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Hydrogen vs Electricity

M. Weeda

Presented at the 6th Sustainable Hydrogen Symposium, 4-5 November 2009, De Reehorst, Ede

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Marcel Weeda, ECN

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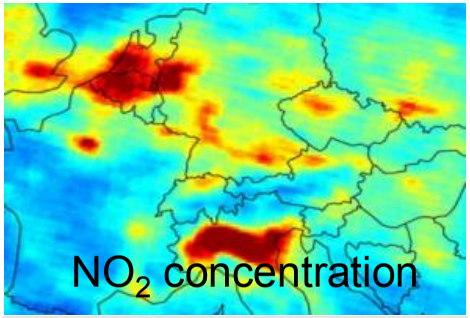
Hydrogen vs Electricity?

- Scope: light duty vehicles
  - Passenger cars
  - Vans
  - Small trucks
  - Busses

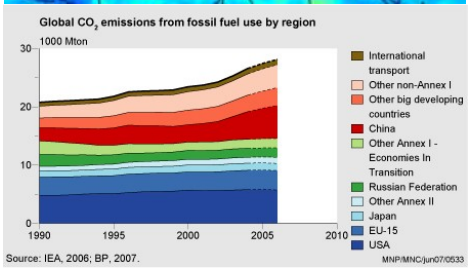
- … should be *Hydrogen Fuel Cells* vs *Batteries*
  - Both enable electric vehicles
  - Electric vehicles are vehicles driven by an electric motor

- There is no ‘Silver Bullet’

Similarities Hydrogen Fuel Cells and Batteries



+ Enable zero emission vehicles (locally)
+ Offer prospects for CO_2-lean/free mobility
+ Reduce dependence on oil



− Still too expensive
− Insufficient durability
− No refill/recharge infrastructure available for large-scale roll-out

! As clean as primary energy mix to produce energy carrier

Favourable attributes Hydrogen Fuel Cells

- Vehicle range
  - Higher specific energy (kWh/kg)
  - Applicability in vehicle segments

- Time needed to get energy on-board
  - Minutes, not hours
  - Fast charging, battery swap?

- Energy delivery infrastructure
  - Resembles current situation
  - Decoupling production and demand
  - Easy build-up capacity

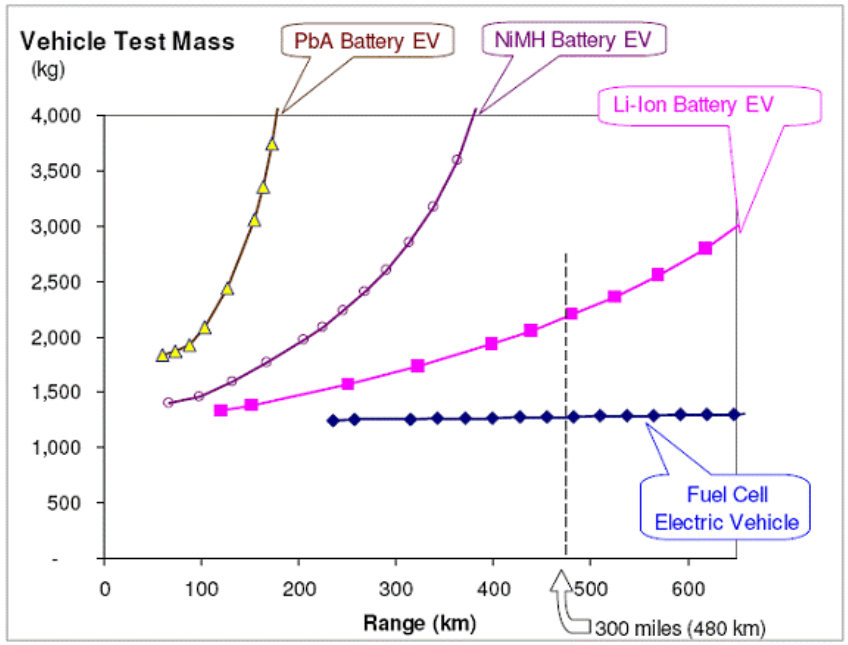
Vehicle range – Specific energy, storage

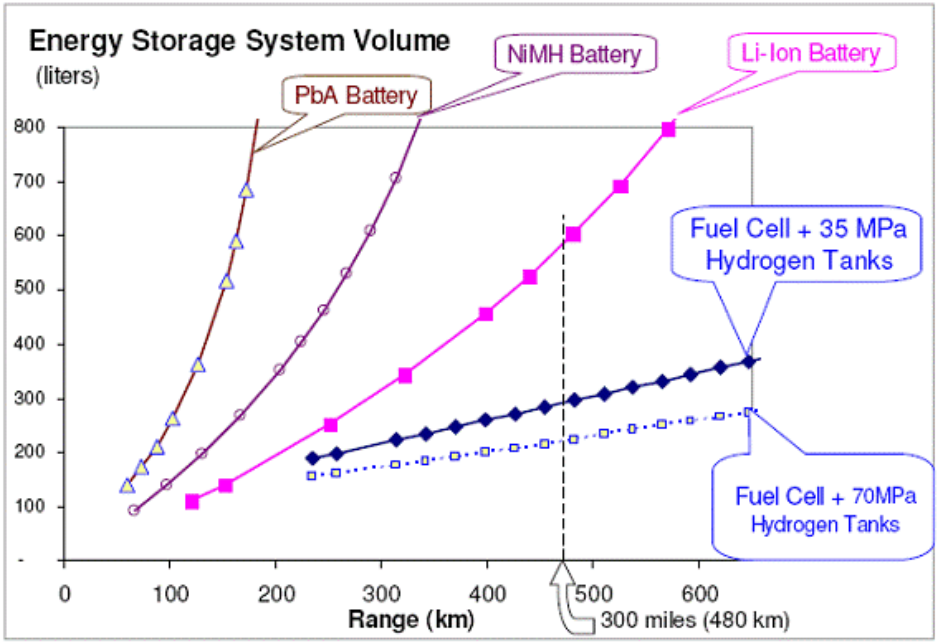
Energy carrier	Energy density (kWh/kg)
Diesel	11.9
Gasoline	12.0
Lead-acid battery	0.04
Ni-MH battery (e.g. Prius)	0.07
Li-cobalt-ion battery (e.g. Tesla)	0.11
$LiFePO_4$-ion battery (State-of-the-art traction)	0.13
Li-ion batteries in portable electronics (target traction)	0.20
Hydrogen in on board storage system (State-of-the-art)	1.7 *)
Hydrogen in on board storage system (target)	3.0

*) ~0.9 kWh/kg including fuel cell system

Vehicle range - Fair comparison

- Equal car type
- Equal performance





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Comparing equivalent battery and FC/H_2 car

BYD-E6

Honda FCX Clarity

l x w x h (m)	4.55 x 1.82 x 1.63		4,83 x 1,85 x 1,47 (m)
Curb weight (kg)	2100	⟷	1620
Max. power (kW)	115-200		100
Max. speed (km/h)	160		160
Range (km)	>300 [1)]		430 [2)]
Energy storage: type kWh	Li-ion battery pack >60		Hydrogen @ 350 bar 136 (4.1 kg H_2)
Refill time: home fast	>20 hours 50% in 10 min.	⟷	- 2-3 min.

[1)] Even statements of 400 km; Details about conditions n/a

[2)] Combined EPA cycle: avg. speed 48 km/h

Different technology – different markets

Mitsubishi i-MiEV

Honda FCX Clarity

l x w x h (m)	3.40 x 1.48 x 1.60	4,83 x 1,85 x 1,47 (m)
Curb weight (kg)	1080	1620
Max. power (kW)	47	100
Max. speed (km/h)	130	160
Range (km)	160 [1)]	430 [2)]
Energy storage: type kWh	Li-ion battery pack 16	Hydrogen @ 350 bar 136 (4.1 kg H_2)
Refill time: home fast	6-7 hours 80% in 30 min.	- <5 min.

[1)] Japanese 10-15 cycle: avg. speed 24 km/h

[2)] Combined EPA cycle: avg. speed 48 km/h

Energy delivery infrastructure

- Current fuel consumption and fuel dispensing
  - 1 liter for 15-20 km
  - 40 liter/min

  } 600-800 km range/min

- Current fuel dispensing and energy content
  - 40 liter/min
  - 10 kWh/l

  } 400 kWh/min

- Current energy content and power
  - 400 kWh/min
  - 60 min/h

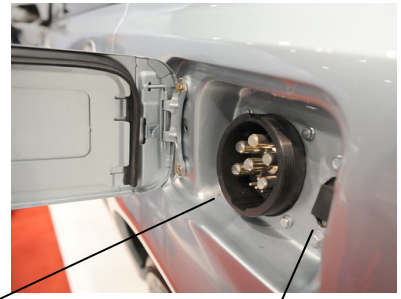
  } 24000 kW = 24 MW !!!

Hydrogen vs Electricity delivery

- Power needed for fast charging?
  - Driving range 100-150 km: → **4 MW**
  - Energy consumption only 33%: → **1.3 MW**
  - Refilling time 10 min: → **130 kW**

- Fast charging only partial recharging, so not instead but on top of slow recharging – 2 infrastructures

- Hydrogen refuelling at conventional retail station: 1 infrastructure similar to current situation



Power plug for fast recharge

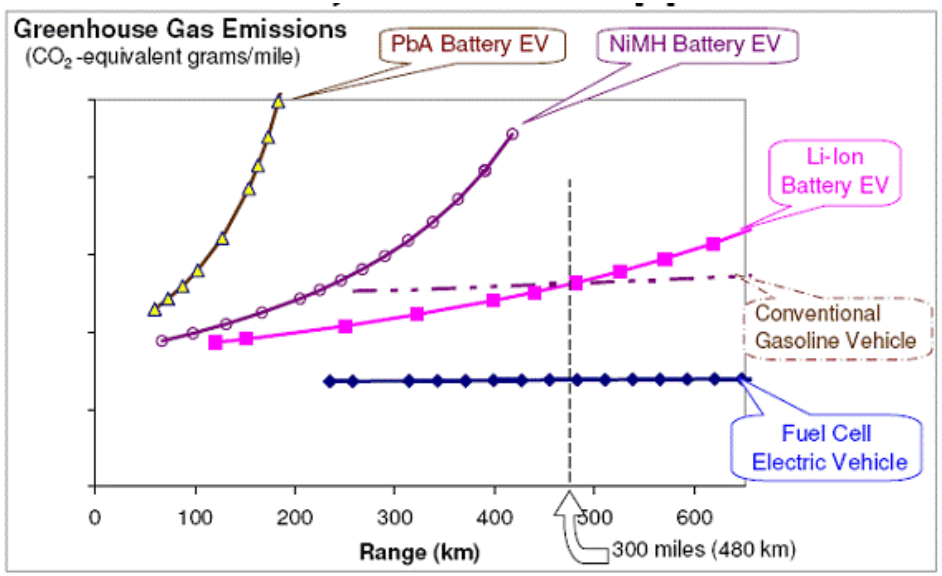
Power plug for slow recharge

Points of discussion Hydrogen Fuel Cells

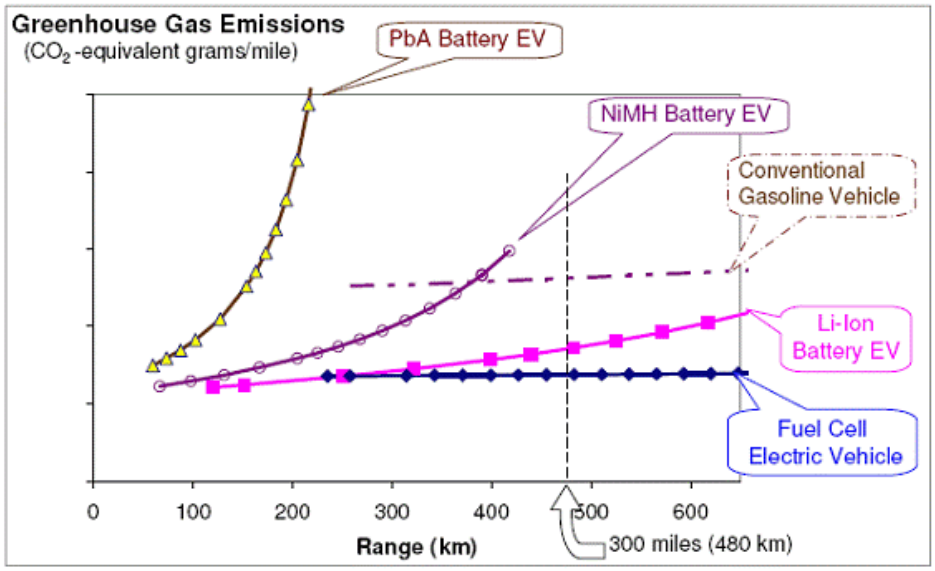
- Well-to-Wheels energy use
  - Comparable to current energy use
  - Type of energy, not the amount is the problem

- Short term CO_2-emissions
  - No simple answer
  - Marginal grid mix vs H_2 from natural gas

GHG emission reduction



Grid mix: US
Hydrogen from natural gas



Grid mix: California

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- Controlled overnight recharging may favour baseload power !!

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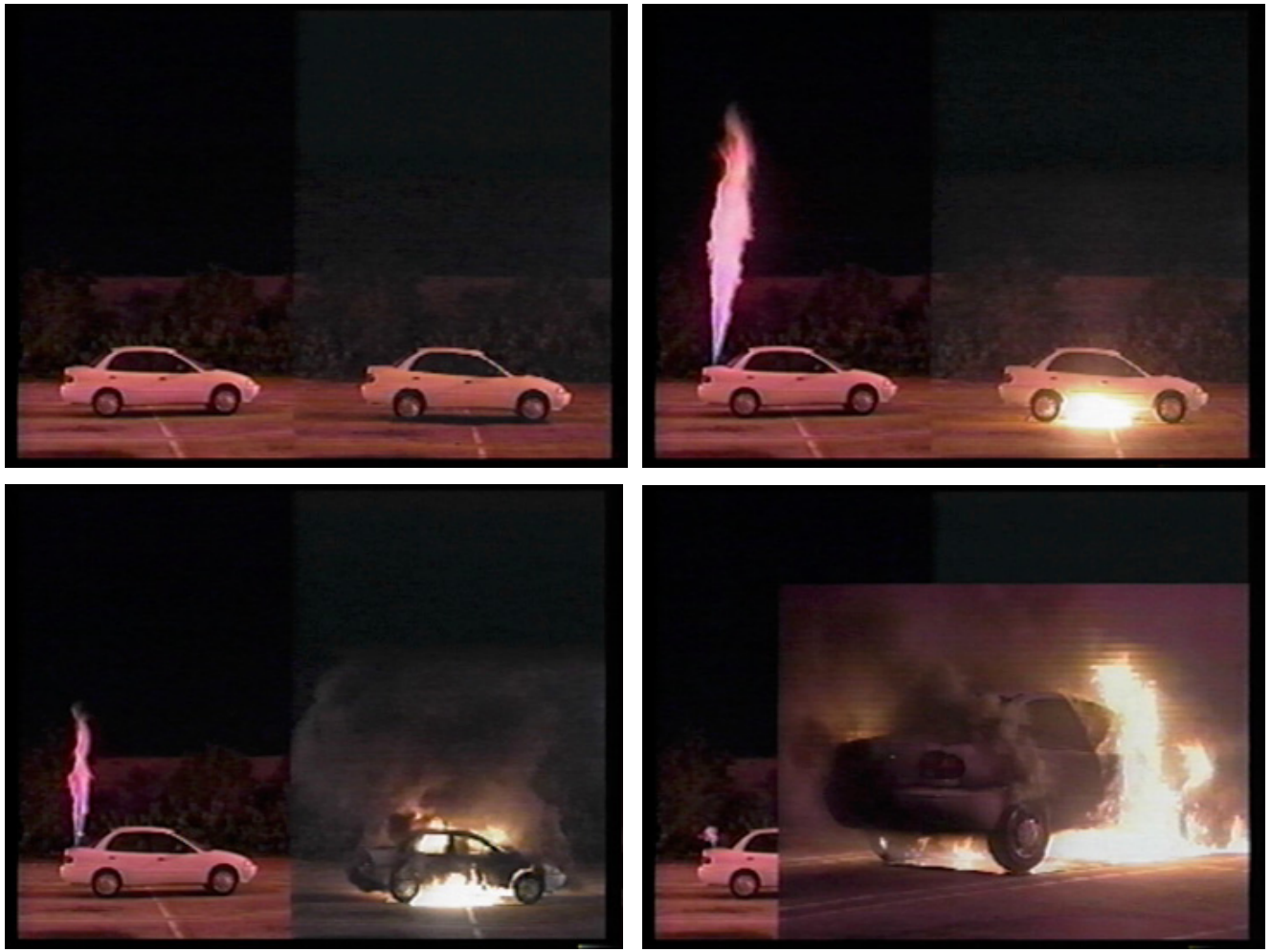
- Safety
  - Issue, but not a problem (technically)
  - Perception may be a problem

Safety



M.R. Swain, Univ. of Miami (2003)

Summary / Conclusions …

Hydrogen Fuel Cells	Batteries
All car segments	Only small cars
Range > 400 km possible	Limited range (100-200 km)
Refuelling time < 5 min.	Recharging time hours
Refuelling stations	Whole grid upgrade & control

- Revolution needed, but public only accepts evolution
- Hydrogen Fuel Cells combine best of both worlds:
  - Advantages of electric cars
  - User characteristics of today's cars
  - Refuelling resembles today's habits, procedures, logistics

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Thank you for your attention

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