

Hydrogen as an Emerging Fuel

Energy Carrier of the Future?

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Presentation to: Minnesota Legislative Energy Commission

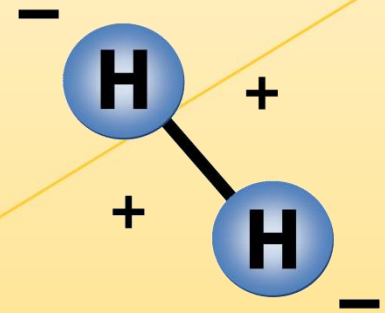
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UNIVERSITY OF MINNESOTA

Hydrogen Basics

- Most abundant atom on earth
- Colorless odorless gas
- **H₂ is an energy carrier, not a source**
 - Must be produced from H-containing source
- Can be combusted or used in a fuel cell
 - Produces only H₂O
- Must be stored at pressure or cryogenically
 - At high pressure, 10 x the power/volume of Li-Ion batteries
 - 10 x lower power/volume compared to gasoline



Hydrogen Powered Vehicles

- Automakers committed to new models in 2015
 - Toyota, Hyundai GM, Volkswagen, Honda
- Advantages:
 - Good range (250-400 miles)
 - Fast refueling
 - High efficiency (~50%)
- Disadvantages
 - Refueling Infrastructure
 - Expensive
 - Safety Questions



Toyota FCV (2015) <http://www.toyota.com/fuelcell/>



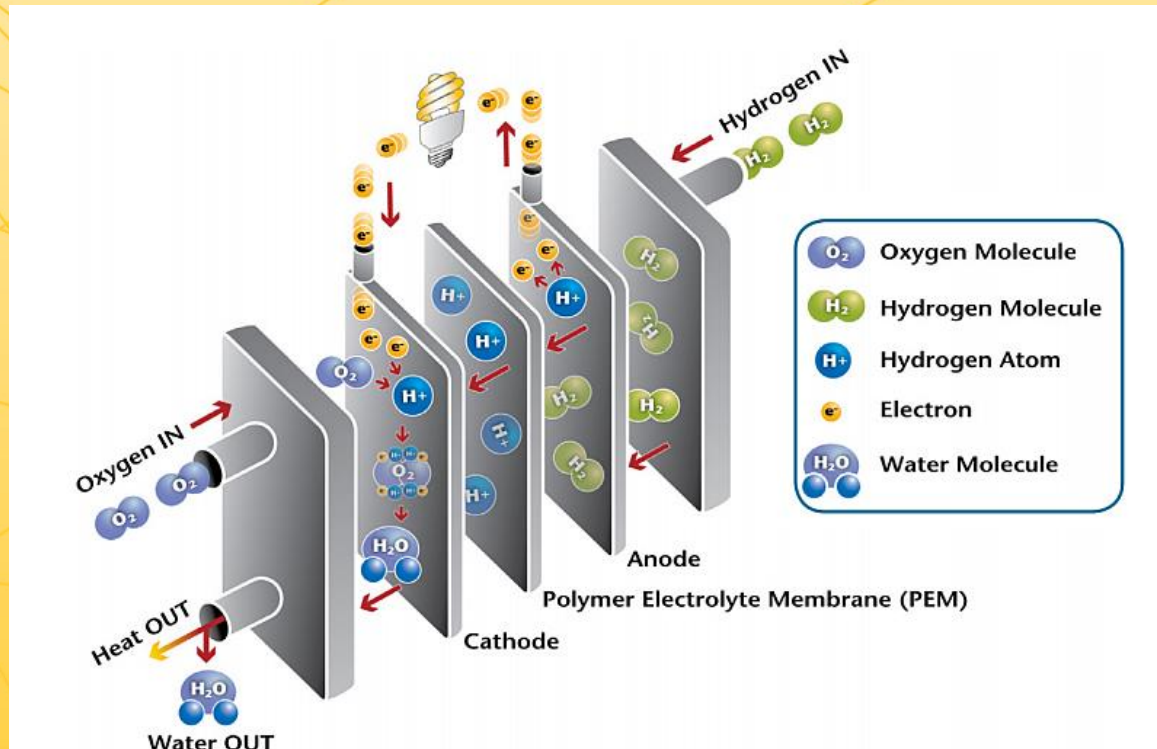
Hyundai Tucson (2015) <https://www.hyundaiusa.com/tucsonfuelcell/>

Gasoline = 25 mpg
Natural Gas H₂ = 38 mpg_{eq}
33% Renewable H₂ = 54 mpg_{eq}

<http://blog.ucsusa.org/how-clean-are-hydrogen-fuel-cell-electric-vehicles-696>

Fuel Cell Technology

- Converts H_2 and air directly to electricity
- Operates at low temperature and with high efficiency

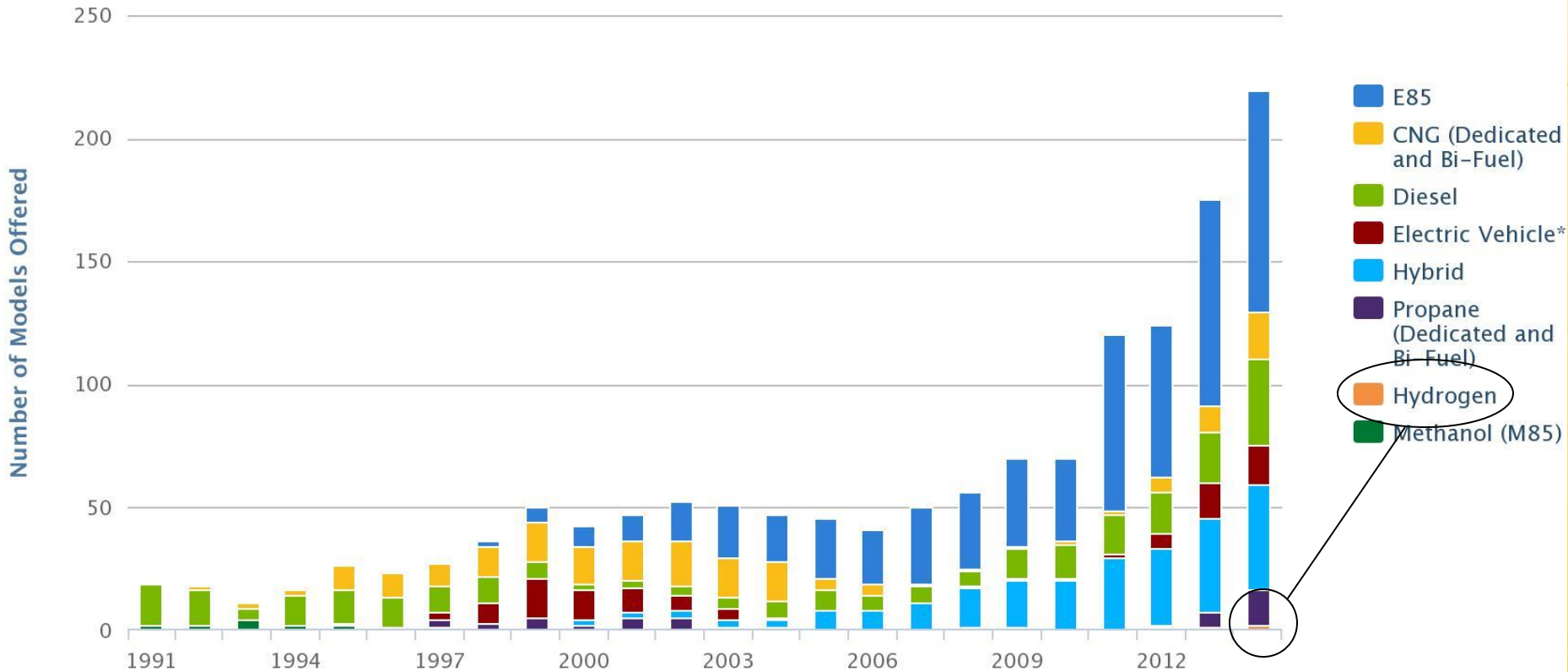


<http://energy.gov/eere/fuelcells/fuel-cells-basics>



Alternative Fuel Vehicle Fleet

Light-Duty AFV, HEV, and Diesel Model Offerings, By Fuel Type



Alternative Fuels Data Center <http://www.afdc.energy.gov/data/>

- H_2 = miniscule portion of alternative vehicle sales

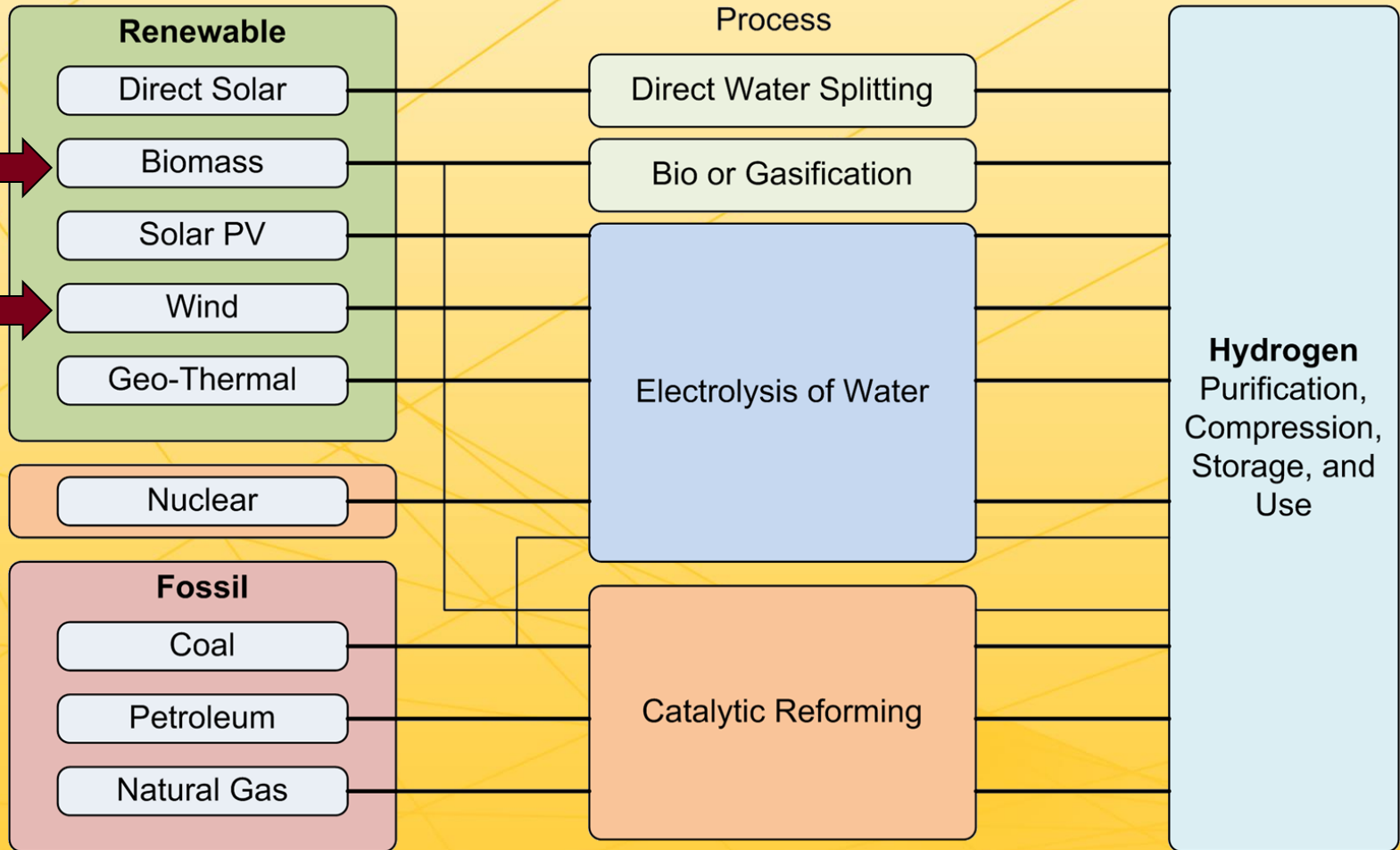
Refueling Infrastructure



Alternative Fuels Data Center <http://www.afdc.energy.gov/data/>

- Only 11 public refueling stations
- California has most of them

Hydrogen Production Pathways



Status

- Federal
 - DOE EERE Hydrogen and Fuel Cells Program
 - H2FIRST Project (April, 2014) \$2.00-\$4.00/gge
- California
 - Most aggressive state in H₂ implementation
 - CA Fuel Cell Partnership
 - 48 stations in Southern California in place by 2016
 - California Energy Commission pledged \$200 million
 - 33% of H₂ produced at state-supported stations generated from low-carbon sources (46% by 2015)
- Minnesota
 - Minnesota Renewable Hydrogen Roadmap (2010)

Hydrous Ethanol Opportunities

- Ethanol in US currently anhydrous (<1% water)
- Potential to save production energy and cost by producing hydrous EtOH
- Expand market for Minnesota biofuels
- Current projects:
 - Hydrous Ethanol in dual-fuel diesel engines
 - Quantifying energy savings gained through production of hydrous ethanol from corn
- **Proposed: Investigation of Hydrous Ethanol Reforming for Vehicular Hydrogen**
 - MN biomass resources attractive for renewable H₂



J.D. 4045 w/Hydrous EtOH



CVEC Plant, Benson, MN



Irrigator

