



Hydrogen Powered Vehicle

The Case for Hydrogen Internal Combustion Engines

Adam Campisi, Kyle Bartosik
 Stephen Poppa, Casey Rivera
 Advisor: Professor Brian Savilonis

Abstract

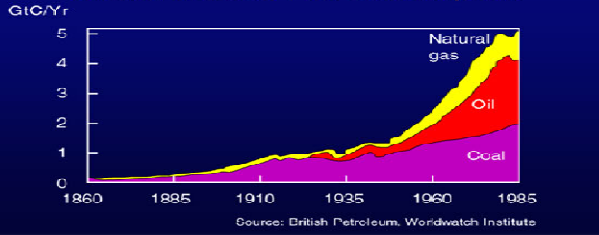
Hydrogen powered vehicles have been in development for the past decade. While hydrogen fuel cells have been receiving the majority of the attention, they will not be ready for mass production for fifteen to twenty-five years. Hydrogen internal combustion engines may prove to be the most effective solution for the immediate future. This project explores the feasibility of making hydrogen internal combustion engines in mass produced vehicles. We researched the different methods for producing hydrogen, storing it in vehicles and converting traditional internal combustion to burn hydrogen instead of gasoline. Through this research we investigated the advantages of hydrogen internal combustion engines over hydrogen fuel cells.

HICE vs. Fuel Cells



| HICE | Vs. | Current Fuel Cells |
|--|------------------------------|---|
| Now | Widespread Availability | 15-25 Years |
| \$5000 to convert ICE to HICE | Cost | >\$100,000 |
| 65% | Efficiency | 50% |
| Up to 120% | Power output compared to gas | 80% |
| None, runs effectively in all conditions | Condition Limits | Difficulties running in freezing temperatures |

Growth in Fossil Fuel Consumption



http://geothermal.marin.org/geopresentation/sld117.htm

Objectives

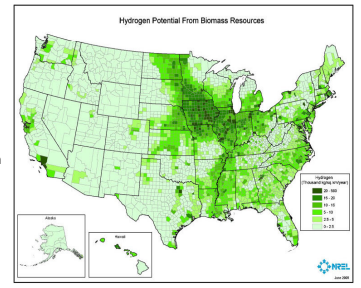
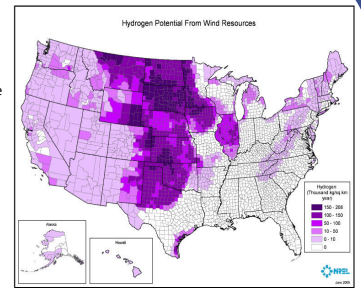
- Find out if HICE is a reasonable possibility
- Find out if it is cost effective to mass produce vehicles with HICES
- Determine the cost of constructing the necessary infrastructure to support a mass produced hydrogen powered car
- Determine the benefits, if any, of adapting HICES now, rather than waiting for fuel cells to become available

Results

- The best method of hydrogen production is area based, (better takes up volume and solar)
- Liquid hydrogen takes up less volume but has the potential for less energy, while the gas takes up more volume but has a higher potential for energy.
- Gas stations would need to spend \$70,000 to modify for hydrogen usage, and in order to build new hydrogen stations it would cost \$470,000.
- Differences between HICE when compared to an ICE are a difference spark plug, changes in the intake system, and the storage tank with shut off valves.
- HICE have zero harmful emissions
- Hydrogen Fuel Cells (HFCs) are zero emissions vehicles
- HFCs will not be publically available on the commercial level for 15-25 years
- HICE would make for an easy transition into HFCs when they are finally available.
- Mass produced cars would cost roughly \$5,000 more to conform to hydrogen fuel for hydrogen internal combustion engines

Production Methods

- Electrolysis is the separation of water into oxygen and hydrogen by running a direct electric current through the water.
- It is the simplest and cleanest way of producing hydrogen, because the hydrogen that comes out of the process is 99.999% pure.
- The total land area of Class 4 (medium purple color) 50-100 thousand kg/sq. km year) and higher wind areas is approximately 568 944 square kilometers. If we assume the output of these areas to be 5 megawatts/sq kilometer (MW/km²), the calculated potential for the United States becomes 2,845,000 MW.
- If we use 58 kWh/kg for the electrolyzer energy (that is an efficiency of 67%) leads to a hydrogen production rate of 154 billion kg/yr. The United States consumed 140 billion gallons of gasoline in 2004
- One kilogram of hydrogen is roughly equal to one gallon of gasoline (on an energy level).
- To meet the U.S. Department of Energy target of \$2.00-\$3.00/kg hydrogen, electrolyzers with today's efficiencies would need to have access to electricity prices lower than \$0.045-\$0.055 /kWh. The average price for electricity today is \$0.103/kWh.
- California's wasted biomass is estimated to be able to provide 335 petaj (1 petajoule=1PJ=10¹⁵ J) of hydrogen energy for transportation fuel.
- California's biomass could effectively replace 16% of the gasoline energy used in the state, and also power 10 million cars by hydrogen.
- There are roughly 25 million cars in California today. By miles driven, hydrogen can power a car an estimate of 51.5 miles per gasoline gallon, while conventional gasoline ICEs can only power a car about 20.6 miles per gallon.



Turner, John. "Renewable Hydrogen Production." International Journal of Energy Research 32 (2008): 381-82.



The BMW Hydrogen 7

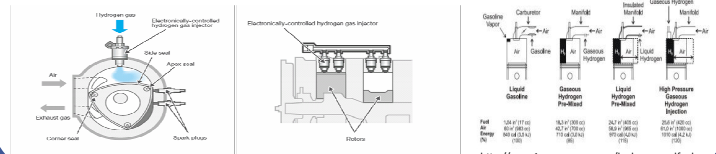
Storage

- 24kg of petrol would power a conventional vehicle 400km
- 8kg of hydrogen would power a HICE for 400km
- 4kg of hydrogen would power a fuel cell for 400km
- To store 4kg hydrogen (as a gas) you would need
 - 225 liters (roughly 60 gallons)
 - Or 5 tanks of 45 liters each

- To store hydrogen as a liquid, it would need to be lower than -241°C
 - Low temperature causes heat loss and with this heat loss, hydrogen is lost
- Storing hydrogen in alloys through sorption
 - Looks promising but needs more testing before anything can be proven

Hydrogen Internal Combustion Engines

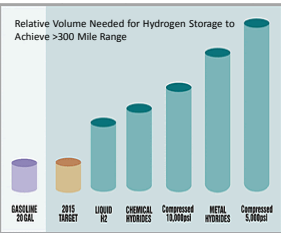
- Hydrogen has different properties than the hydrocarbon fuels. It has a lower ignition point, a higher range of flammability, and a shorter quenching distance
- Two injection ports at each intake must be formatted in such a way to inject the gas-air mixture more evenly into the chamber evenly without pre-ignition
- The combustion chamber itself should be a flat disc shape, with a flat ceiling and piston, to be sure that all the hydrogen is burned.
- A modified cooling system is very important so as to further prevent the ignition, because if the engine is kept too, the injected fuel can combust early.



http://www.greencarcongress.com/2005/10/mazda_to_displa.html

Conclusion

Hydrogen internal combustion engines show more promise for the immediate future than hydrogen fuel cells. HICES have the benefits of being inexpensive and easy to install, producing zero harmful emissions, and having higher efficiencies than gasoline internal combustion engines. This technology is also ready to be implemented in the very near future, allowing HICE to act as a transition mechanism into hydrogen fuel cells. For the United States to become compatible with HICE, a hydrogen infrastructure would need to be built. This infrastructure would pave the way for hydrogen fuel cells. In conclusion, hydrogen internal combustion engines are currently superior to fuel cells, and would help bridge the technological gap between traditional internal combustion engines and hydrogen fuel cells.



| | Compressed Gas | Liquid Hydrogen | Metal Hydrogen | Storage in Alloys |
|------------------|--|--|--|--|
| Advantages | Good technology base for production and volume storage | Good technology base for production and volume storage | Good technology base for production and volume storage | Good technology base for production and volume storage |
| Disadvantages | Cost of compression and storage | Cost of liquefaction and storage | Cost of hydrogen and storage | Cost of hydrogen and storage |
| Future prospects | Good technology base for production and volume storage | Good technology base for production and volume storage | Good technology base for production and volume storage | Good technology base for production and volume storage |

http://isaee.hydrogen.ru/?pid=275