Methanol to Power Future Transportation

Hydrogen as a fuel source for powerplants

There is probably no fuel that is less suitable as a fuel source for the transportation industry than hydrogen, for the following reasons:

- Compared to batteries the well-to-wheel cost of hydrogen powered fuel cells can be ten times higher [1]
- The cost to provide fueling capability at existing stations is estimated at one-half a trillion dollars.
- Produces 48% less power than gasoline in an engine [2].
- The three storage options are cryogenic, compressed, or hydride. All are complex, costly, and inefficient particularly when used in a vehicle.
- Using compressed hydrogen as an engine fuel requires a tank pressurized to 10000 psi that is seven times larger than for gasoline or four times larger for a fuel cell. [3]
- Quantifying the various potential accident scenarios will take time and potentially bad experiences.
- It is contemplated that solar and wind farms could store off-peak energy production in the form of hydrogen. However, these energy sources are generally located in remote areas to reduce land cost. Hydrogen is difficult to transport because its low density requires it to be pressurized to very high pressure or liquefied. Both processes are costly and complex [4].

Methanol as a fuel source for powerplants

Methanol is an excellent fuel source for the transportation industry for the following reasons:

- Renewable (green) methanol can be created at the solar or wind energy site by combining hydrogen with CO_2 [5]. The CO_2 could be extracted from the air or from sequestered sources. Methanol is easily trucked to filling stations or piped to distribution centers.
- In case of an accident, it has only an 11% of the heat release rate of gasoline. EPA determined that it was much safer than gasoline over 30 years ago [6].
- Its only toxic emission is formaldehyde compared to dozens of carcinogenic components in gasoline, including formaldehyde, and Is readily biodegradable compared to petroleum-based fuels.
- Its higher octane rating than gasoline allows a higher compression ratio leading to higher thermal efficiency [7].
- **Produces much more power than gasoline when the engine is designed for it like the Rotapower® engine** [8].
- Can operate at a fuel/air ratio much lower than stoichiometric compared to gasoline, which further reduces toxic emissions.
- Methanol is expected to cost significantly less than gasoline on a useful energy basis, as it proven in China [9].
- It can be 15% more thermally efficient than gasoline in an engine due to less radiant heat loss, higher compression ratio, and faster fuel burn.
- Providing fueling capability at existent US stations will be relatively simple by replacing the largely unused middle octane grade.
- **Aircraft make up 13.3% of greenhouse gas emissions and are sufficiently energy intensive that batteries and hydrogen are inadequate energy sources. Consequently, renewable methanol is the only viable green aviation fuel.**

Freedom Motors Inc.
Paul Moller, Ph.D.
1855 N 1st St. Suite B.
Dixon, CA 95620
(530) 760-7177

The following figure shows that in the current use status, methanol generates less CO_2 than battery electric or hydrogen. In the green scenario, renewable methanol outperforms hydrogen and matches green battery electric. This is due to the use of **CO_2** to create green methanol.

Well-to-wheel CO2 emission
from Danish Department of Energy, Alternative Drivetrains 2014

Type	Current Status	Green Scenario
Diesel	132g/km	100g/km
Gasoline	176g/km	123g/km
Hybrid	142g/km	80g/km
Battery electric	98g/km	2g/km
Hydrogen	178g/km	3g/km
Methanol	**83g/km**	**2g/km**

Source: JENSEN, Mads Friis

The green scenario indicates that renewable methanol could lead to a 98.9% reduction in CO_2 emission compared to current gasoline based transportation.

End Notes

[1] "Hydrogen Cars Lost Much of Their Support, But Why?". At: https://cleantechnica.com/2015/06/26/hydrogen-cars-lost-much-support/

[2] "Development of Hydrogen Rotary Engine Vehicle". Norihira Wakayama, Kenji Morimoto, Akihiro Kashiwagi, Tomoaki Saito. Mazda Motor Corporation. At: https://www.cder.dz/A2H2/Medias/Download/Proc%20PDF/PARALLEL%20SESSIONS/%5BS22%5D%20Internal%20Combustion%20Engines/13-06-06/169.pdf

[3] "Hydrogen Storage". At: https://www.energy.gov/eere/fuelcells/hydrogen-storage

[4] "California ISO Impacts of Renewable Energy on Grid Operations". At : https://caiso.com/documents/curtailmentfastfacts.pdf

[5] "Beyond Oil and Gas: The Methanol Economy." By George A. Olah, Nobel Prize Winner in Chemistry ISBN 3-527-31275-7

[6] "Flammability and Toxicity Trade-Offs with Methanol Fuels" By Paul Machiete SAE. Technical paper 872064 (1987)

[7] "Methanol: "Clean Burning High Octane from Non-Petroleum Energy". Methanol Institute. At: www.methanol.org

[8] "Rotapower® Engine Comparison" at: https://freedom-motors.com/freedom_rotapower.html.

[9] "Coal-derived alternative fuels for vehicle use in China: A review". By Hao, Han, Liu, Zongwei, Zhao, Fuquan, Du, Jiuyu, Chen, Yisong. *Journal of cleaner production*. September 2017.