Emission Impossible

A sustainable energy system with batteries, hydrogen and fuel cells



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May 26, 2021







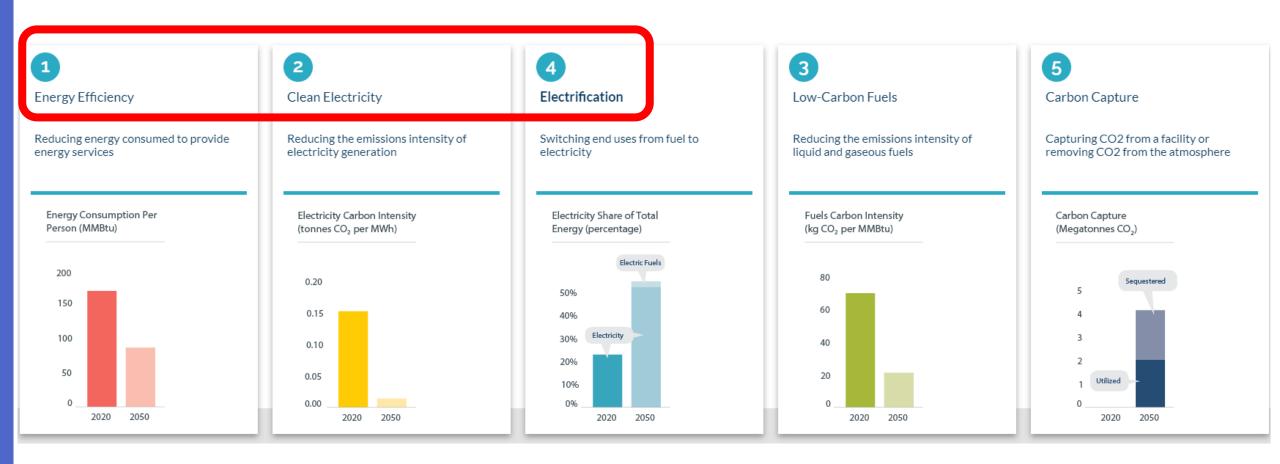




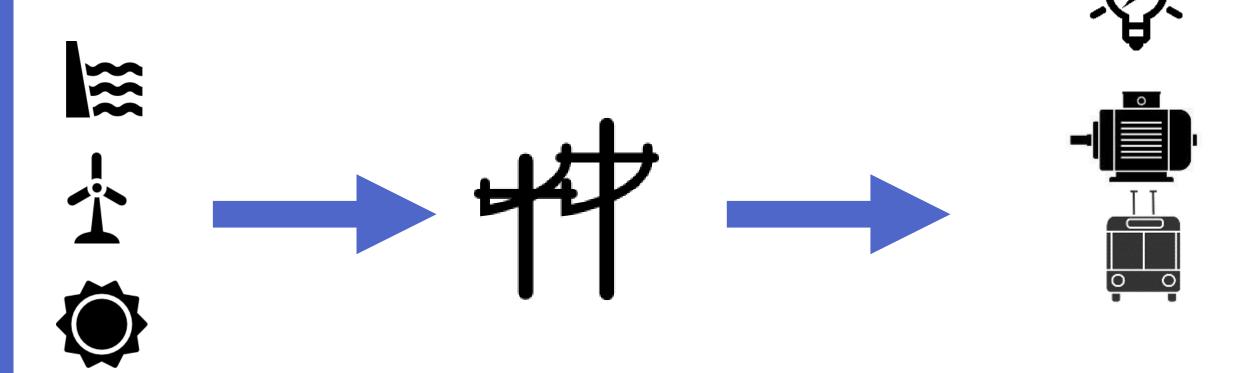




Key decarbonization strategies



The flow of (renewable) electrical energy,



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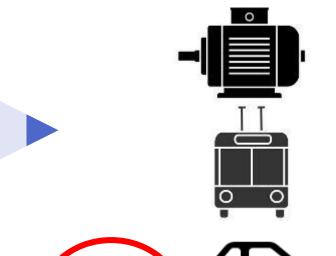








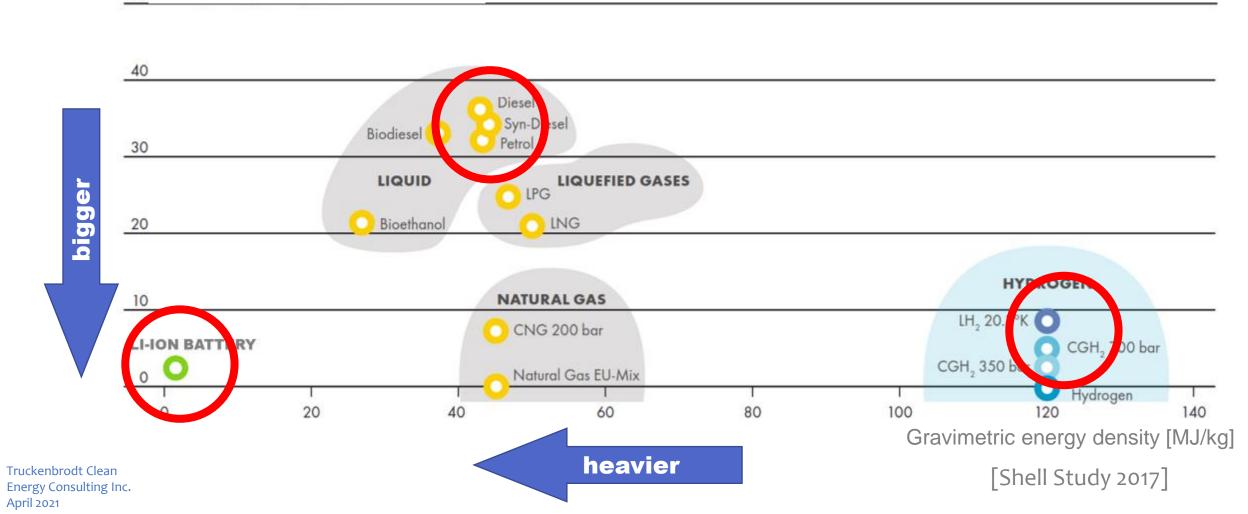
We need energy storage and an energy carrier!

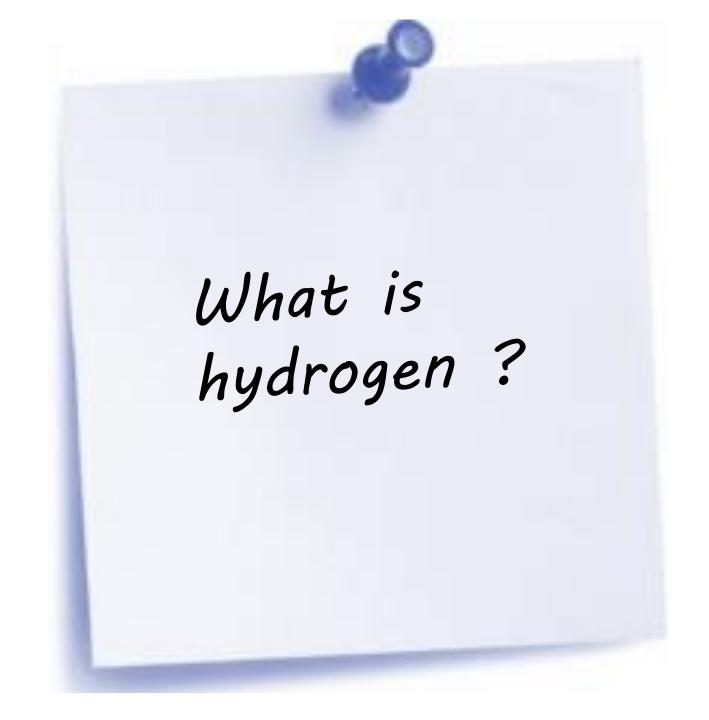


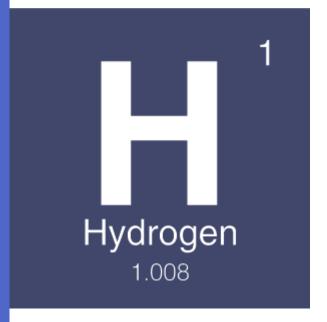
Weight and volume of energy storage/carriers

13 ENERGY DENSITY OF FUELS

50 Volumetric energy density [MJ/ltr]









Lightest and simplest chemical element consisting of only one proton and one electron



Makes up 2/3 of all molecules on our planet that represents = 75% of the mass of the universe



Hydrogen is a gas at room temperature but changes to a liquid at a temperature of -252.8 °C



It contains up to 3 times more energy per unit mass than diesel

Hydrogen production

Natural gas, Methane (Oil, coal)

CH₄



"steam reforming"



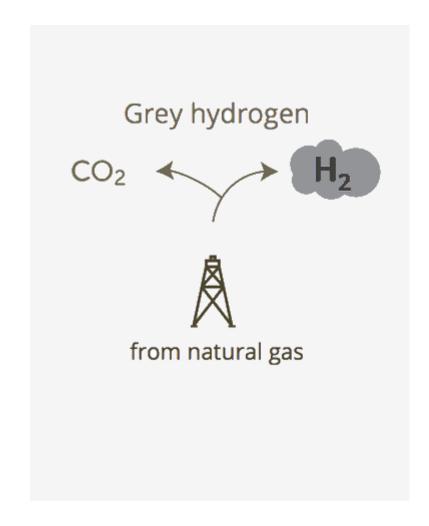


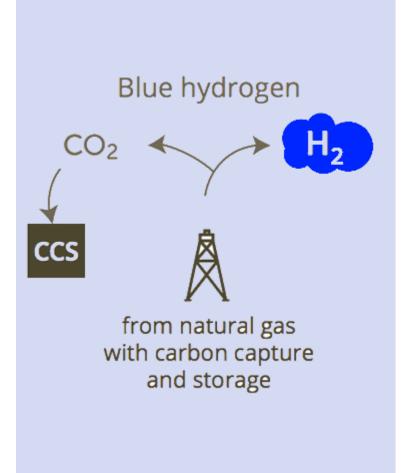


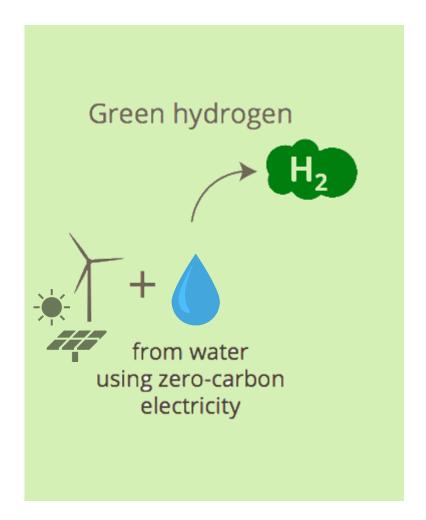
$$\frac{\text{H2O}}{\text{H2}}$$
 (+ electricity) -> $\frac{\text{H2}}{\text{H2}}$ + $\frac{1}{2}$ O2

"electrolysis"

The colours of hydrogen









Fuel cell = pile à combustible

H2 combustion vs fuel cell

combustion: "burning the fuel"

fuel cell: "chemical reaction"

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2 O$$

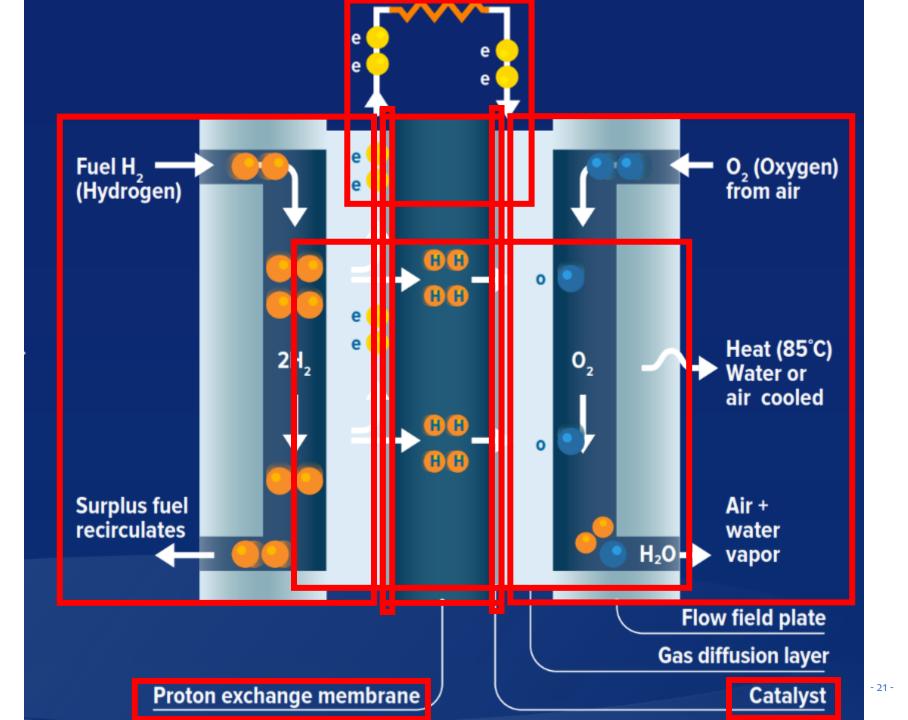
$$H_2 \iff 2 H^+ + 2 e^-$$
 (anode)

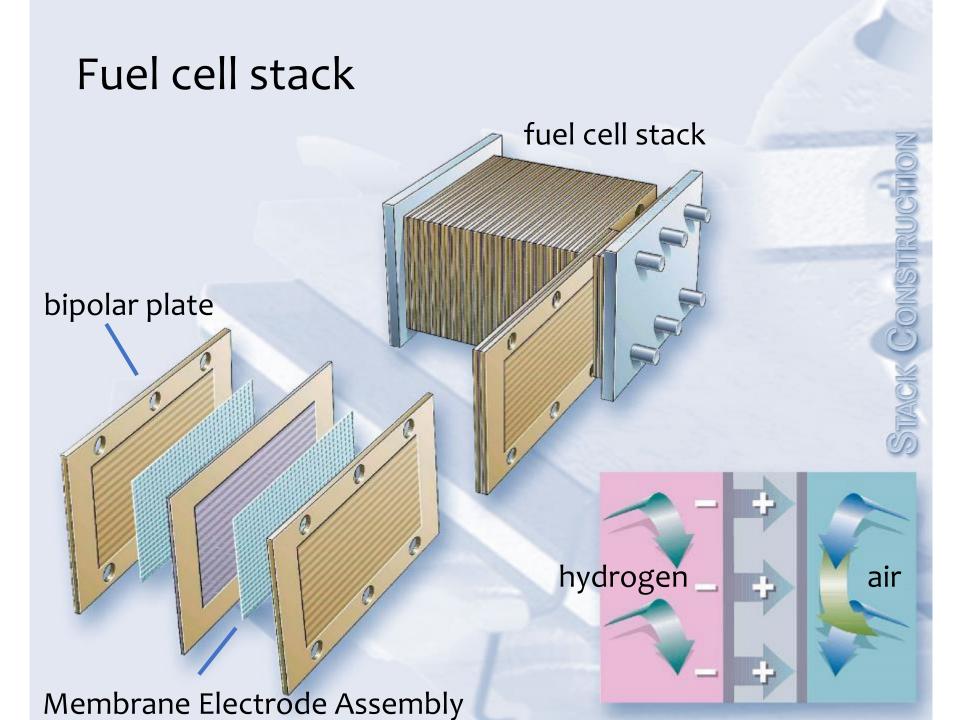
$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O$$
 (cathode)

PEM fuel cell

Proton Exchange Membrane

<u>P</u>olymer <u>E</u>lectrolyte <u>M</u>embrane







Key advantages of fuel cells

- no emissions
- high efficiency (fuel cell 60 % vs combustion engine 35 %)
- no noise
- high reliability

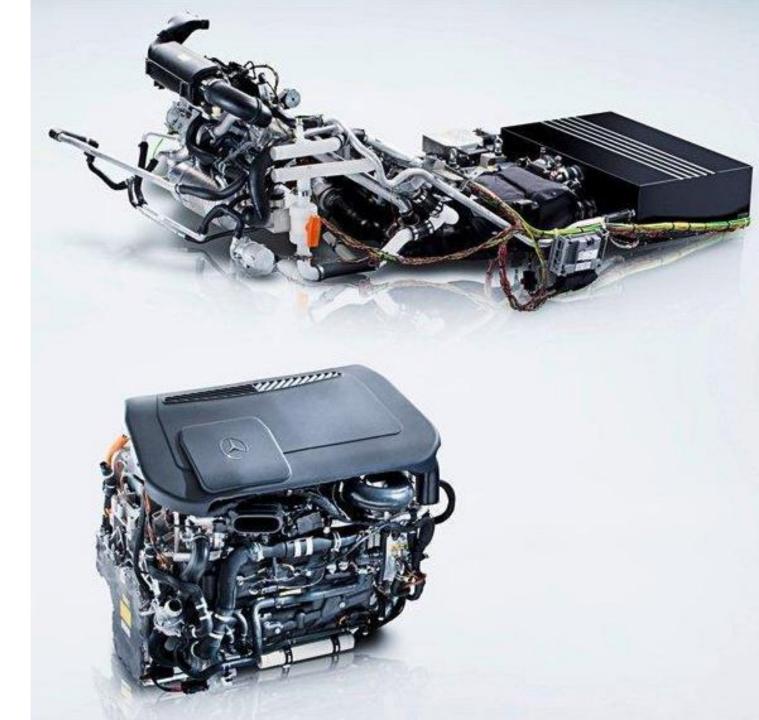
Hydrogen as the fuel provides

- long range
- short refill times

2010

Fuel cell engine

2018





30 and 50 kW systems





	application	typical power range	examples
Fuel cell applications	portable	1 W to 20 kW	 APUs (auxiliary power units) for boats, RVs, lighting military applications
	stationary stationary	0.5 kW to 2 MW	 Large powerplants and combined heat/power units (CHP) Small/home CHP units Uninterruptible power supplies Large APUs (trucks, ships)
	transportation 6	1 kW to 300 kW	ForkliftsCarsTrucks and busesRailAirplanes





Puel Cell Flecuic Vehicle









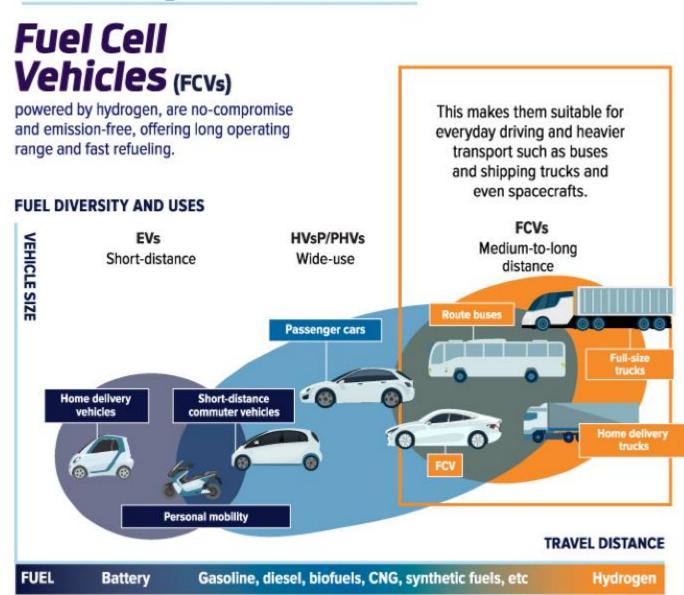


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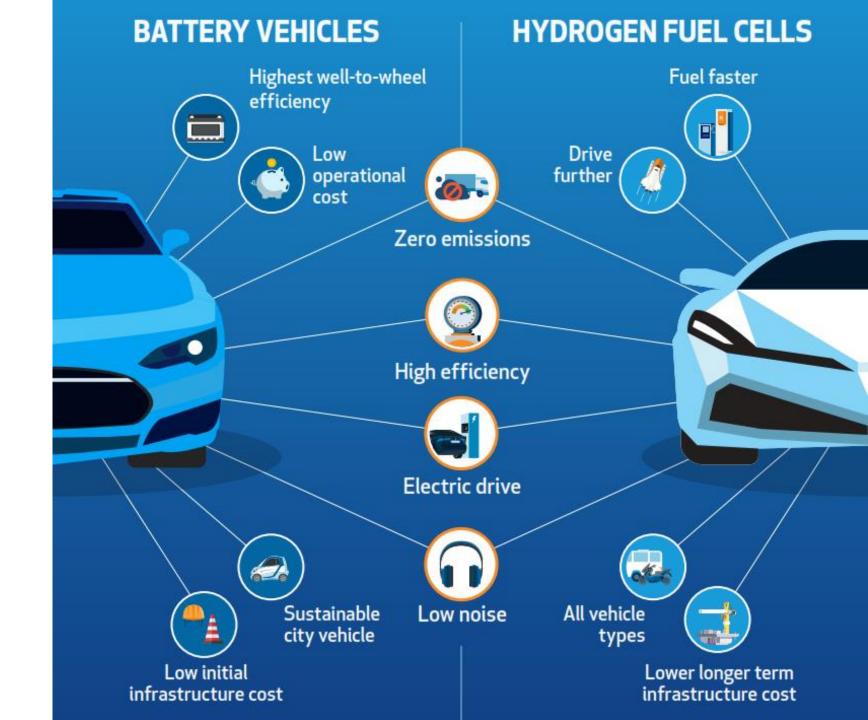




Transportation



Key aspects of electric vehicles





and fuel cell vehicles.

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Sustainability

Events

- 34 -

What is important?



Energy efficiency



Weight and package



Range



Operational schemes



Infrastructure -Charging and Hydrogen



Recharge/refueling times



KS Engineers

Problem of all electric vehicles: How to store and replenish the energy?



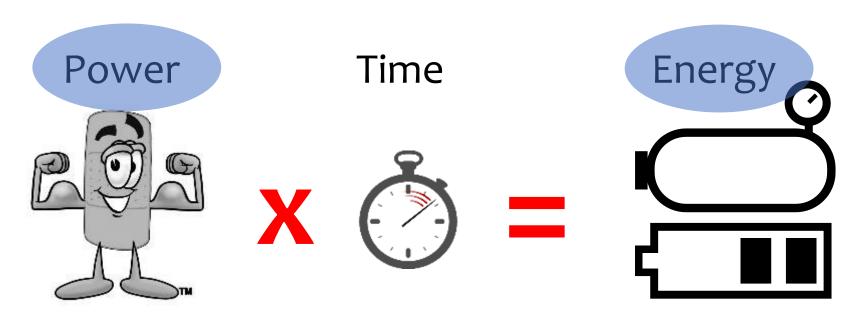
Battery charging challenge

Battery chemistry

Required electrical power



Electric vehicle fundamentals



kW

HP speed acceleration weight

h

driving time

kWh

range





	Tesla 3 long-range	Toyota Mirai
range	500	km
power	192 kW	113 kW
energy consumption	15 kWh,	/100 km
battery/tank size	75 kWh	5 kg H2
battery/tank weight	480 kg	88 kg

	charge power [kW]	charo [hr]	ge time [min]
Battery capacity 75 kWh	75	1	60
Level 2 charger	7.5	10	600
Fast charger	50	1.5	90
Tesla Supercharger	120	0.6	38
Porsche Fastcharger	350	0.2	13
5 min Charger	900	0.08	5
Hydrogen refueling time	n/a	0.08	5



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Charging infrastructure in Canada



Level 2: 16 to 32 kilometers per 1 hour of charging time.

Fast charging: 95 to 130 kilometers per 20 minutes of charging time.

Hydrogen station



Hydrogen stations in BC



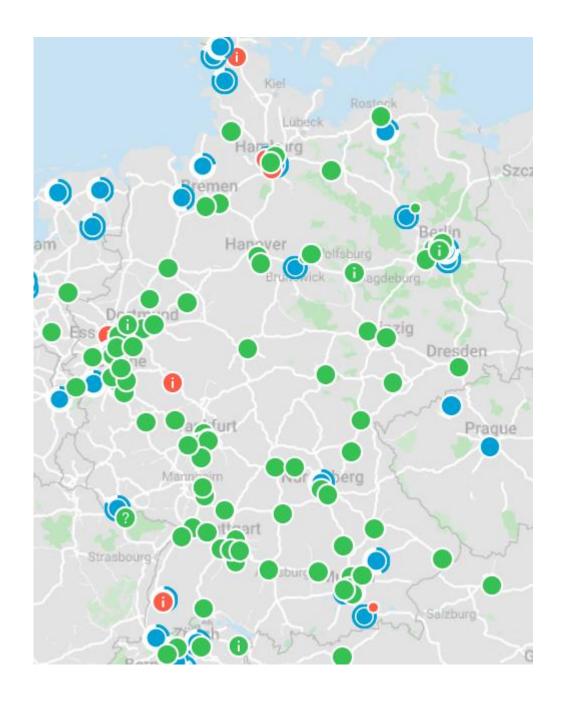
H₂ stations



123 16 In operation

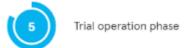
52 in progress







90 Open









total: 106

Cost of Infrastructure - Charging vs Hydrogen

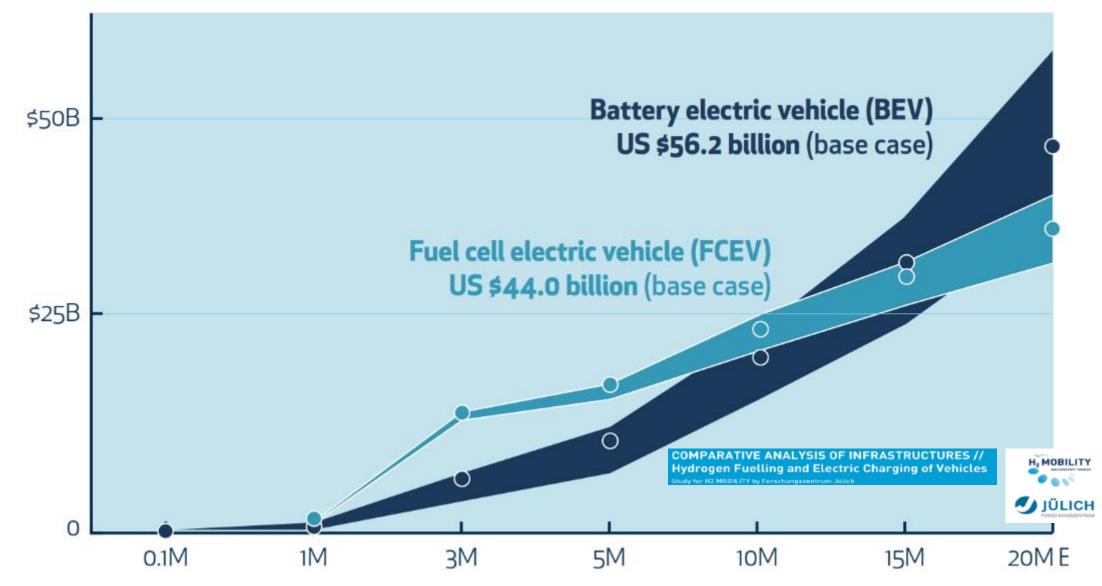
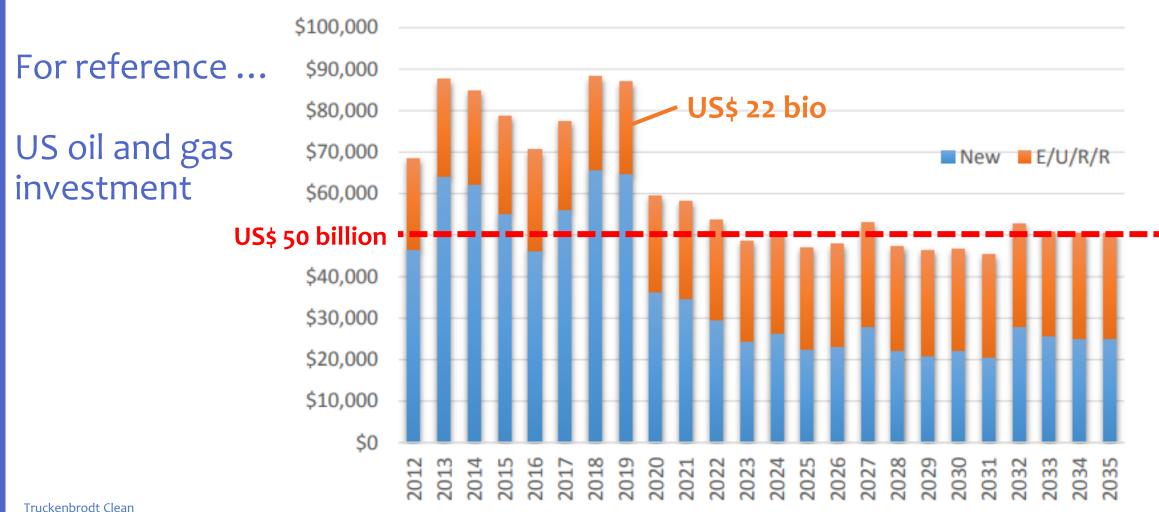


Exhibit ES-2: Oil and Gas Infrastructure CAPEX by Year (Million 2015\$)

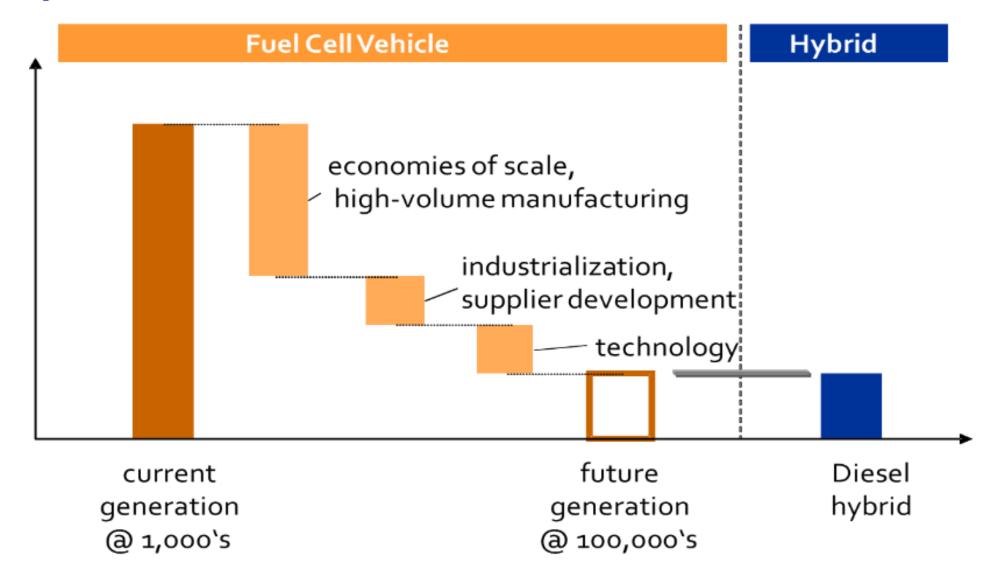
Base Case Projected (2017-2035) Average Annual CAPEX = \$55,773



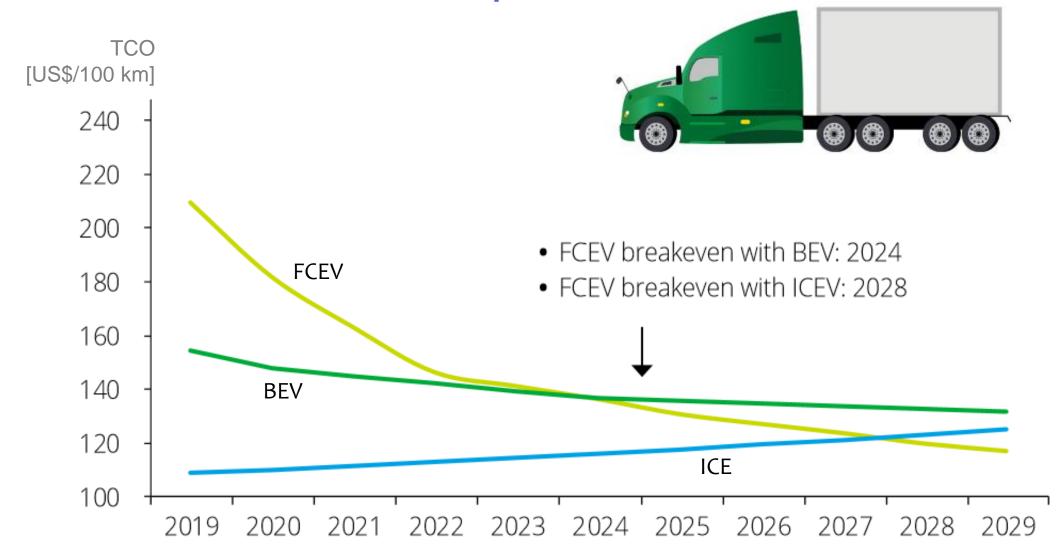


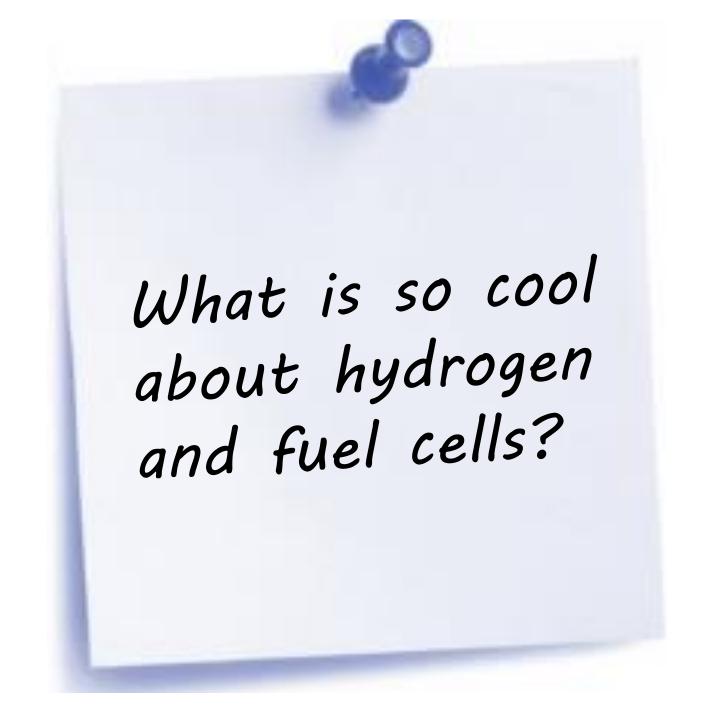


The path to cost reduction



TCO (total cost of ownership) development



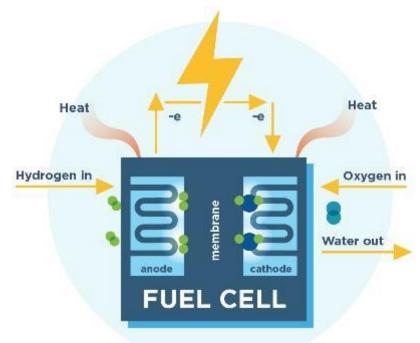


Key advantages of hydrogen and fuel cells



- the most abundant element on earth
- energy carrier with the highest energy density, nontoxic, safe
- many (renewable) and local ways to make hydrogen
- a universal "energy vector" for use as storage, transport, fuel

- zero emissions
- 2x efficiency as combustion engine
- no noise
- high reliability
- multiple applications



Key takeaways



Batteries, hydrogen and fuel cells are major elements of our sustainable future



Commercialization has started and is increasing at an amazing speed



The technologies are available and ready for the market



There is no wonder drug - we need the right technology for the right application



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