Solar-Hydrogen Fuel Cells

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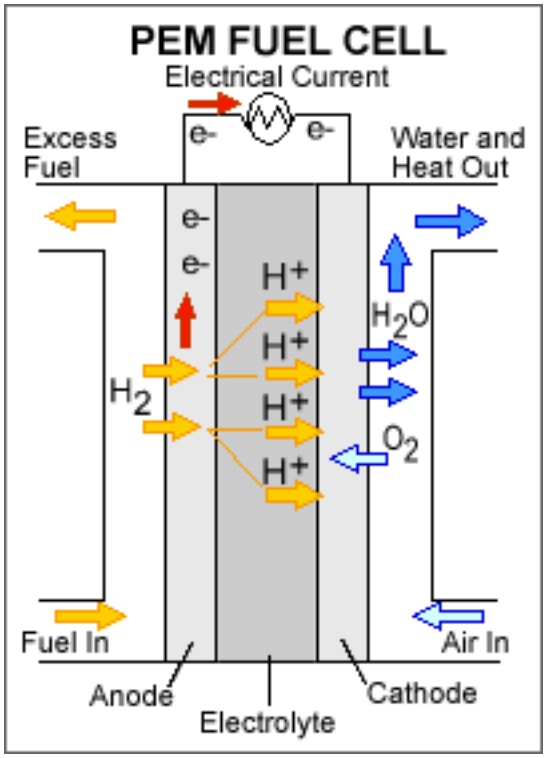
Overview

- Hydrogen Fuel Cells
- Hydrogen Generation
- Solar-Hydrogen Generation
- Hybrid PV/Fuel Cell
- Limitations

Hydrogen Fuel Cells

- Converts hydrogen and oxygen into electricity, heat, and water
- Produces near zero emissions
- Zero moving parts
- Constant efficiency regardless of size
- Does not degrade over time

Hydrogen Fuel Cell cycle



Proton Exchange-Membrane

- Cathode Reaction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
- Anode Reaction: $2H_2 \rightarrow 4H^+ + 4e^-$
- Output: $2H_2 + O_2 \rightarrow H_2O$ | $E°_{Max} \cong 1.3V$

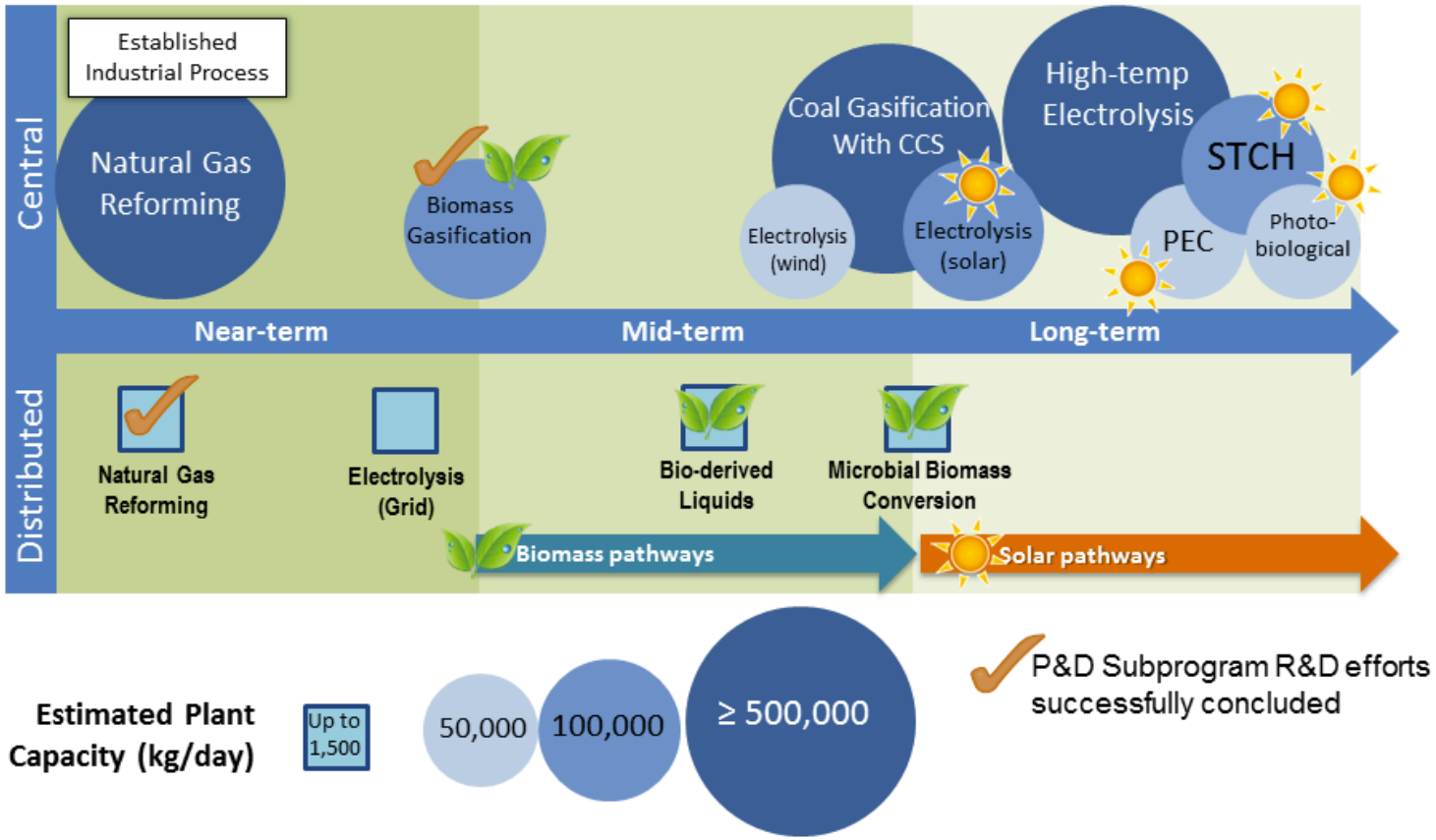
- Efficacy of 40%-60%
- Fuel Cells are stacked in series to generate usable voltages
- Operating temperature 80°C

http://energy.gov/eere/fuelcells/types-fuel-cells

Hydrogen Generation

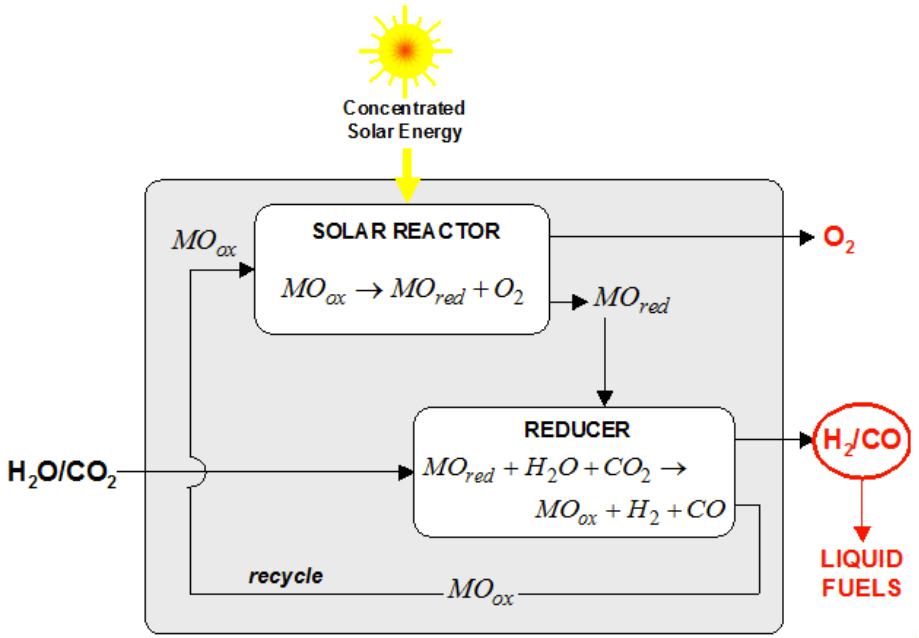
- Natural Gas
  - Steam methane reforming accounts for 95% of hydrogen used in US.
- Gasification
  - Conversion of coal or biomass into gaseous components through heat and pressure.
- Electrolysis
  - Using electrical current to split water into hydrogen and oxygen.

Hydrogen Production Pathway



http://energy.gov/eere/fuelcells/hydrogen-production

Thermochemical Water Splitting



MO denotes a Metal Oxide
Iron, Zinc, and Copper are popular choices

High Temperature (500°-2,000°C)

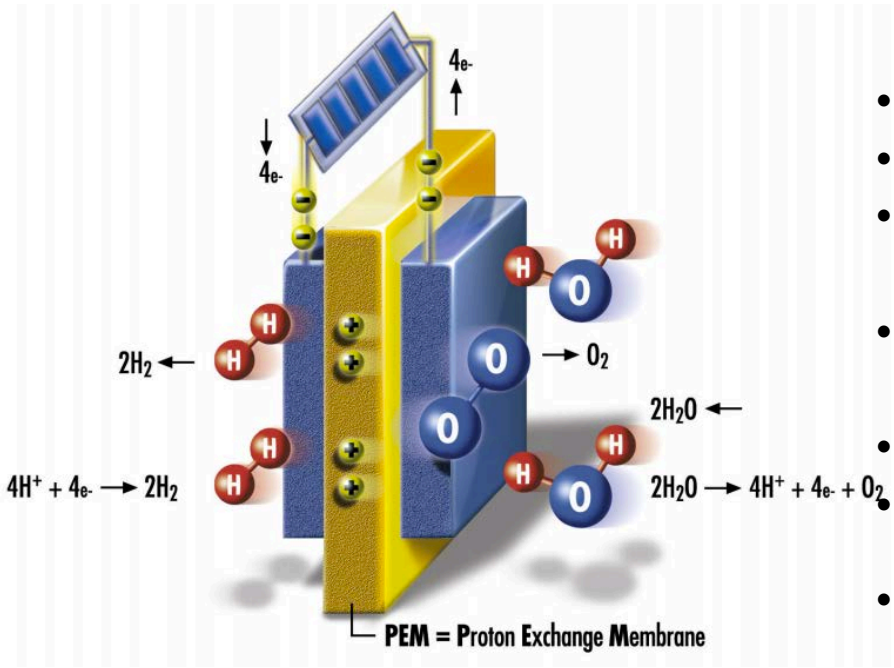
Two-step process:

- Endothermic reduction of a metal oxide to release oxygen
- Exothermic reaction of water with metal to increase the oxidation state of the metal and release hydrogen.

- Requires large, permanent installation of mirrors pointing to a collecting tower

http://www.pre.ethz.ch/research/projects/?id=solarjet

PEM Electrolyzer



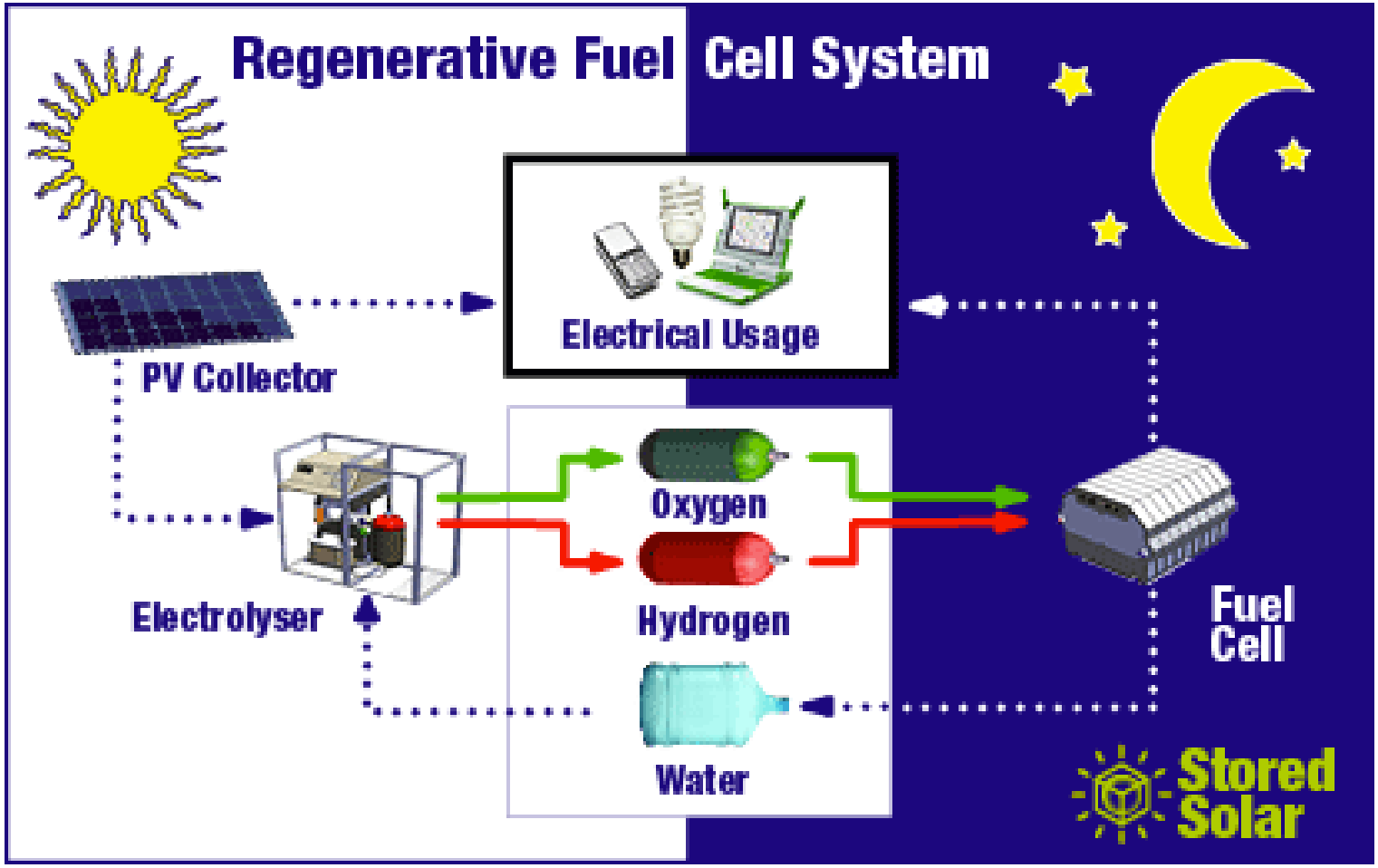
- Similar to a PEM Fuel Cell in reverse
- DC voltage is applied two electrodes
- Decomposition voltage of water 1.23V
- Efficiency of ~85%

- Cathode: $4H^+ + 4e^- \rightarrow 2H_2$
- Anode: $2H_2O \rightarrow 4H^+ + 4e^- + O_2$

- Can be implemented at small scale levels, such as on a house
- Limited by efficiency of Photovoltaic cells

http://www.h-tec.com/fileadmin/content/edu/Lehrmaterialien/Transparencies.pdf

PV-Fuel Cell System



http://www.storedsolar.com/electrolysers.html

Limitations

- Hydrogen generation is currently expensive to produce
- Most hydrogen production is currently made through non-renewable processes
- Difficult to store
- Compressed hydrogen is very combustible
- Current plant to wheel efficiency is ~22%

References

http://energy.gov/eere/fuelcells/

https://extranet.kenan-flagler.unc.edu/kicse/ORIG%20Shared%20Documents/Solar%20Powered%20Hydrogen%20Fuel%20Cells.pdf

http://www.pre.ethz.ch/research/projects/?id=solarjet

http://www.h-tec.com/fileadmin/content/edu/Lehrmaterialien/Transparencies.pdf

http://www.storedsolar.com/electrolysers.html