND**

- **President's H₂ Initiative**
- **2050 Study**
- **EIA Reference Case**
- **PNGV Low**

**Percent of current US use to make H₂ for LDVs**

- NG: Coal
- Wind*: Bio*

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* > class 3 wind

**fraction of range + pastureland required for H₂ via gasification**
DEBATE ABOUT H₂ SUPPLY: III
(Primary Supply)

• Myth: Making H₂ for vehicles would vastly increase natural gas use.

During the transition period when NG would be used (next 20-30 years), H₂ use will be relatively small, so the increased NG demand to make H₂ would be <10%
WHERE WILL H₂ COME FROM?

• **Near term**: Natural gas “transitional” source for H₂ in US
  – 10-40% GHG emissions reduction v. Advanced gasoline vehicles
  – Small impact on natural gas use, at H₂ use <2025

• **Long term**: Ample resources for near-zero GHG emission H₂ production in US, globally

• **Many solutions for H₂ supply**: depends on level of demand, resource availability, geography.
HOW MUCH WILL IT COST?

• Several hundred to several thousand $ per vehicle for **mature** H₂ refueling infrastructure. (Near term costs higher. Costs decrease w/learning, scale)

• Shell estimates 11,000 H₂ stations needed nationwide for “coverage”, initial cost $12 B

• Full implementation of H₂ infrastructure $100sB

• But costs to maintain, expand conventional transport fuels infrastructure also large.

• Delivered H₂ cost range ~$2.5-4/kg for mature H₂ economy. With efficient (2-3 X) H₂ FCV, fuel cost per mile < current cost for gasoline cars. (near term H₂ costs higher)

• (energy in 1 gallon gasoline ~ energy in 1 kg H₂)
OPTIMIZED PIPELINE NETWORK
IF 10% OF VEHICLES = H2 FCVS

- 1 coal plant - 253 tons H₂/day
- 12 cities
  - 1345 km of local distribution pipelines
  - 187 refueling stations,
- 936 km intercity pipeline
- CO₂ sequestration system 4500 ton CO₂/day
- Total capital cost = $1.3B or $3400/vehicle

DEBATE ABOUT H₂ SUPPLY: IV (Cost)

• Myth: Hydrogen infrastructure will be extraordinarily expensive.
  *Initial cost barrier. Mature costs may be comparable to maintaining and expanding conventional fuel infrastructure*

• Myth: Hydrogen fuel will be extraordinarily expensive at the pump.
  *For H₂ FCV, fuel cost per mile < today’s gasoline vehicles*
Case study for CA H2 Highway Network:
17 planned H2 stations + 23 fleet sites

17 planned H2 stations + 43 fleet sites + 40 largest cities + 100 gasoline locations

Legend
- Red: Planned and Existing Stations
- Black: 43 CNG, 40 cities, 100 gas sites
- White: All retail stations (3961)

Station dot diameter ~ 3.5 miles
Ave. Travel Time to Nearest Station

H2 at 1% of gasoline sta. => 10 minutes; 3% => 5 minutes

Number of Hydrogen Stations

Average Time to the Nearest Station in Freeflow Traffic (min)

Planned and Existing Stations

CNG Stations Included

Selecting from Gasoline Locations

Gasoline Stations Included
HOW SOON COULD H₂ MAKE A MAJOR DIFFERENCE?

• Time to change energy system ~ decades.
• H₂ end-use technologies need more development before entering mass markets, and time to penetrate markets.
• It will be several decades before hydrogen could reduce emissions and oil use on a global scale. (local impacts sooner)
• Beyond 2025, potential for large impact of H₂ technologies on reducing emissions.
• Potential to transform energy production and use
ACTIONS TO ENABLE A H₂ ECONOMY

• **RD&D:**
  – Fuel cells
  – H₂ storage for vehicles
  – Small scale H₂ production systems
  – Advanced vehicle systems (ICEs, hybrids. FCVs)
  – Low-cost “zero-C” energy supply (elec, H₂, fuels)

• **Demonstrate/enable H₂ infrastructure**
  – Demonstrate technology
  – Codes and standards
  – Infrastructure transition cost barrier
  – Strategies for H₂ infrastructure

• **Policies reflecting external costs of energy** (near term->long term)