

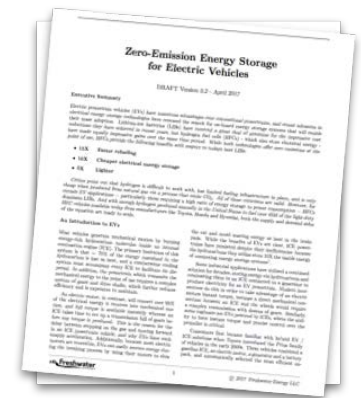
# Zero-Emission Energy Storage for Electric Vehicles

*Zach Jones, Freshwater Energy*

DOE Electrical Energy Storage and Applications Conference  
October 11<sup>th</sup>, 2017 | San Diego, CA

# Background

- Work for a small private equity firm in SF
  - Freshwater is our clean energy investment vehicle
- Thesis: electric powertrains will proliferate due to their many advantages over internal combustion engine powertrains, but electrical energy storage remains challenging
  - Lithium ion battery mfg. too big for us
  - Can we find opportunities in hydrogen?
    - Drafted paper and submitted to EESAT



# Hydrogen Fuel Cell Media Coverage:

“...a total scam”

“...a very silly idea”

“...a big-oil conspiracy”

“...the perpetual technology of the future”

“...so bullsh\*t”

- So why is hydrogen worth looking at?

# ZEV Electrical Energy Storage

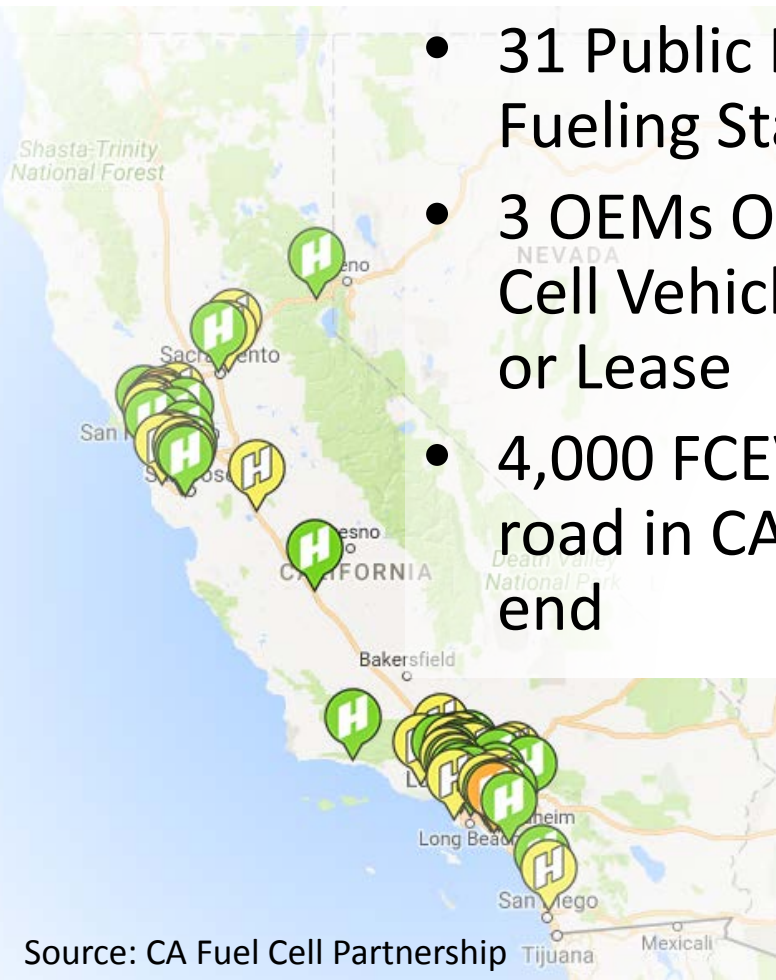
With respect to today's best Lithium Ion Battery (LIB) technology, Hydrogen Fuel Cells (HFCs) offer the following advantages:

**15X** Faster refueling

**10X** Cheaper electrical energy storage

**5X** Lighter

# Light Duty Vehicles



- 31 Public Hydrogen Fueling Stations in CA
- 3 OEMs Offering Fuel Cell Vehicles for Sale or Lease
- 4,000 FCEVs on the road in CA by years end



Source: CA Fuel Cell Partnership

# Industrial Vehicles

- Over 16,000 hydrogen fuel cell forklifts deployed at companies like Walmart and Amazon
- For the two years ended May 2017:
  - 4,000,000 kg of H2 dispensed
  - 6,500,000 H2 fills



Source: Plug Power Q2 2017 Investor Letter

Cumulative GenDrive Deployments



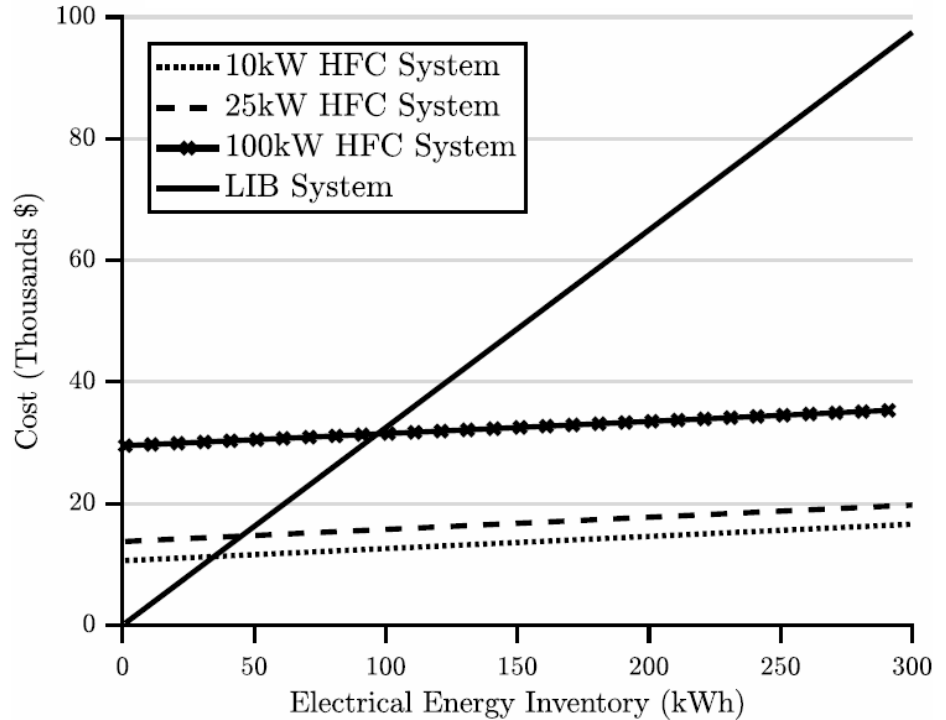
# 15X Faster

- HFC charge rate = **1500 kW**
  - 5kg of H<sub>2</sub> in 3.6 min @ 18kWh / kg H<sub>2</sub>
- 15X throughput of a 100kW DC Fast Charger at full utilization
  - 31 stations x 15 = 465 DC Fast Charger Equivalents
  - Currently 543 DC Fast Chargers in CA\*
- Critical for asset utilization in industrial applications
- Critical for consumers who will not be able to access dedicated home charging for their light duty vehicles (44% of CA drivers\*)

\*Sources: CA Hydrogen Business Council Conference, Sep 25 & 26<sup>th</sup> 2017

# 10X Cheaper

- High pressure gaseous H<sub>2</sub> storage cost = **\$28.59 / kWh**
  - 450L 8,000 PSI Cylinder; 15kg of H<sub>2</sub> at 18kWh / kg H<sub>2</sub>; 2016 market price= \$7,750
- For **high energy to power ratios**, dramatically cheaper storage offsets the cost of the fuel cell required to convert H<sub>2</sub> to electricity.

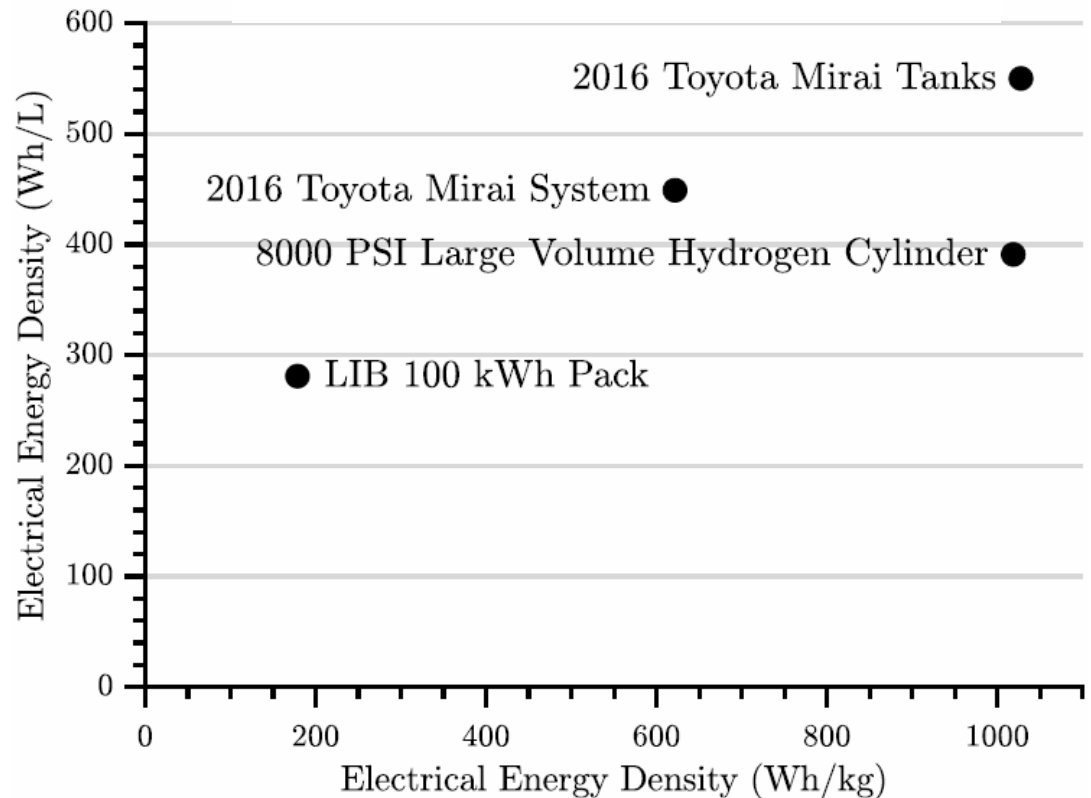


- For stationary applications, where energy density is less important, low pressure steel tanks are even cheaper on a \$ / kWh basis

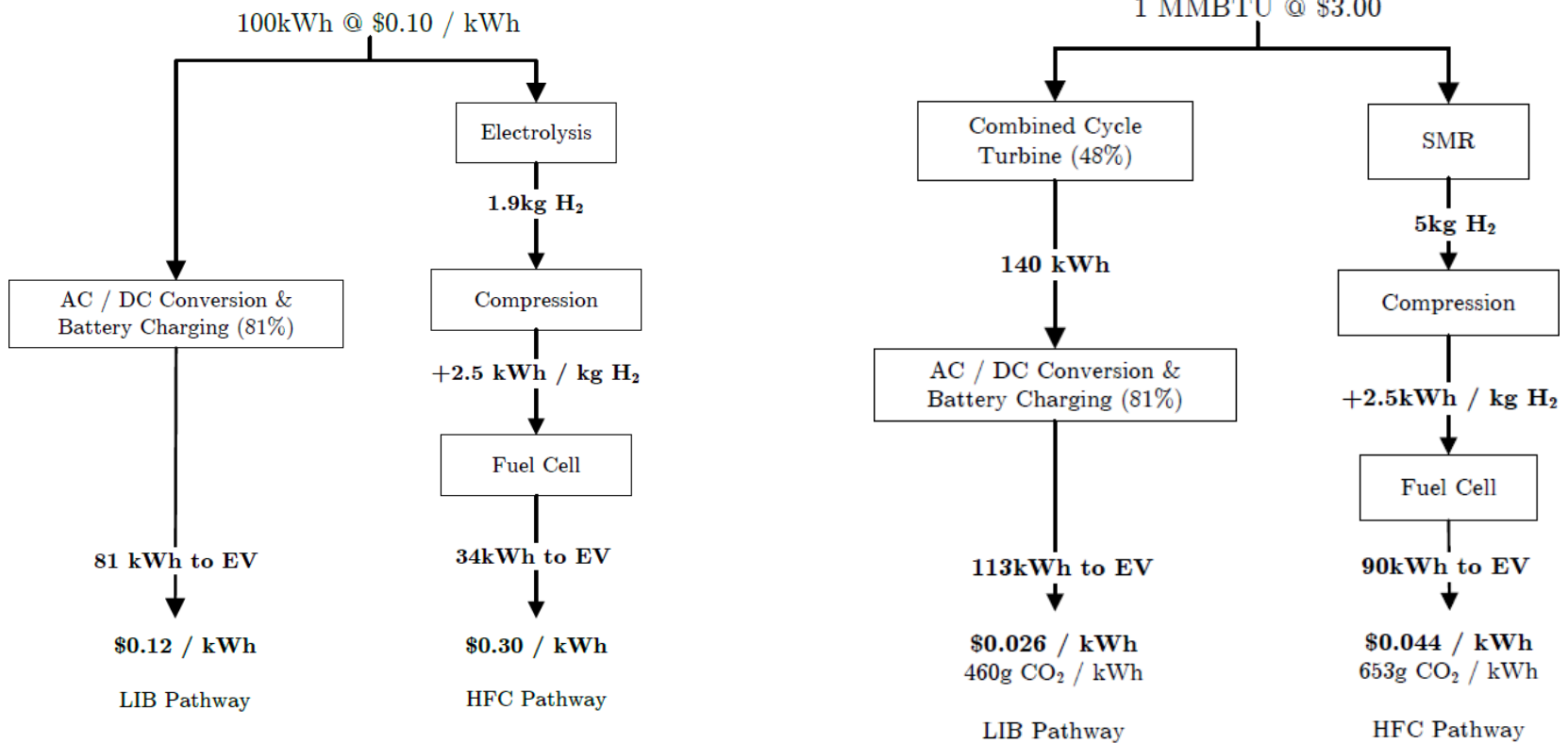


# 5X Lighter

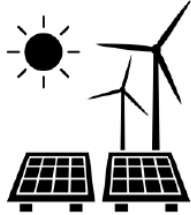
- Critical for weight-constrained goods transport applications
- For light duty vehicles, additional battery mass reduces efficiency by 6-12% for every mile the vehicle ever drives
- Critical for aerospace applications (drones, etc)



# Feedstock-to-Wheels Efficiency



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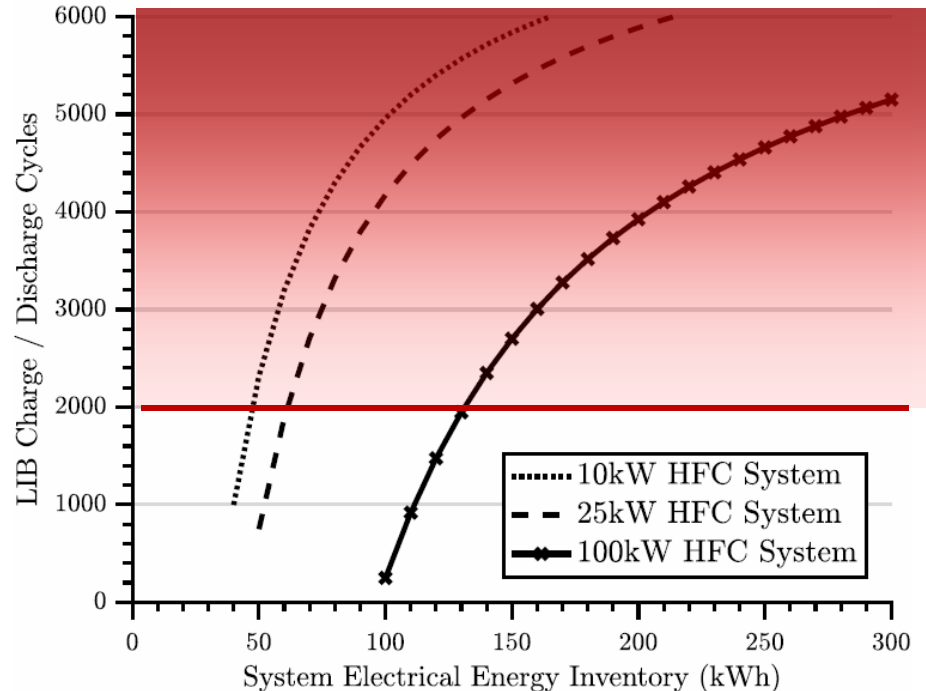


LIB pathway is 2.5X  
more efficient than an  
HFC pathway

LIB pathway is 1.7X  
more efficient than an  
HFC pathway

# ...but energy efficiency doesn't drive economics

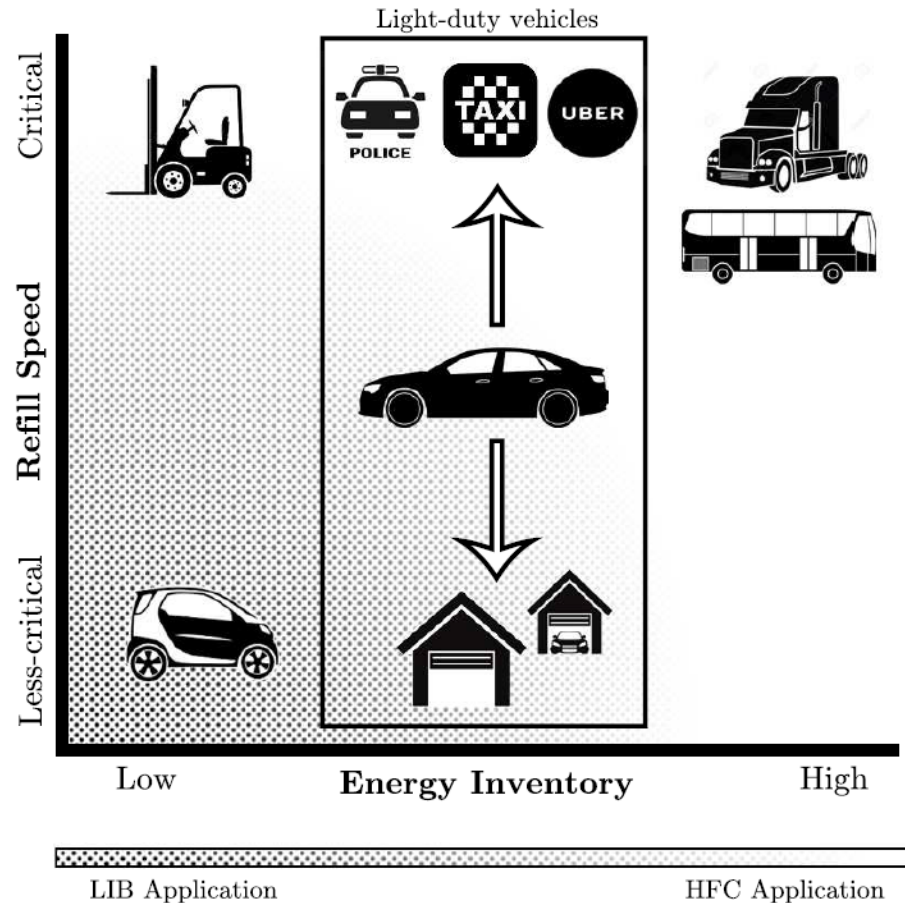
1. For large inventories of energy, LIBs will exceed their cycle lifetimes before their higher efficiency breaks even with HFCs lower cost of storage
2. As the price of renewable electricity drops, **efficiency becomes even less important**
  - In March of 2017 the CAISO curtailed 80 GWh of renewables
  - Enough energy to power 100,000 HFC vehicles for a month!



HFC to LIB Energy Cost Ratio = 1.7 to 1

# Conclusions

- HFC energy pathways are **less efficient** than LIBs.
- ... but it is the **efficiency of the overall energy storage system**, as measured in time and capital, that will govern the selection of an energy storage technology.
- Based on the 15X, 10X, 5X value propositions discussed, HFCs have strong advantages in certain applications.



# Thank you!

- Full paper available for download at [www.freshwaterenergy.com](http://www.freshwaterenergy.com)
- My email: zach.jones@freshwaterenergy.com