

Hydrogen Economy the Good, the Bad, the Ugly: the Hope and the Opportunity

Mark Johnson

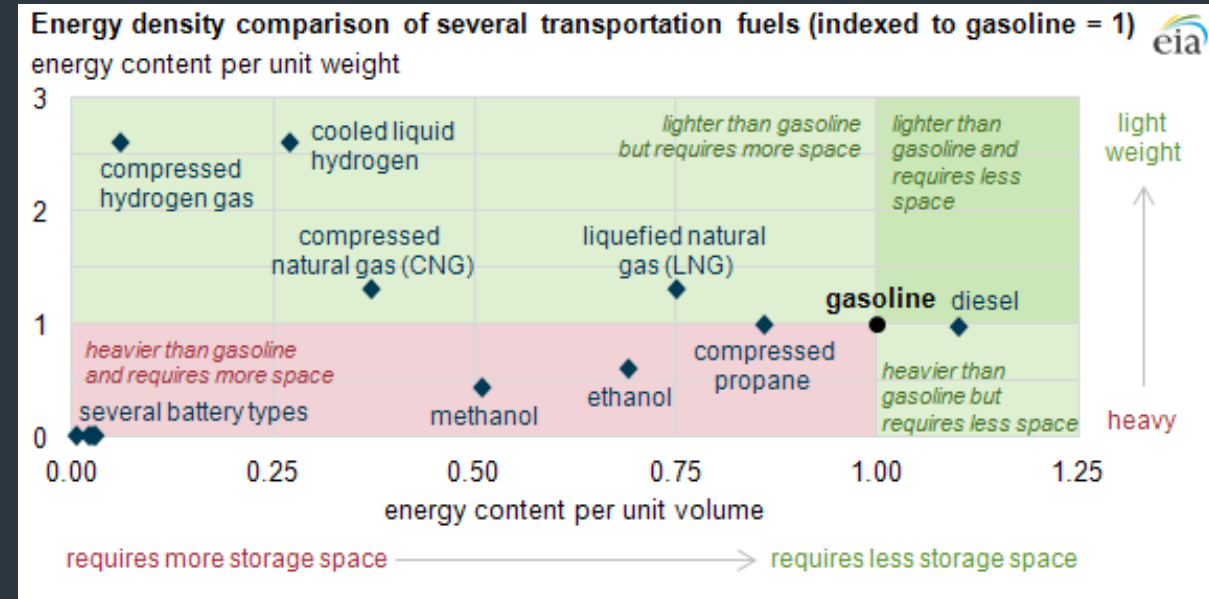
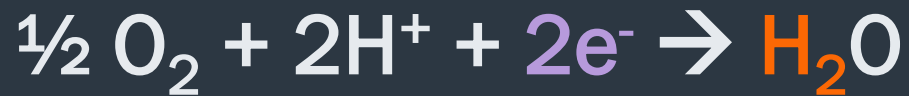
Thomas F. Hash / Smart-State Chair for Sustainable Development

Director of Clemson Center for Advanced Manufacturing

October 10, 2019



the Good: Transportation and Sustainability with Hydrogen Fuel



(1 Kilogram H₂ ~ 1 Gallon of Gasoline Equivalent)

- Tech Challenges: H₂ is a Gas (not Dense), & H₂ is 'Initially' more Expensive than Gasoline



the Bad: Cost of Existing “Clean” Hydrogen

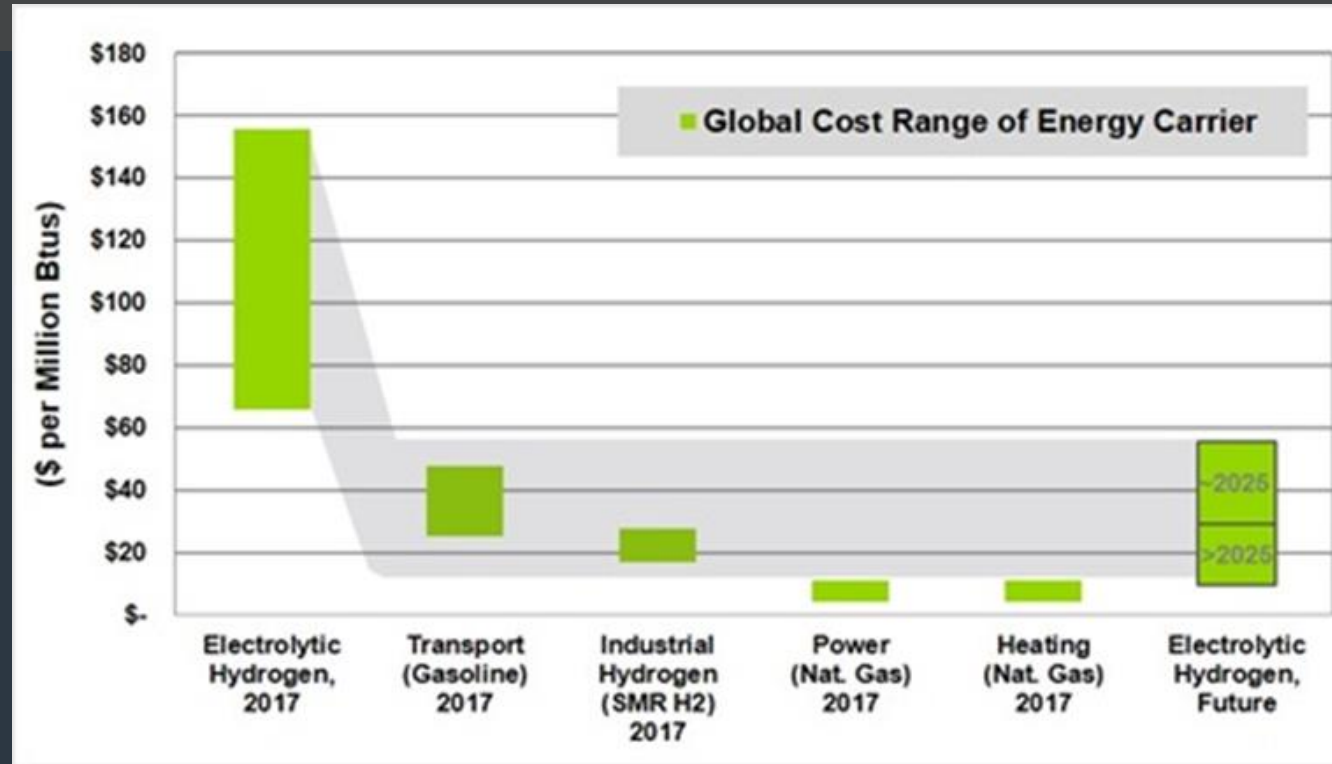
H₂ Cost: \$5 to \$20/kg

Costs

Electricity (with Renewables?)

CapEx (Installed) – 24/7

Losses – Innovation and Laws of Physics



Navigant Research (2017)



the Ugly: Current Production of Hydrogen

- Annual US:
 - 9.7 Billion Kg (9.7 million tonne)
 - \$19.4B @ ~ \$2/kg
- 60% Captive (v Merchant)
- 68% for Petroleum Refining
- Steam Methane Reforming:
Methane + Water →
Carbon Monoxide + Hydrogen



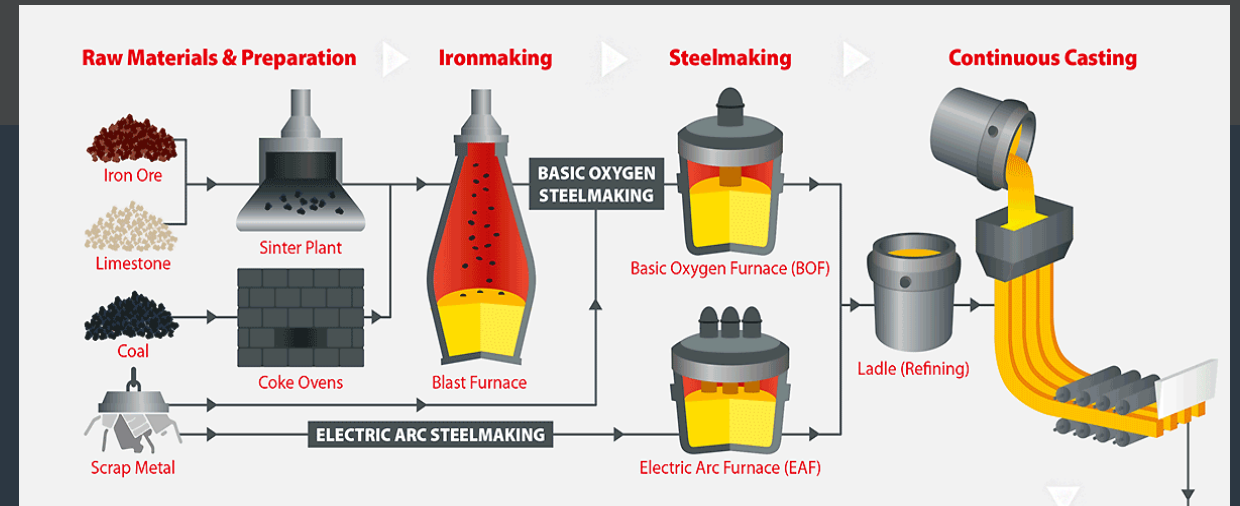
Caloric (2019)



a Hope: Hydrogen and Steelmaking

- US (2014): 29M Tonnes Pig-Iron & 88M Tonnes Steel (Balance includes scrap)

- Iron Ore to Pig-Iron Chemistry:



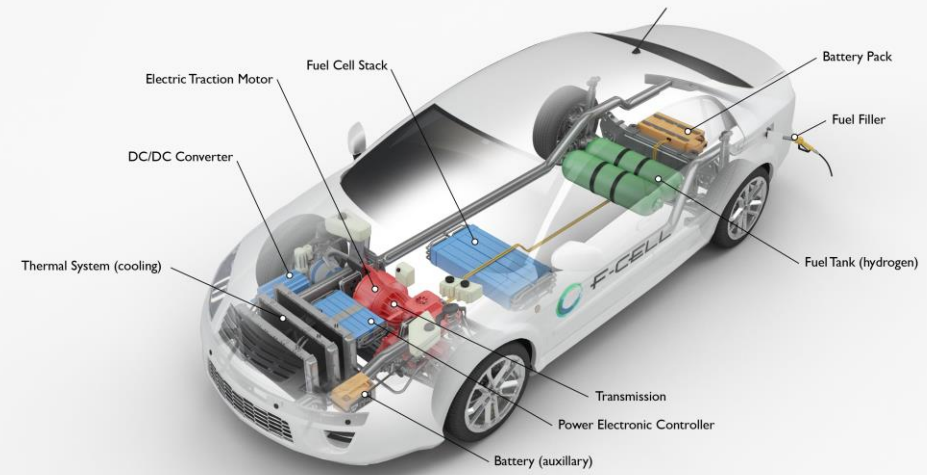
- 29M Tonne Pig Iron requires 0.8M Tonne H₂ (.027 Tonne-H₂/Tonne-Fe) AISI (2015)
- \$ 9.6/kg H₂ maximum theoretically allowed per Tonne Pig-Iron ‘for Breakeven’
 - at \$400 per Tonne Pig Iron less \$140 per Tonne Iron-Ore
 - assume only costs are materials and 100% theoretical use efficiency
- If US Steelmaking (pig-Iron) 100% H₂-based:
 - 8% Increase in H₂ Industrial Demand above 9.8M Tonnes Currently Used



an Opportunity: Focus on Making Electrified Transport

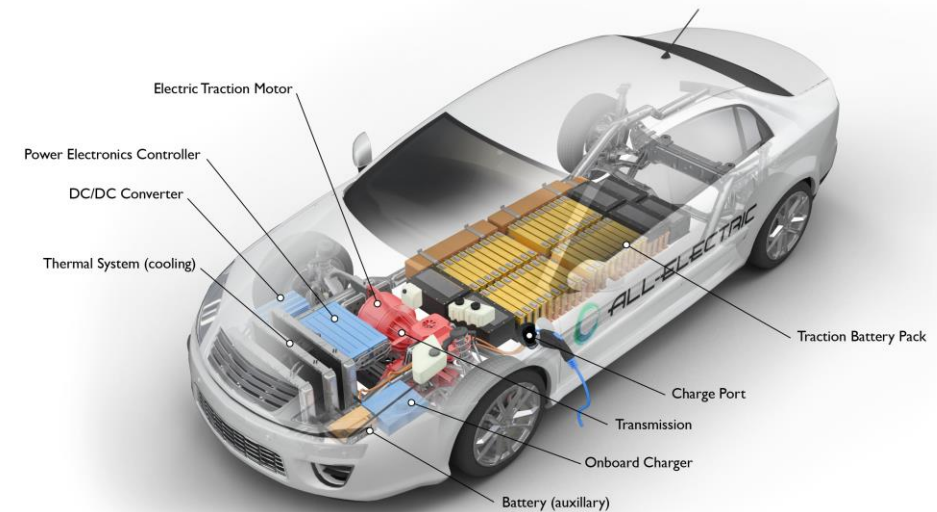
- Make the Shared Elements (New wrt ICE):
 - Electric Traction
 - Power Electronics
 - Ancillary: Thermal, Safety
- Manufacturing Supply-Chains:
= Economic Strength
- South Carolina & I-85 Corridor:
 - Vehicle Manufacturing
 - Hydrogen Expertise
 - Electric Motors and Electronics

Hydrogen Fuel Cell Electric Vehicle



afdc.energy.gov

All-Electric Vehicle



afdc.energy.gov

DOE/EERE (2015)

