Hydrogen Fuel Cell Vehicle Study

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Thanks to Barbara Levi for editing.

Rationale

- Fuel cells are an important aspect of the nation's energy policy (new initiative in President's State of the Union message).
- Fuel cells are of interest to the physics community—*Physics Today* article.
- Physicists do system analyses and research on potential hydrogen storage, *e. g.*, carbon nanotubes.

Intended Audience

- POPA
- APS Membership, especially those who have read Ogden's article in *Physics Today*

FreedomCAR and FUEL

- Government/industry program (2002, 2003)
- **Long Term Vision:** *A transportation system powered by hydrogen from renewable energy sources.*
- Engineering goals for fuel cell technology and H_2 infrastructure.

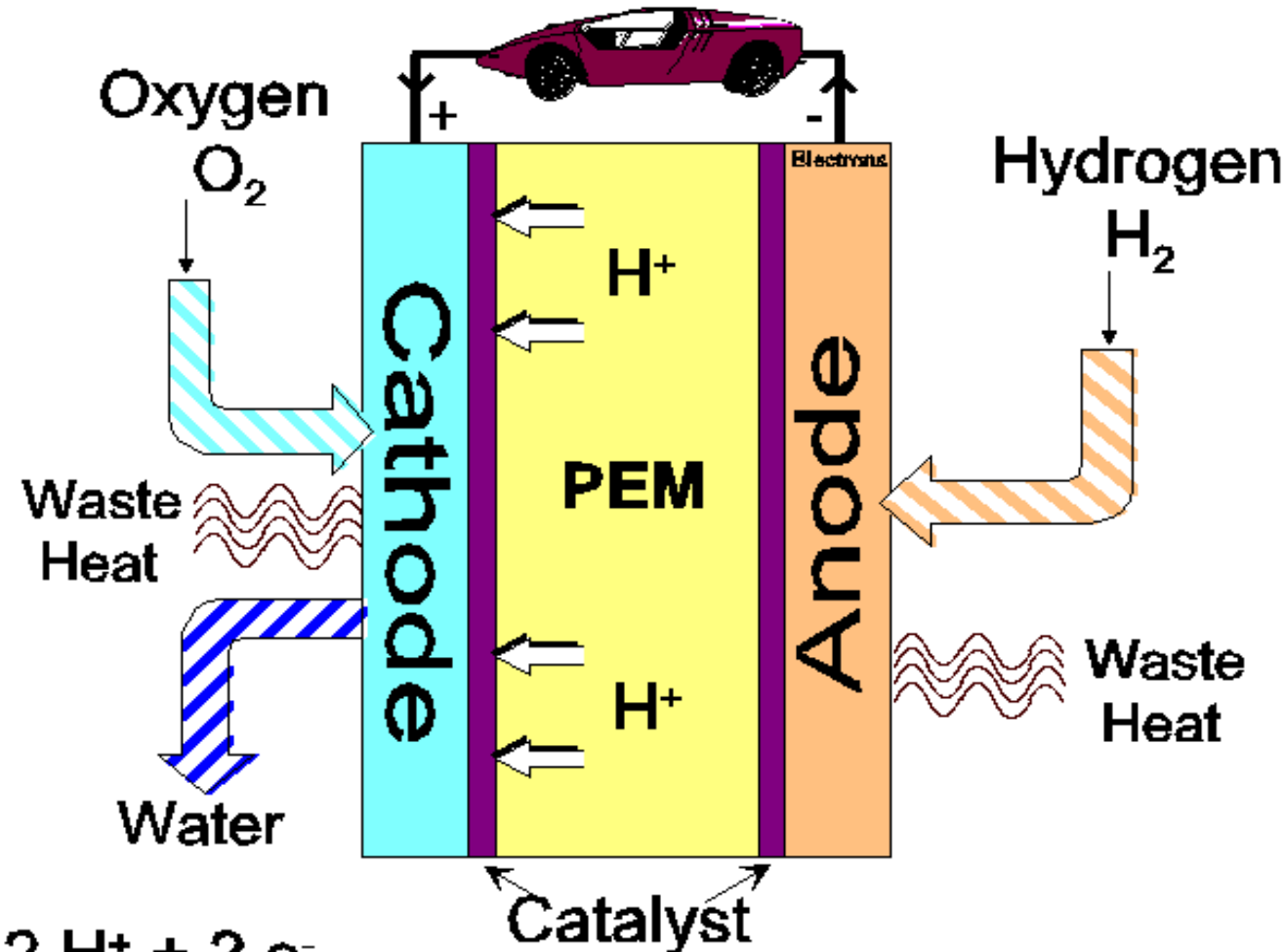
This report intends to *educate*, rather than to persuade or advocate.

This is *not* a report about policy recommendations.

Topics

- Efficiency
- Cost
- Storage
- Infrastructure
- H_2 safety

Operation of a PEM Fuel Cell

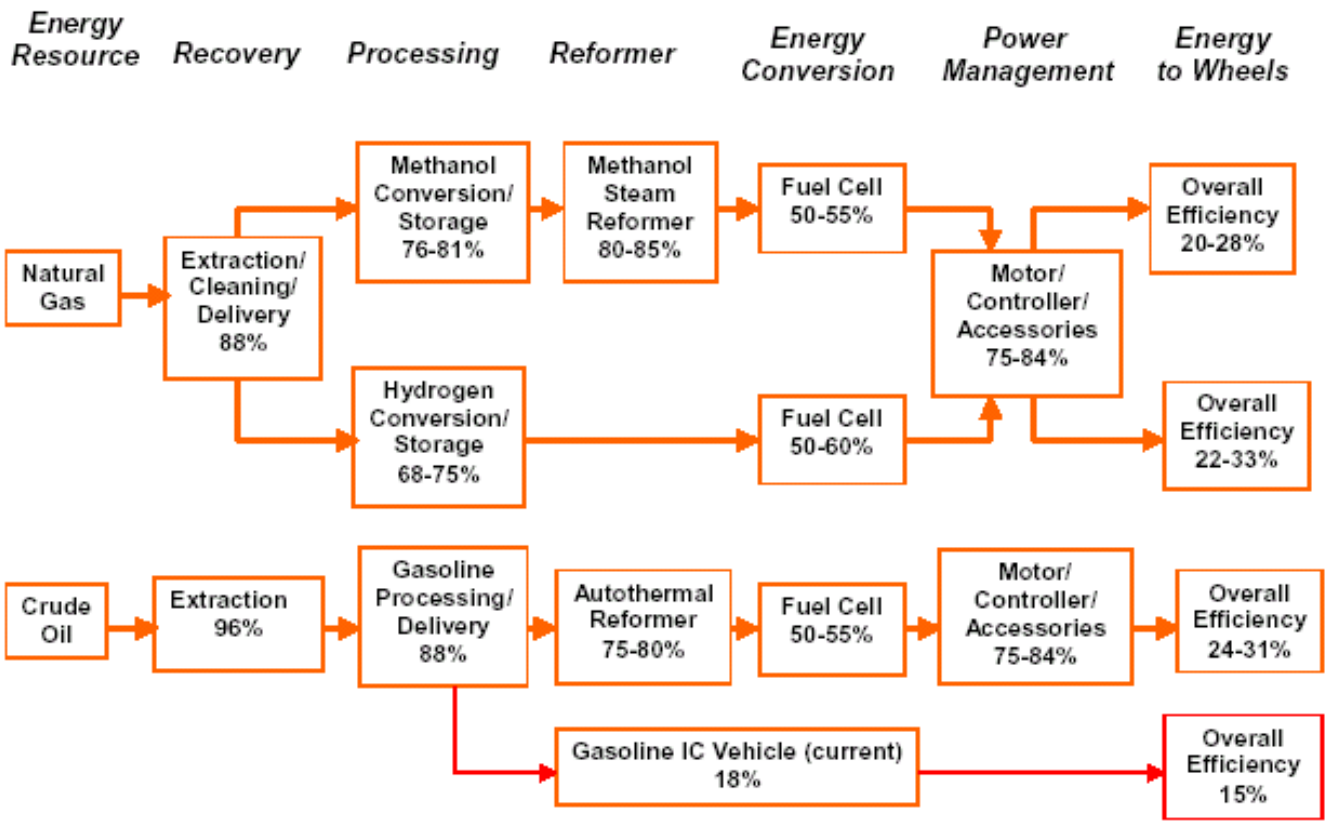


$$1/2\ O_2 + 2\ H^+ + 2\ e^- \rightleftharpoons H_2O$$

$$H_2 \rightleftharpoons 2\ H^+ + 2\ e^-$$

$$H_2 + 1/2\ O_2 \rightleftharpoons H_2O$$

Well-to-Wheels Energy Efficiency



Energy consumed in MJ/km (1 MJ/km = 1500 BTU/mi is equivalent to 0.013 gal/mi of gasoline.).

	2001 gasoline ICE	2020 gasoline ICE HEV	2020 diesel HEV	Fuel cell vehicle
Vehicle operation	2.47	1.07	0.92	0.54
Fuel cycle	0.52	0.22	0.13	0.42
Manufacture	0.29	0.26	0.26	0.28
TOTAL	3.28	1.55	1.31	1.24

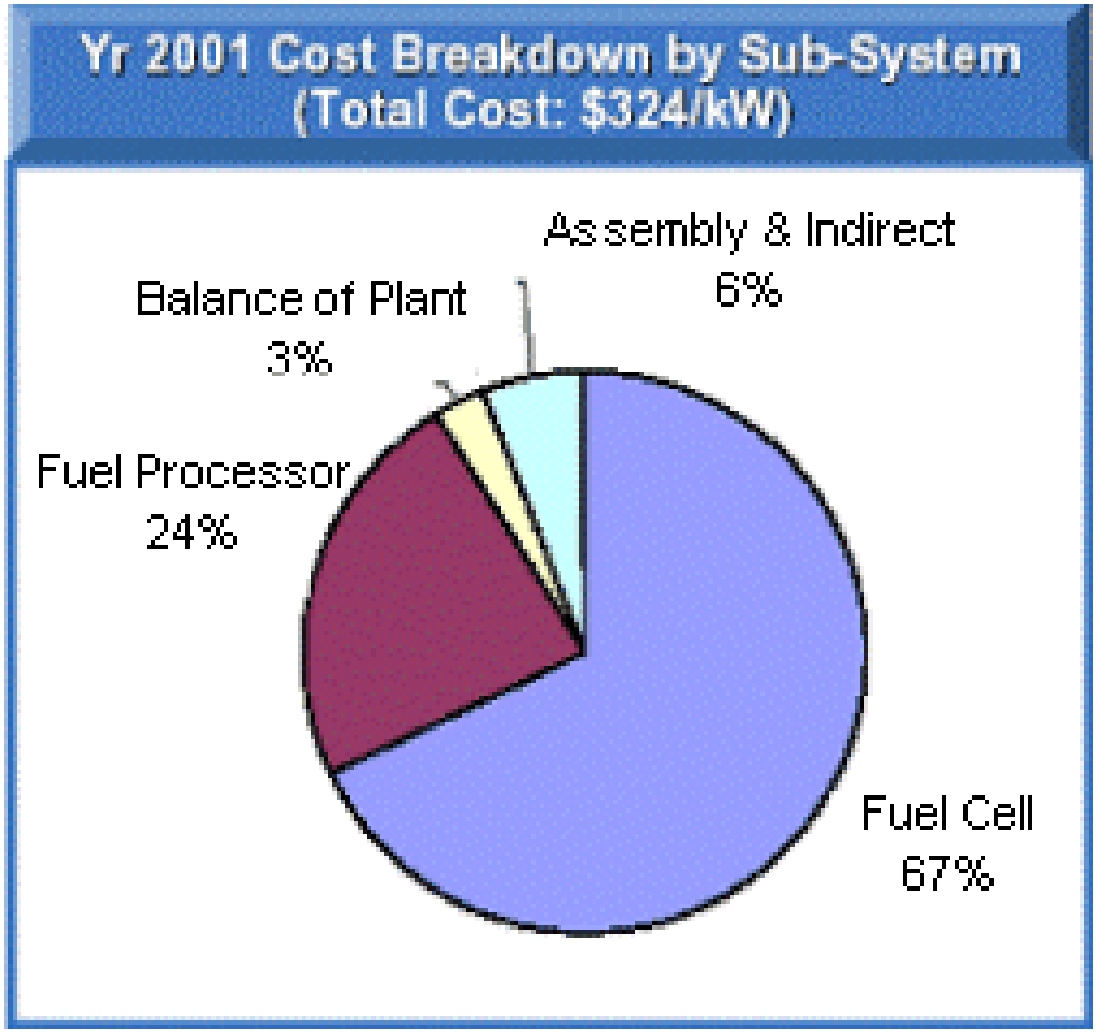
"Comparative Assessment of Fuel Cell Cars," M. A. Weiss. J. B.Heywood, A. Schafer, and V. K. Natarajan, February 2002, MIT LFEE 2003-001 RP,

COSTS

Current cost is $1500/kW. (50 to 80 kW required.)

Pt catalyst usage reduced, costs < $10/kW in advanced technology.

Target is $45/kW.


Yr 2001 Cost Breakdown by Sub-System
(Total Cost: $324/kW)
Assembly & Indirect
6%
Balance of Plant
3%
Fuel Processor
24%
Fuel Cell
67%

Argonne National Lab Estimate for Central Production Facilities (Prof. Daniel Sperling, U. of California, Davis):

Infrastructure cost for producing H_2 equivalent to 1.6×10^6 barrels/day of oil (~20% of light vehicle usage):

$400 billion for production

$175 billion for distribution

[For comparison, the Exxon-Mobil market capitalization is $200 billion.]

BP Company Estimate for Outfitting Local Stations with Natural Gas Reformers

- $400,000 for reformer to make hydrogen using local gas lines
- $1.5 million to build conventional gas station

ON-BOARD HYDROGEN STORAGE

Only proven system for hydrogen storage is compressed gas high pressure tank storage [70 GPa (10,000 psi)].

Breakthrough is needed to be confident that carbon nanotubes will be able to satisfy storage requirements.

Hydridation of metal-N-H systems are interesting.

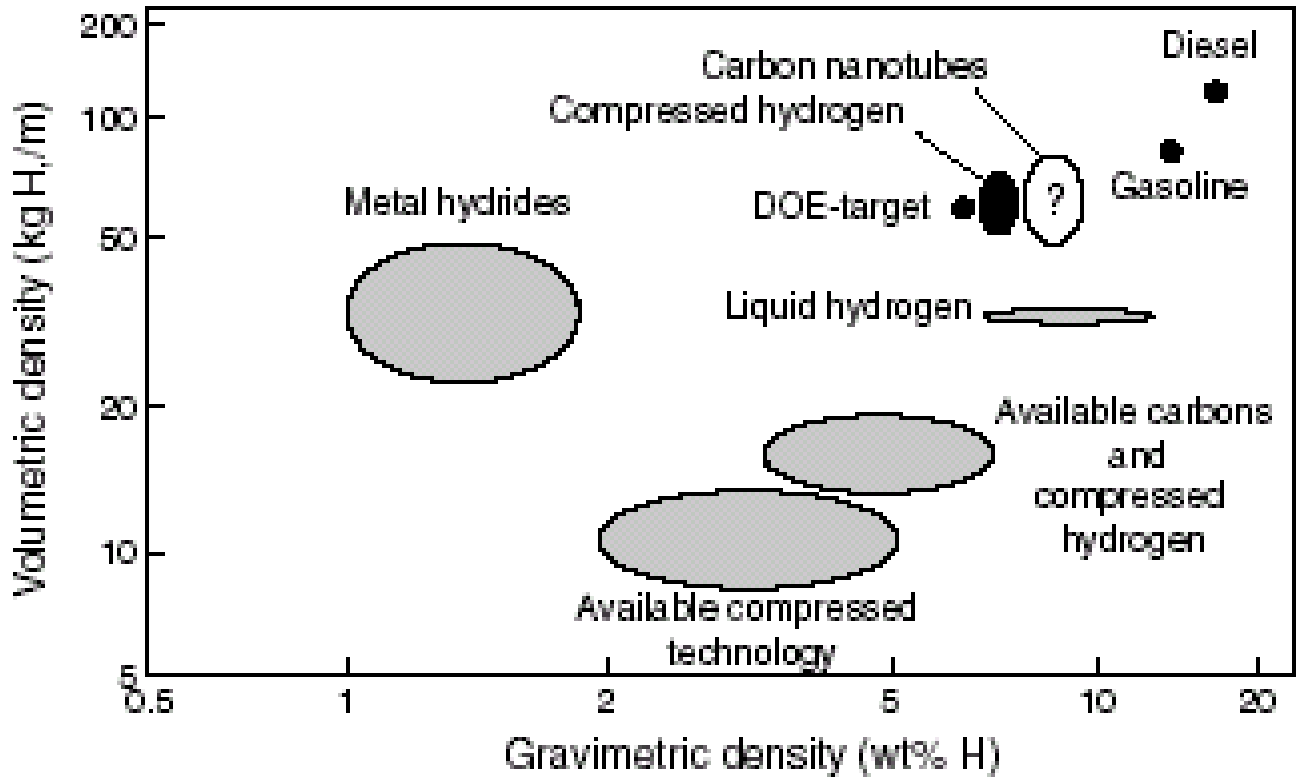


Figure 1. Summary of how current and future hydrogen storage systems relate with respect to gravimetric and volumetric densities.[3]

INFRASTRUCTURE

H_2 transmission lines exist.

Short haul is by cryogenic tanker trucks.

FreedomFUEL initiative addresses issues.

Safety

- Codes and standards required
- H_2 no more dangerous than gasoline
- More research needed