MOVET

Centro d'iniziativa per i MOtori, VEicoli e Tecnologie

La transizione ecologica del settore automotive

07 – 08 luglio 2022

Sviluppo ed evoluzione dei veicoli a Fuel Cell

Prof. Lorenzo Ferrari

Università di Pisa - DESTeC

lorenzo.ferrari@unipi.it

IN SUPREMÆ DIGNITATIS · 1343 ·

UNIVERSITÀ DI PISA

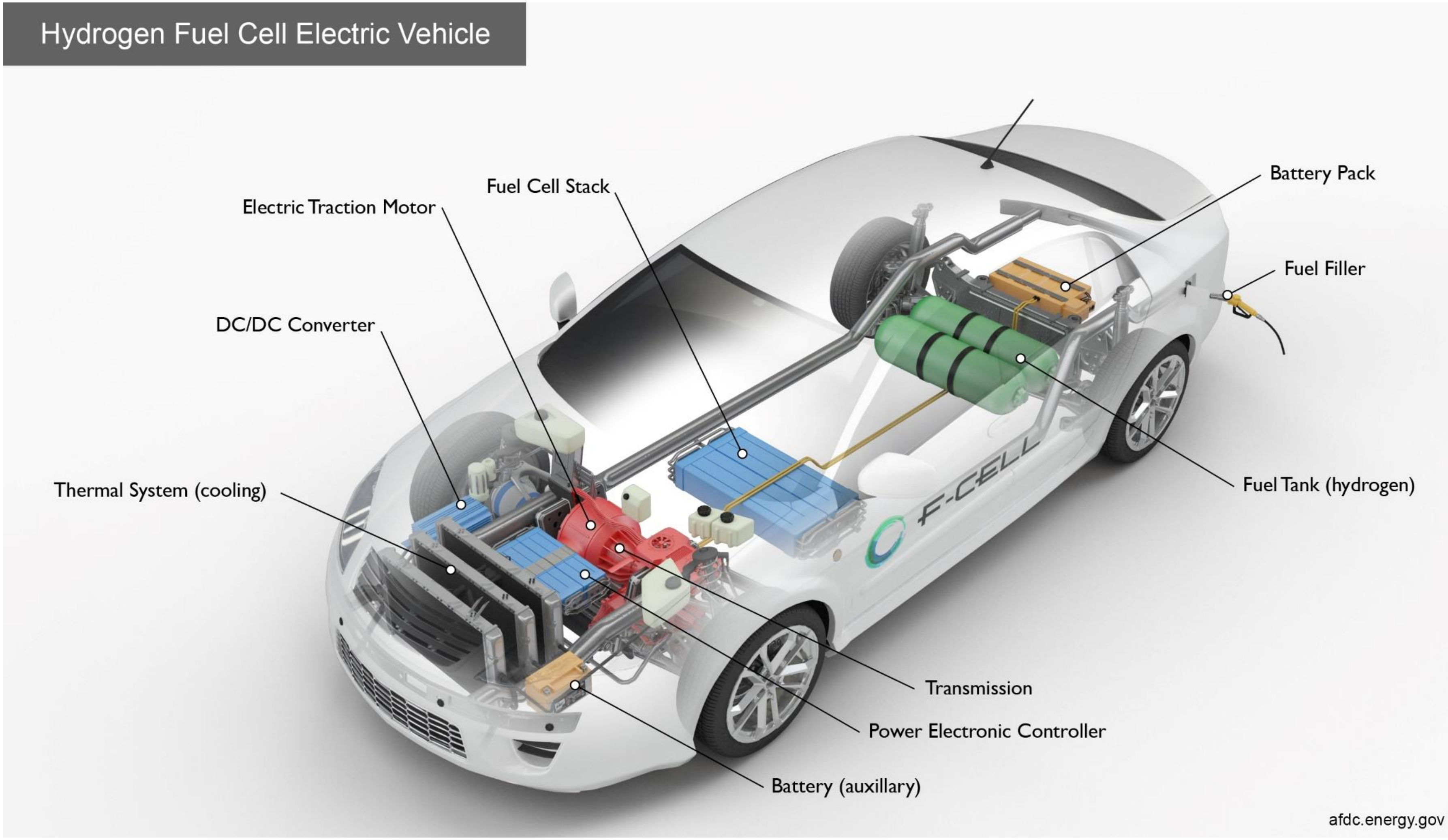
Premessa

- Supponiamo di avere a disposizione a basso impatto ambientale…

Color	GREY HYDROGEN	BLUE HYDROGEN	TURQUOISE HYDROGEN*	GREEN HYDROGEN
Process	SMR or gasification	SMR or gasification with carbon capture (85-95%)	Pyrolysis	Electrolysis
Source	Methane or coal	Methane or coal	Methane	Renewable electricity

Note: SMR = steam methane reforming.
** Turquoise hydrogen is an emerging decarbonisation option.*

Veicolo a Fuel Cell



In sintesi

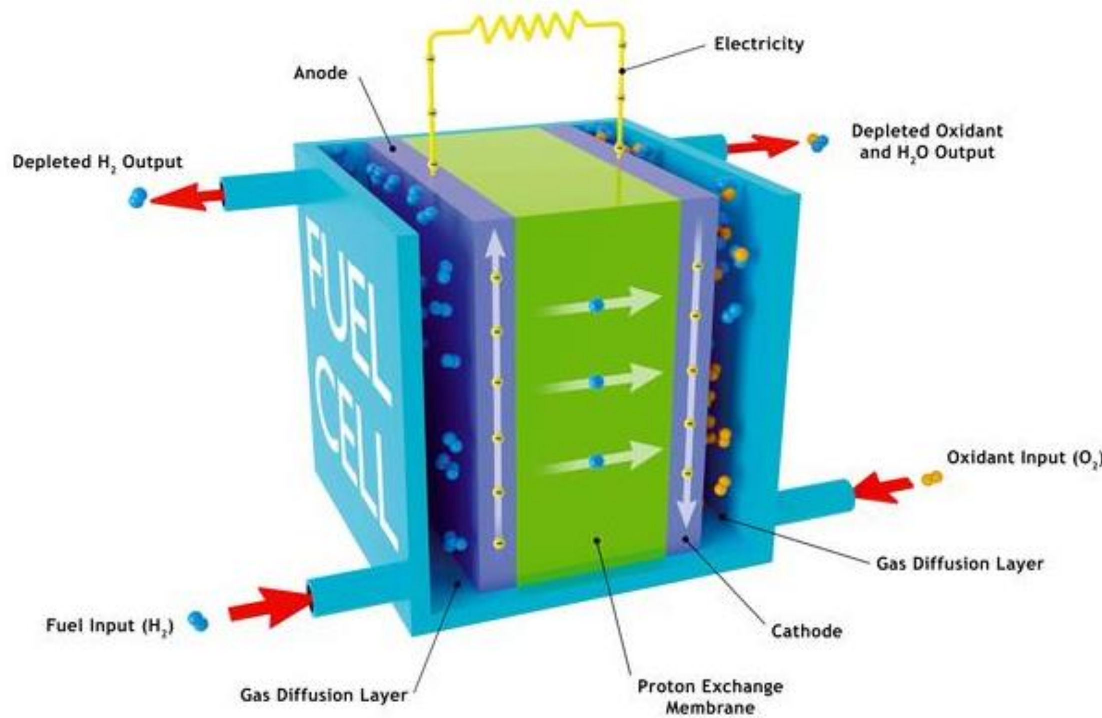
Veicolo con motore elettrico (con batterie) che utilizza idrogeno come vettore energetico, convertito in energia elettrica in una fuel cell (per via elettrochimica)

Pregi

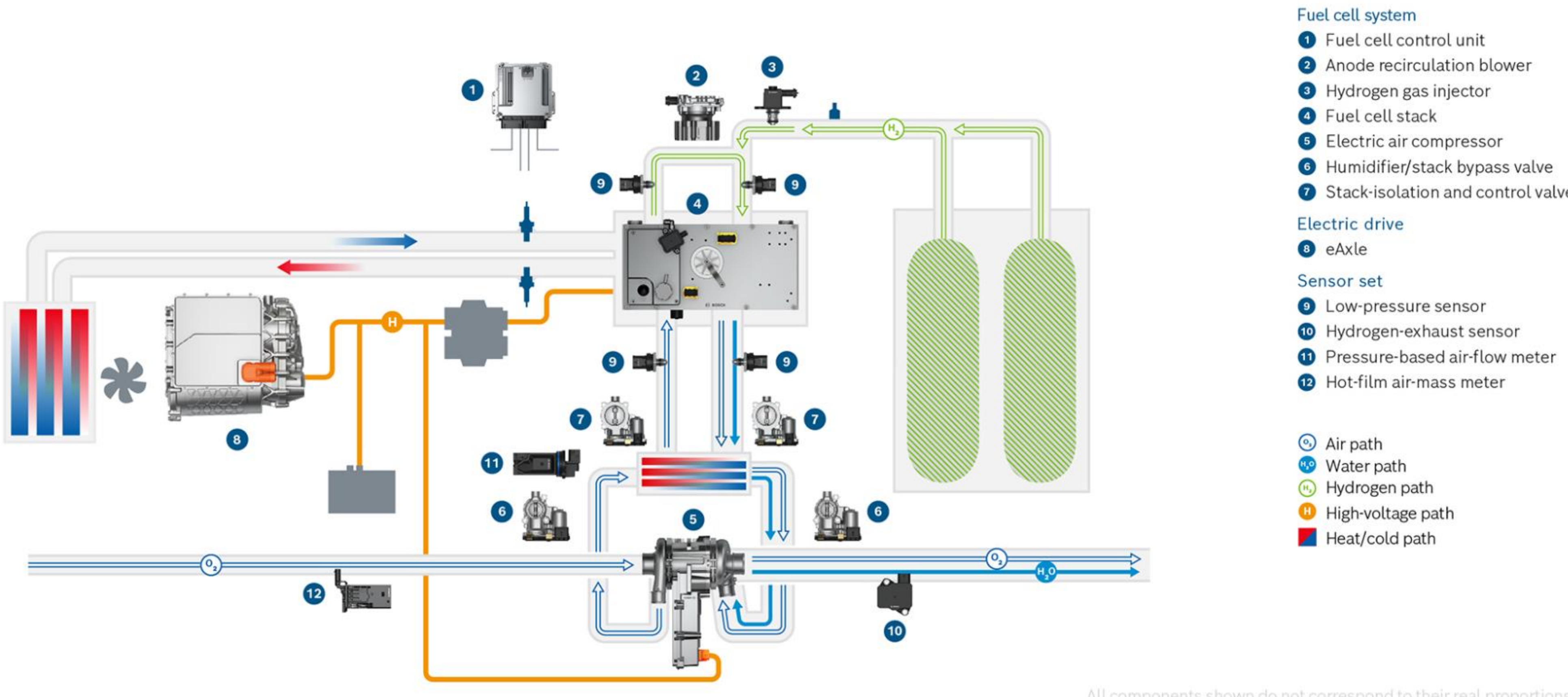
- ✓ Rifornimento rapido
- ✓ Buone autonomie
- ✓ Buone efficienze
- ✓ Emissioni locali nulle

Criticità

- ✗ Durata/costo della FC
- ✗ Rifornimento/Stoccaggio
- ✗ Disponibilità di H2
- ✗ Sicurezza

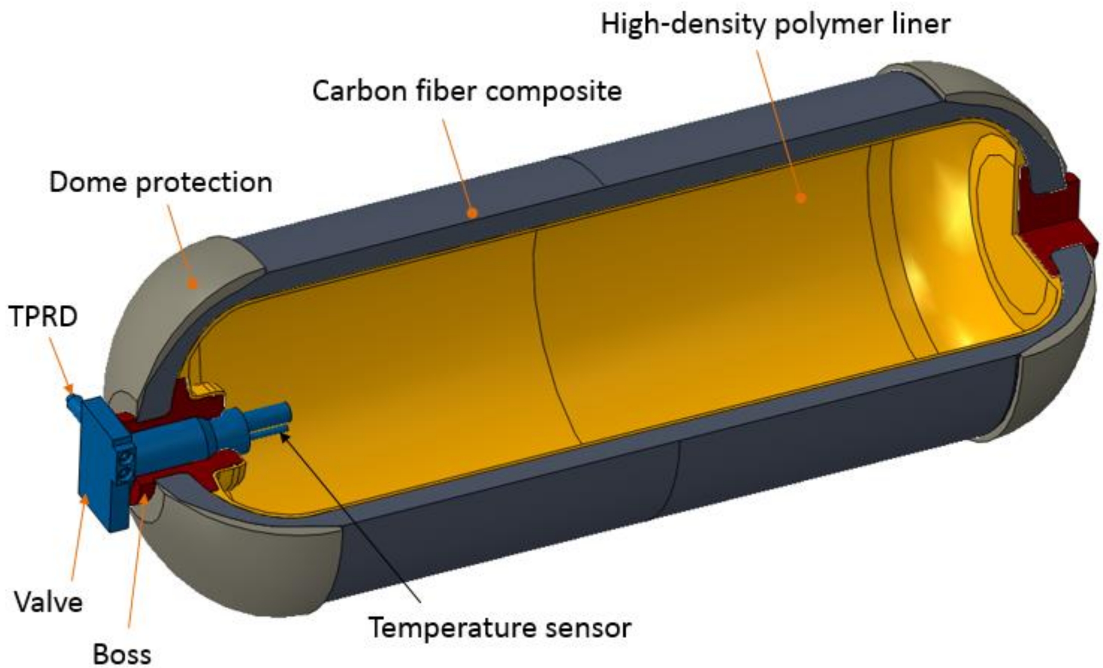


Sistema di gestione Fuel Cell



https://www.bosch-mobility-solutions.com/en/solutions/powertrain/fuel-cell-electric/fuel-cell-stack/

Stoccaggio (in fase gassosa)



TPRD = Thermally Activated Pressure Relief Device

Credit: Process Modeling Group, Nuclear Engineering Division. Argonne National Laboratory (ANL)

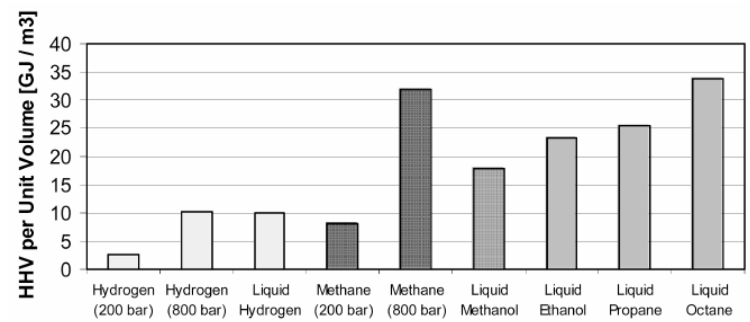
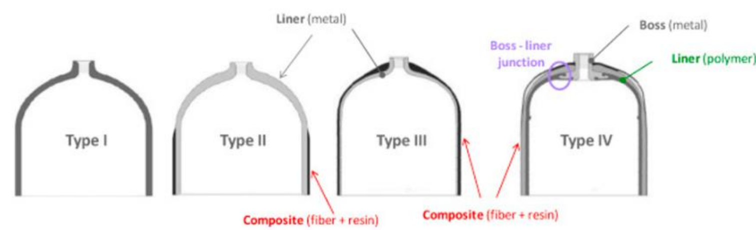


Table 2 – Different types of hydrogen compressed tank.

Cylinder types	Materials	Features	Applications	Hydrogen storage pressure and mass percent (WT%)
Type I	All metal	Heavy, internal corrosion	For industrial, not suited for vehicular use	17.5–20 MPa 1 WT% [21]
Type II	Metal liner with hoop wrapping	Heavy, short life due to internal corrosion	Not suited for vehicular use	26.3–30 MPa
Type III	Metal liner with full composite wrapping	Lightness, high burst pressure, no permeation, galvanic corrosion between liner and fiber	Suited for vehicular use. 25–75% mass gain over I and II	35 MPa: 3.9 WT% –70 MPa: 5 WT%
Type IV	Plastic liner with full composite wrapping	Lightness, lower burst pressure. Permeation through liner, high durability against repeated charging Simple manufacturability	Longer life than Type III (no creep fatigue).	70 MPa: more than 5 WT%,

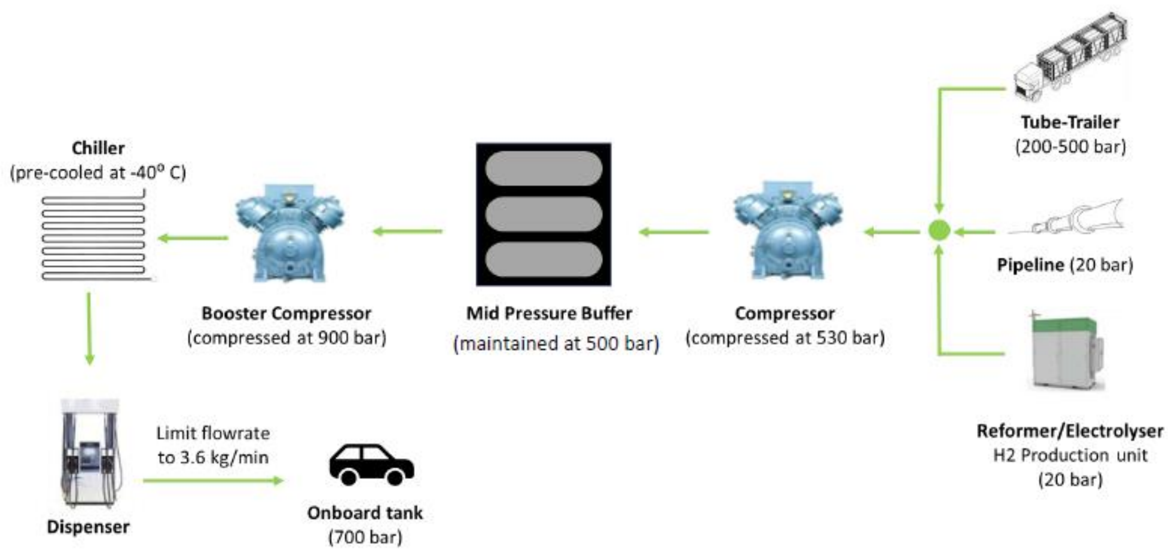


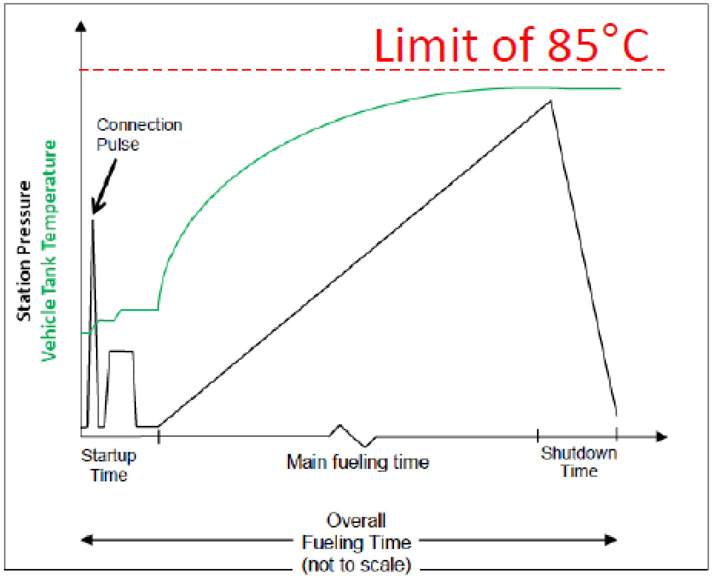
Rifornimento

Per essere competititvi con le tecnologie attuali:

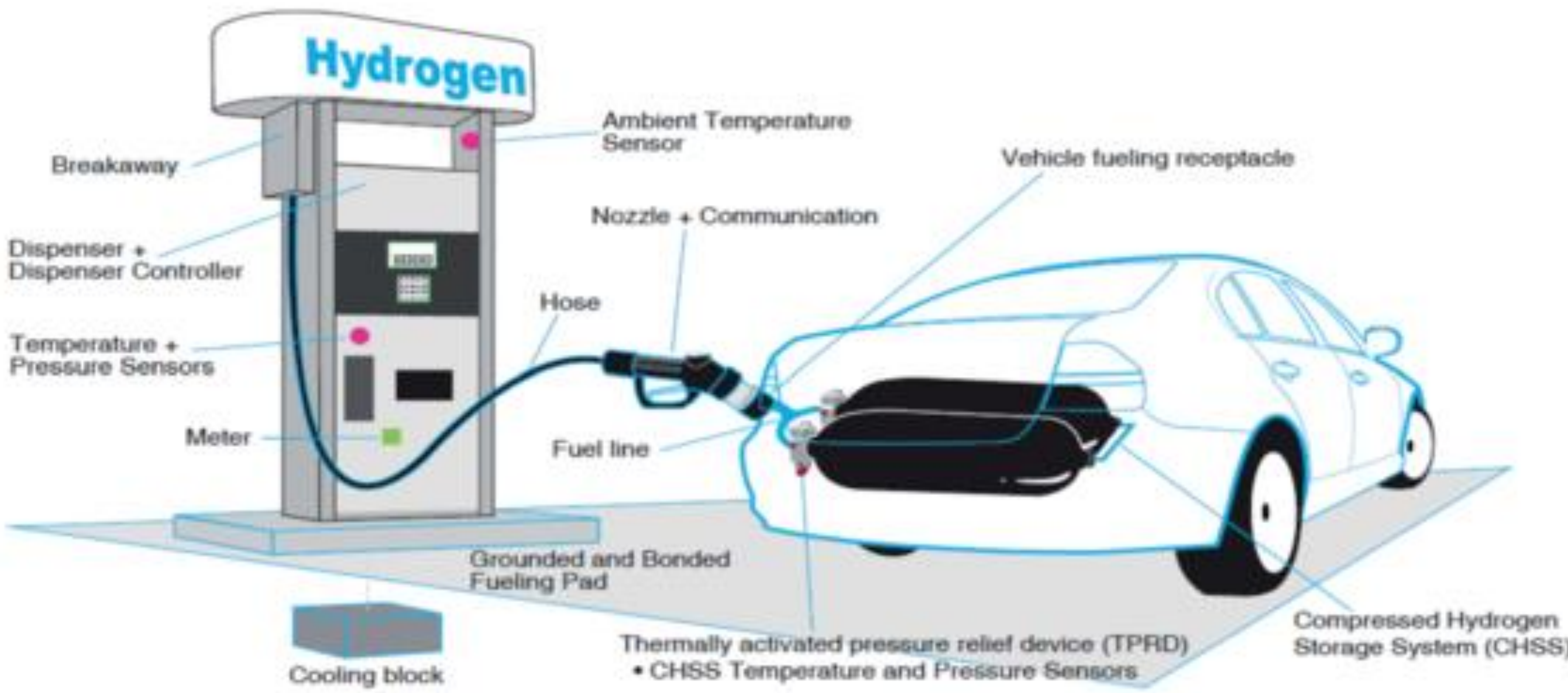
- Tempi di rifornimeto brevi (3 minuti)
- Garantire autonomie adeguate (450 km)
- Garantire un rifornimento sicuro ed affidabile

La normative impone una temperature massima di 85°C (ISO/TS 15869, 2009)

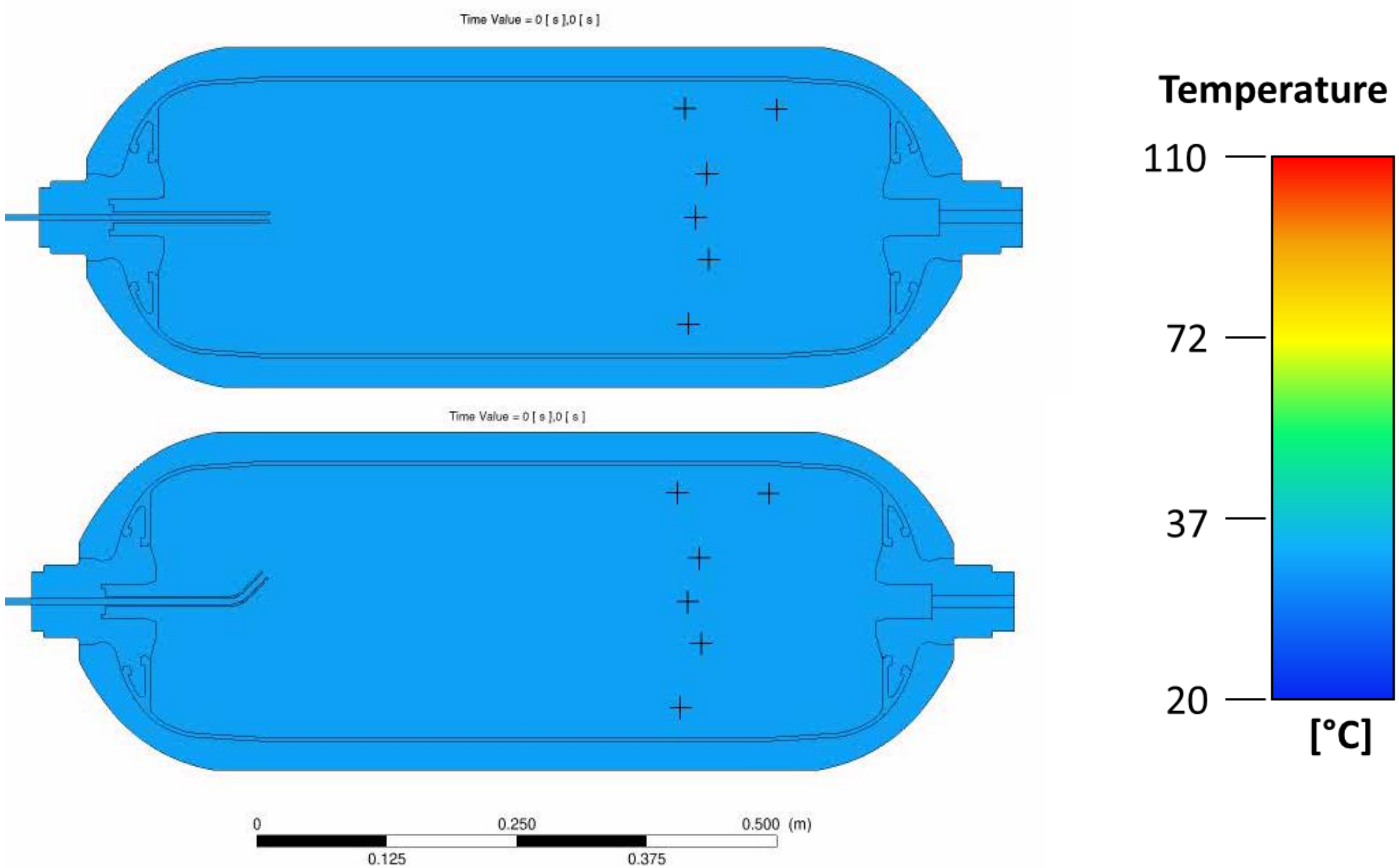




Rifornimento



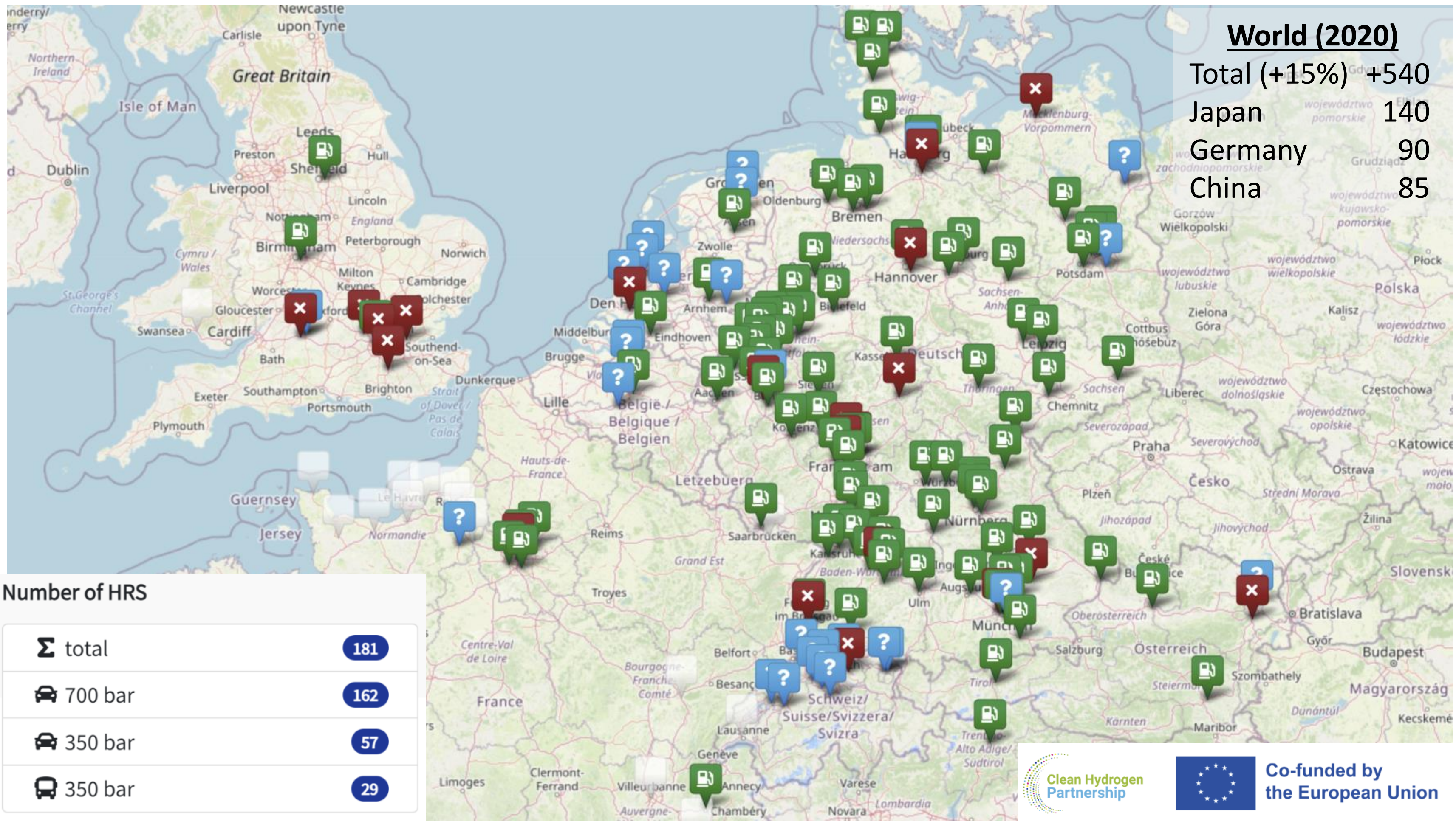
Rifornimento



Distributori di idrogeno

Distributori di idrogeno

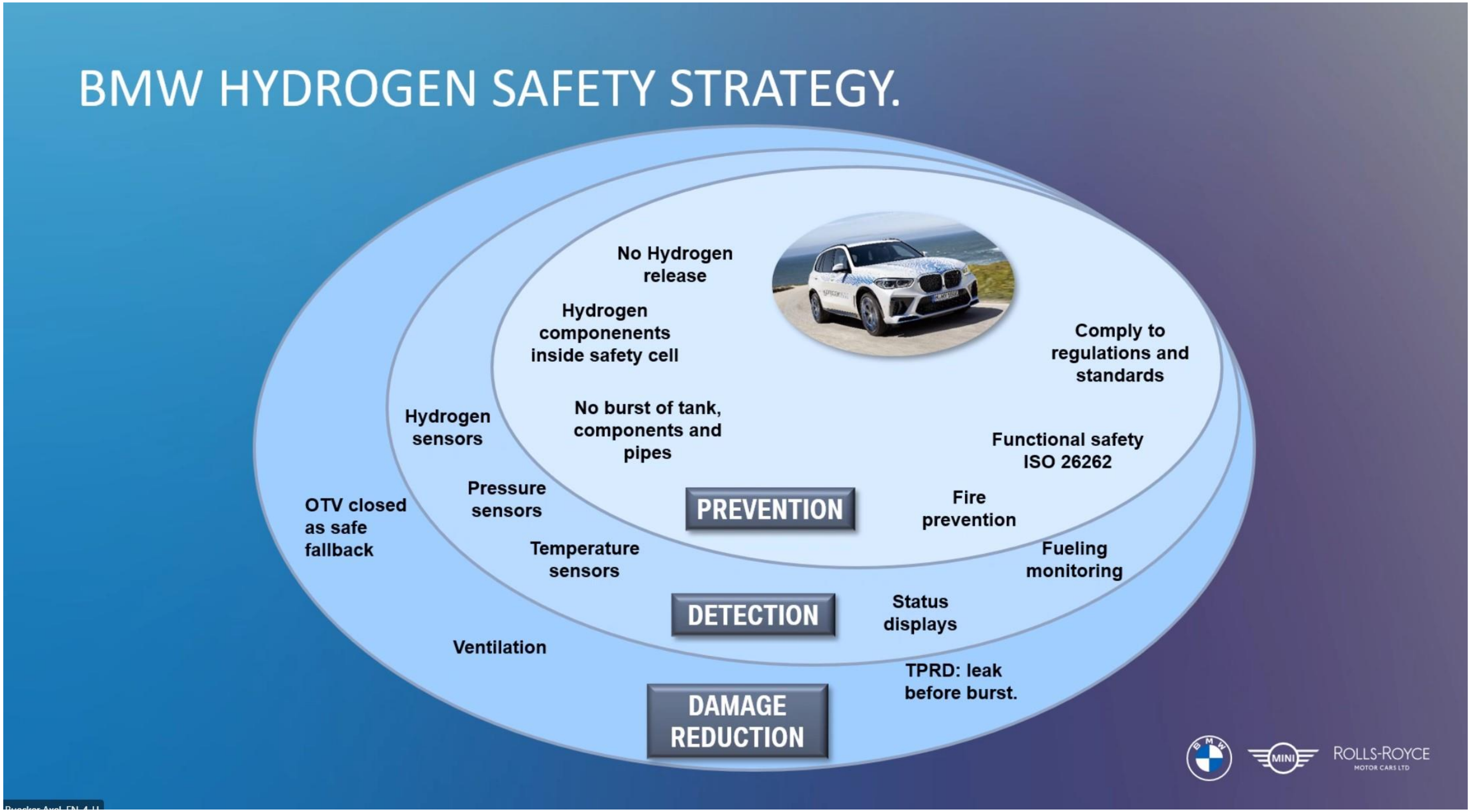
https://h2-map.eu/



Number of HRS

Σ total	181
700 bar	162
350 bar	57
350 bar	29

Sicurezza


BMW HYDROGEN SAFETY STRATEGY.
No Hydrogen release
Hydrogen components inside safety cell
Comply to regulations and standards
No burst of tank, components and pipes
Functional safety ISO 26262
Hydrogen sensors
OTV closed as safe fallback
Pressure sensors
PREVENTION
Fire prevention
Temperature sensors
Fueling monitoring
DETECTION
Status displays
Ventilation
TPRD: leak before burst.
DAMAGE REDUCTION
ROLLS-ROYCE
MOTOR CARS LTD

Veicoli in commercio

Toyota MIRAI II

Fuel Cell Vehicle

Range: 650 Km

Electric motor: 184 HP

Tank capacity: 5,6 Kg

Fuel consumption (H2) combined: 0.76 kg/100 km;

CO2 emissions combined 0 g/km (NEDC*)

Type: Sedan

Price: 63.900 €

* Statutory data in accordance with the Passenger Car EnVKV, based on NEDC values. The vehicle tax is based on the often higher WLTP values

Hyundai NEXO

5th- generation fuel-cell vehicle

Range: 756 km

Electric motor: 120 kW/163 hp

Tank capacity: 6.33 kg

Fuel consumption (H2): 0.84 kg/100km (NEFZ*)

CO2 emissions (combined): 0 g/km

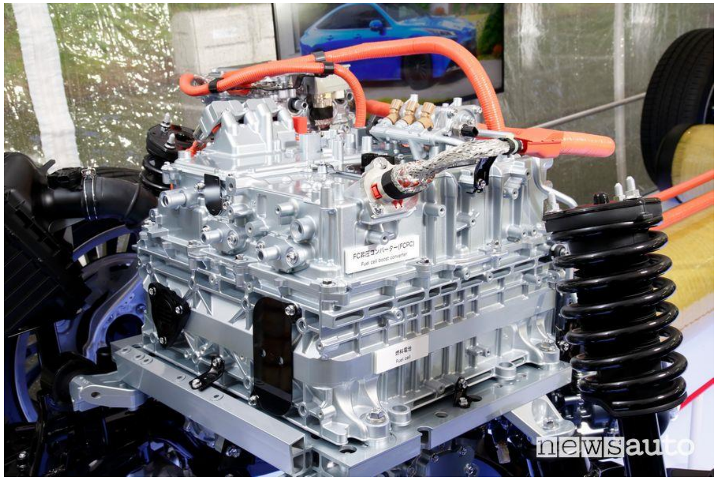
Model: SUV

Price: 69,000 €

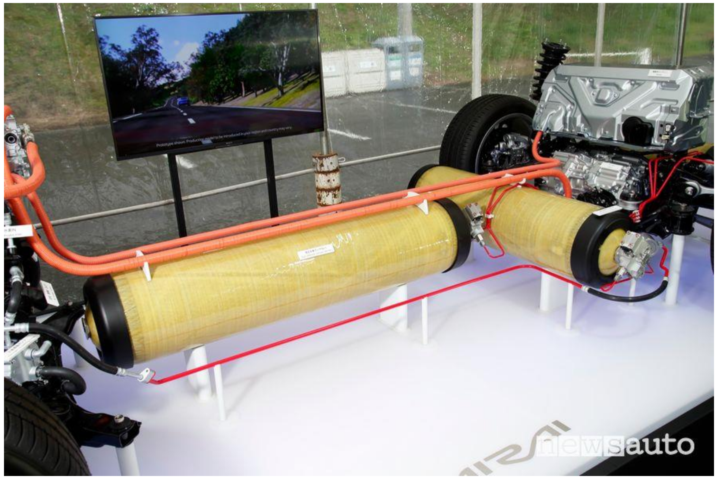
Available: from 08/2018

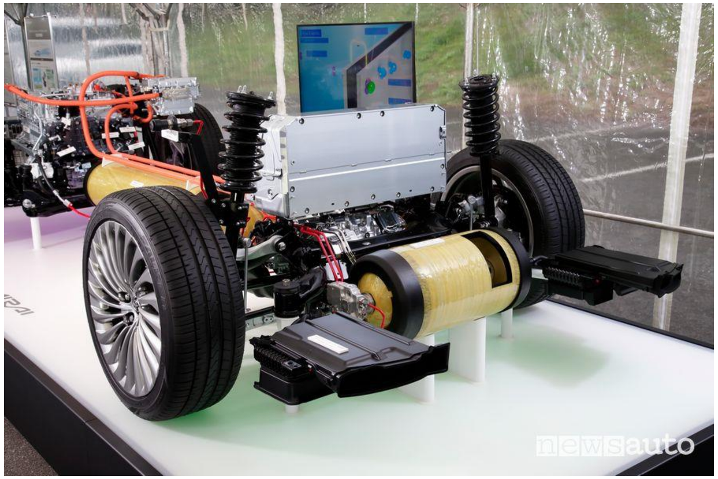
* The stated consumption and CO2 emission values were determined according to the prescribed WLTP measuring method and converted into NEDC values.

Alcuni dettagli (Mirai)

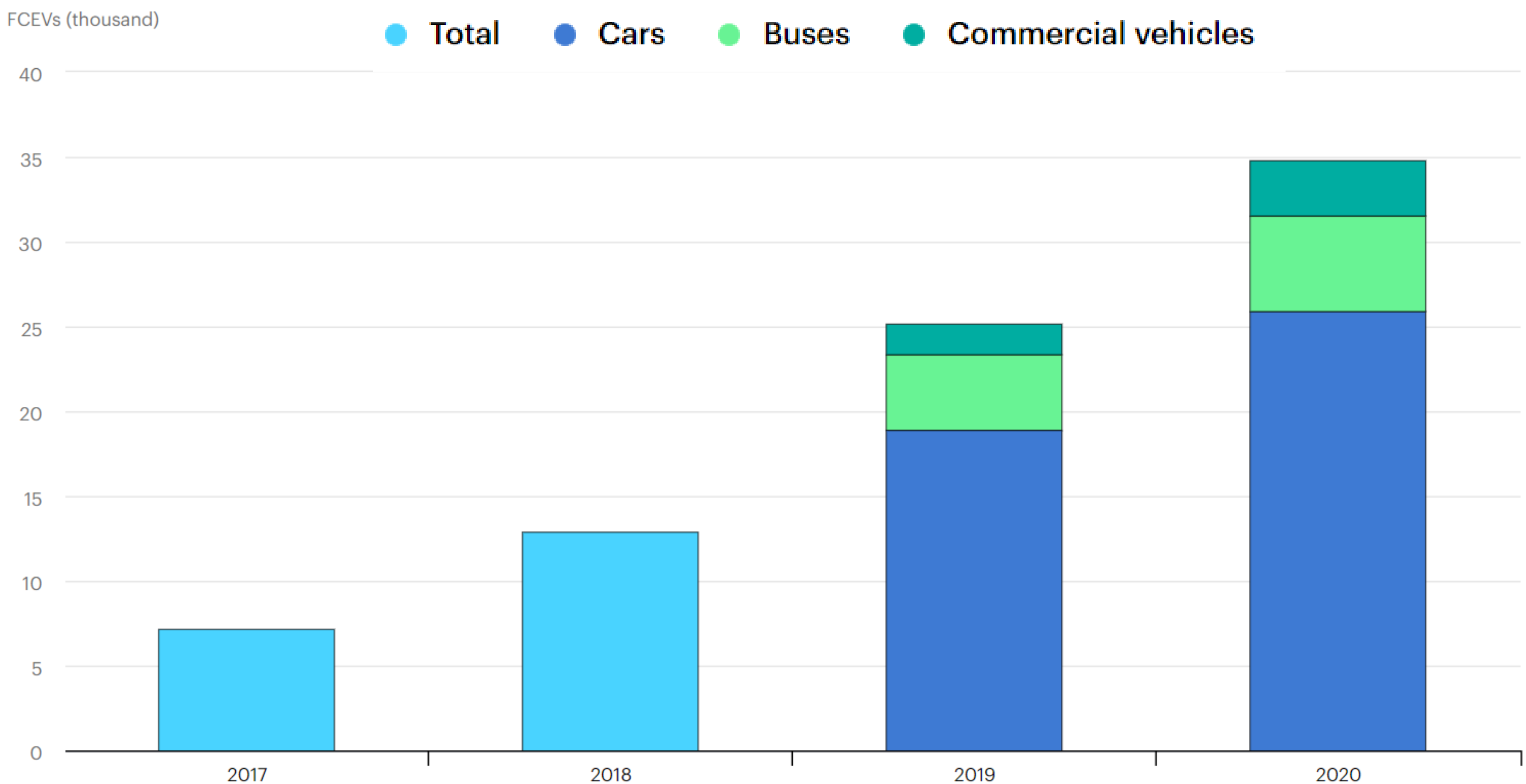


- Autonomia 650 km
- 3 serbatoi ad alta pressione (5,6 kg; 6%WT)
- FC a polimero solido (330 elementi; 5,4 kg/l)
- Peso FC: 25.5 kg
- Potenza massima: 128 kW
- Batteria:
  - N. celle: 84
  - Tensione nom.: 310.8 V
  - Capacità: 4.0 Ah
  - Peso: 44.6 kg
  - Potenza: 31.5 kW x 10s
- Filtro con catalizzatore per il trattamento dell'aria in ingresso e rimozione delle particelle

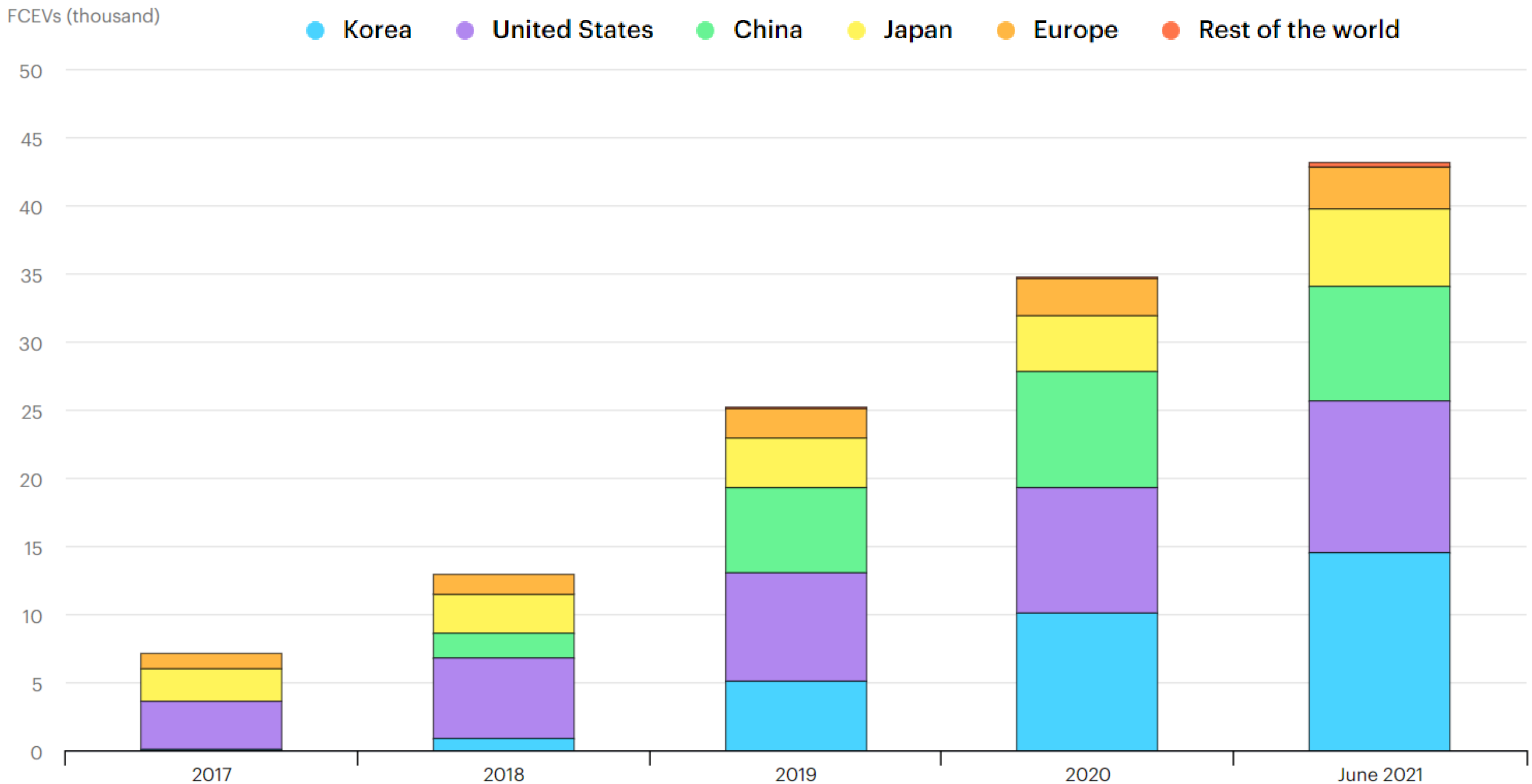




Veicoli circolanti



Distribuzione geografica

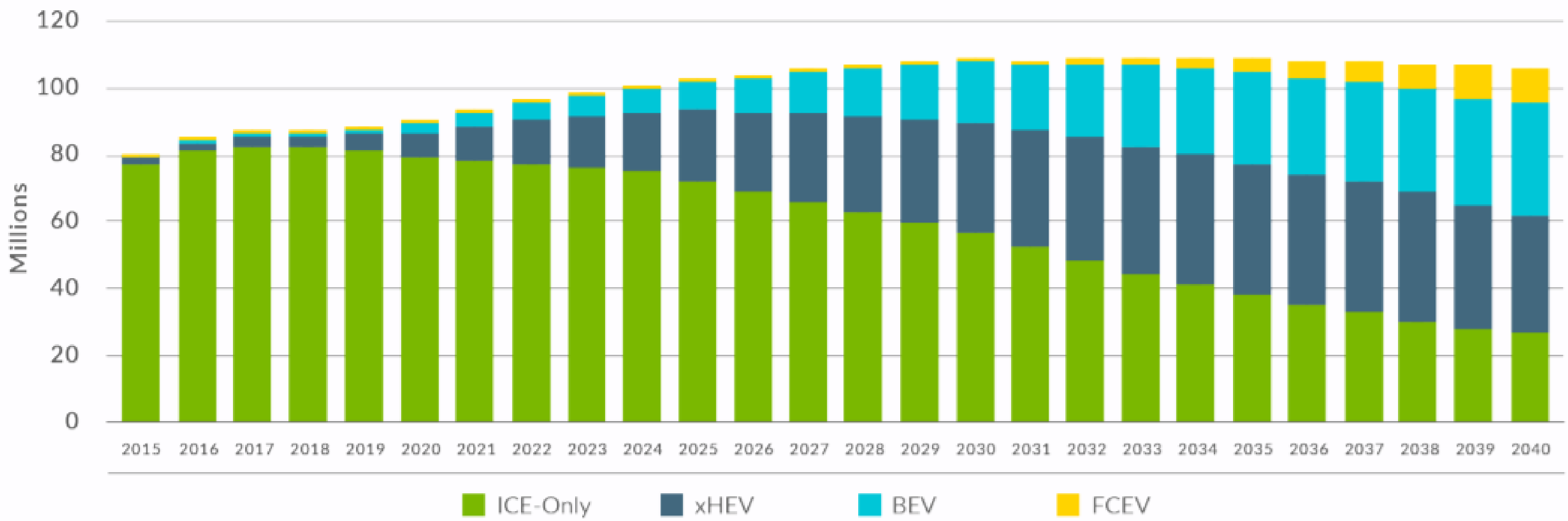


Prospettive

È difficile fare previsioni, soprattutto sul futuro

(Niels Bohr)

Previsioni vendite (cars + light trucks)

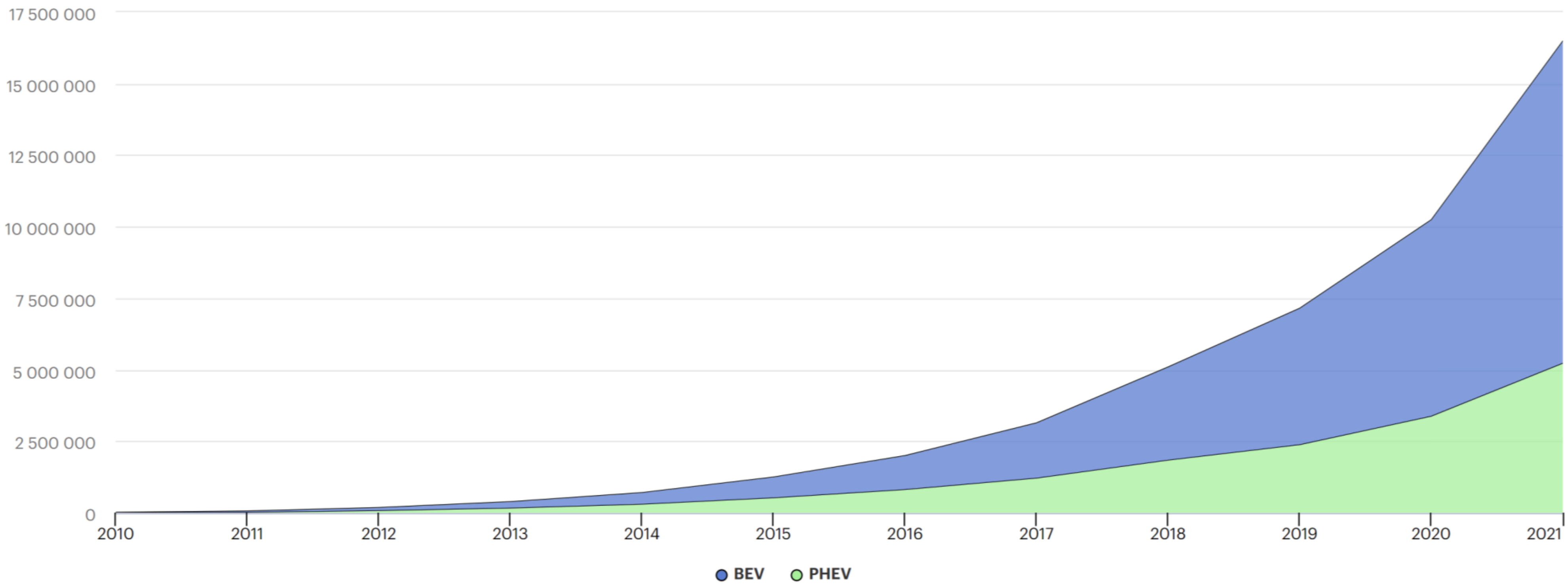


Globally, sales of cars with ICEs (including hybrids) will peak by 2025.

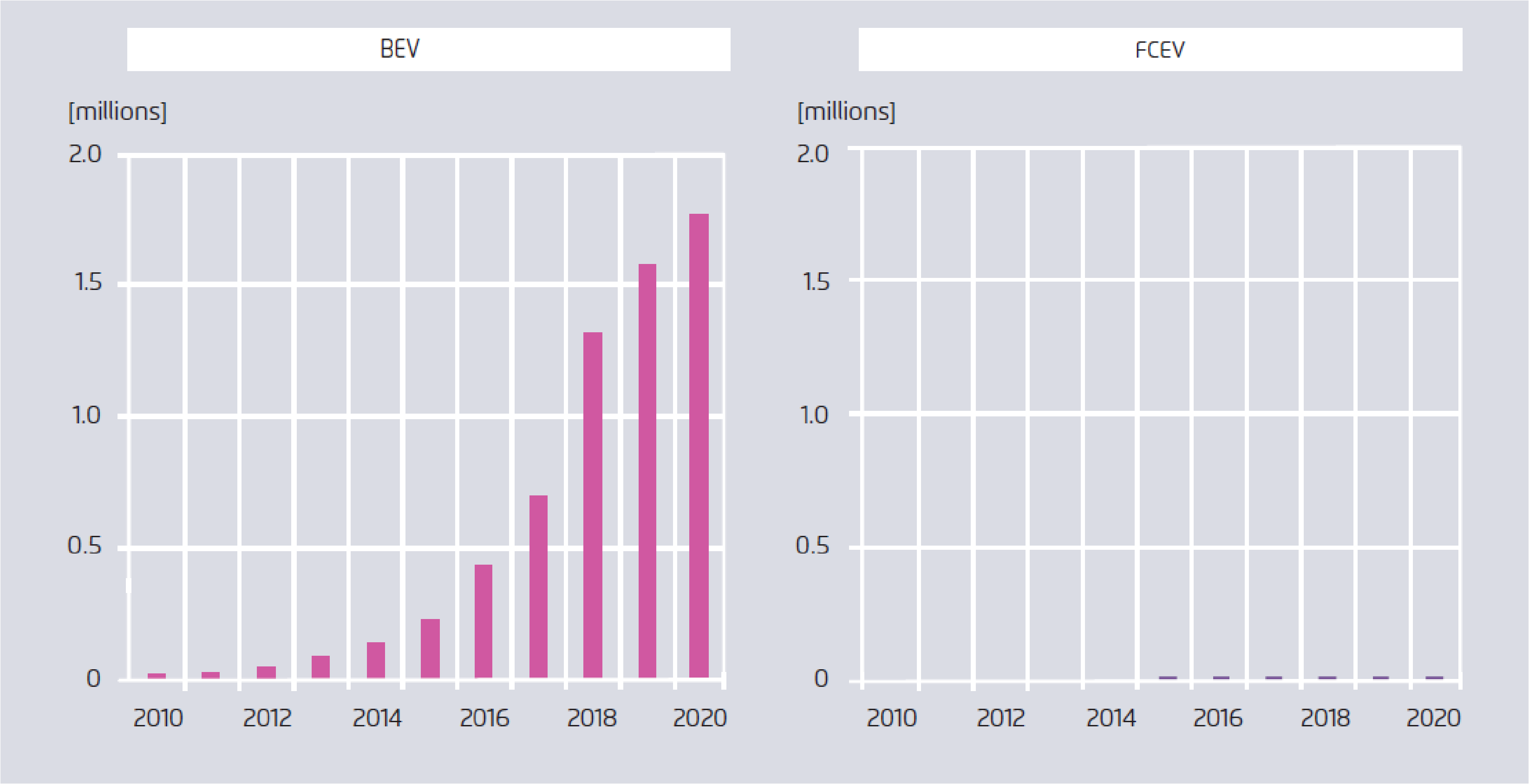
IC-only still plays a major role in 2040, but sales will be 75% lower than now.

By 2040, BEV is the largest single technology, but hybrid sales are bigger overall.

Veicoli elettrici

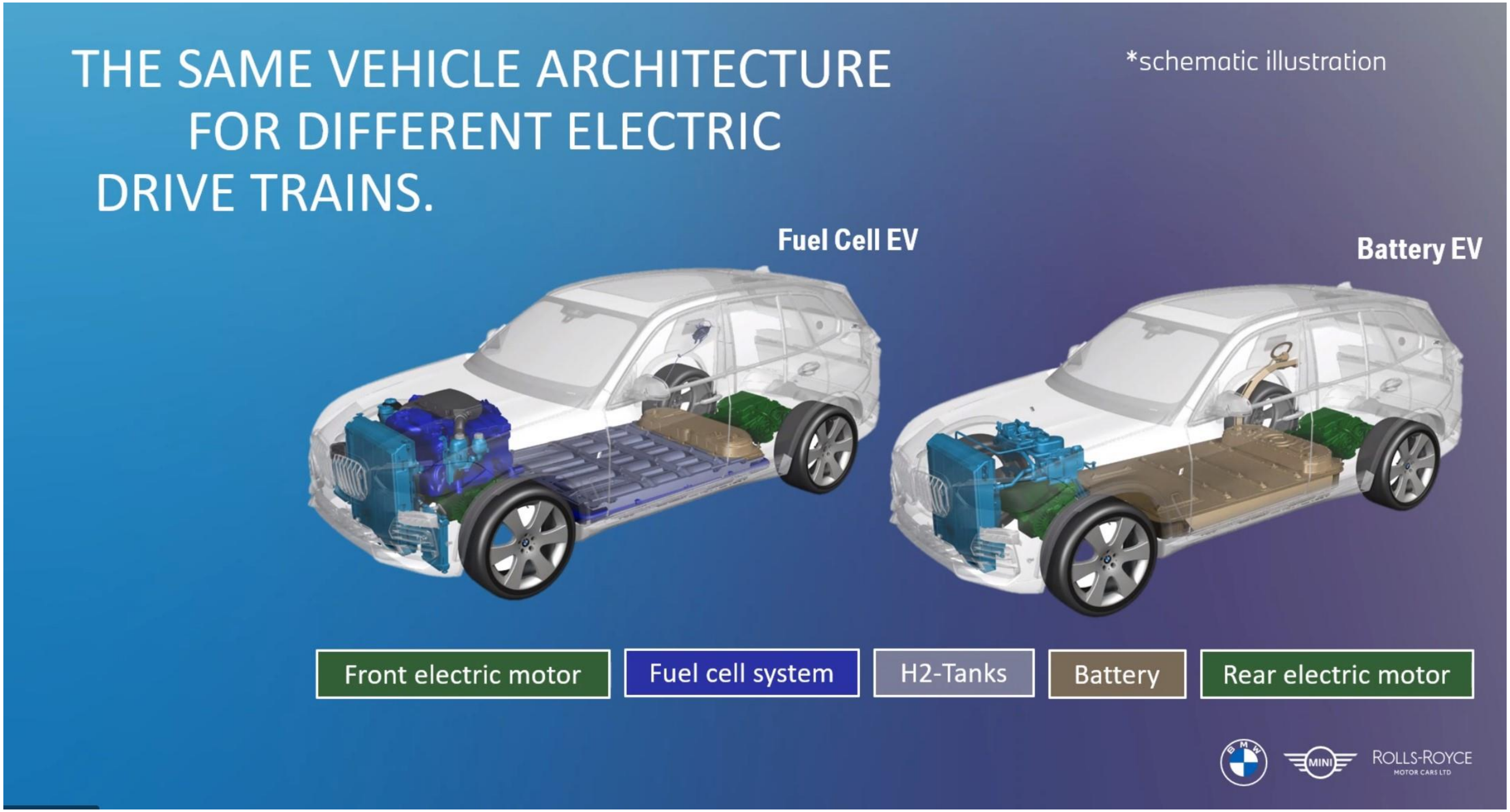


Confronto

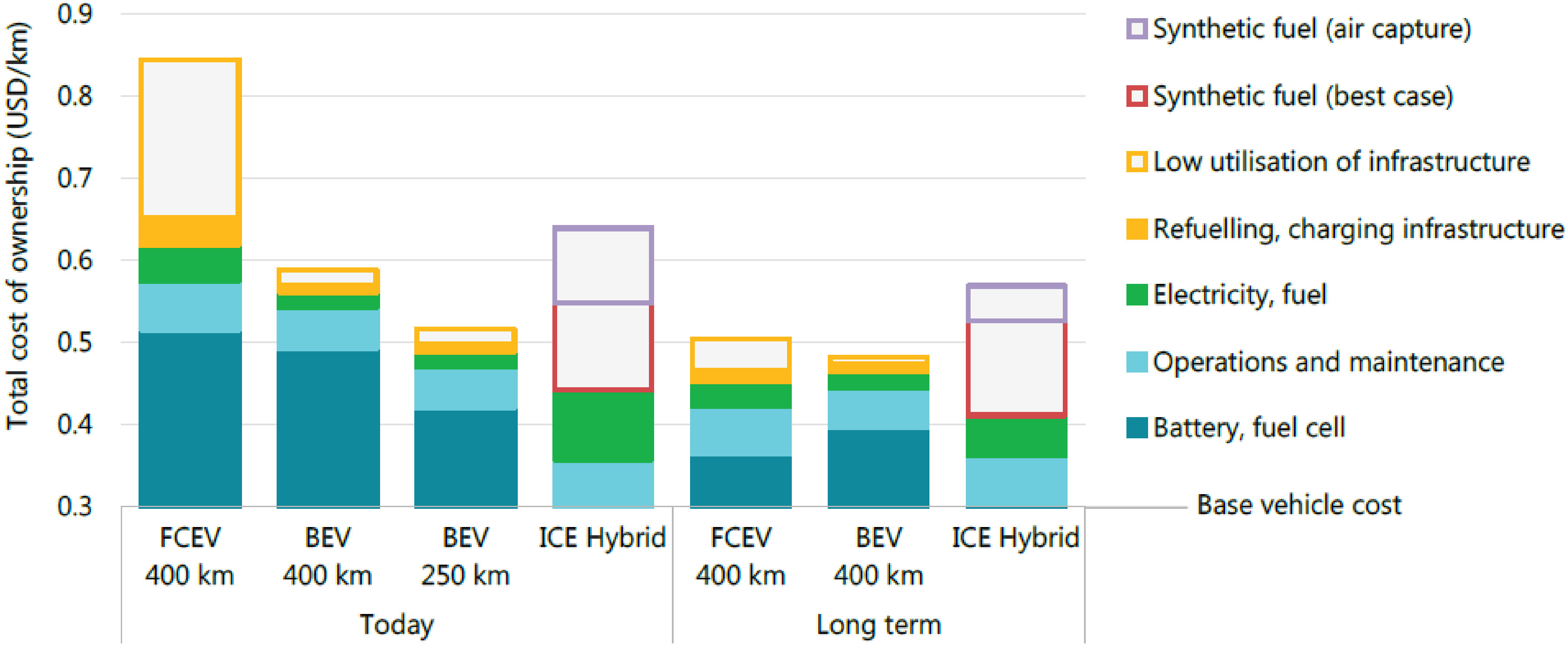


BloombergNEF (2021b)

Riduzione dei costi

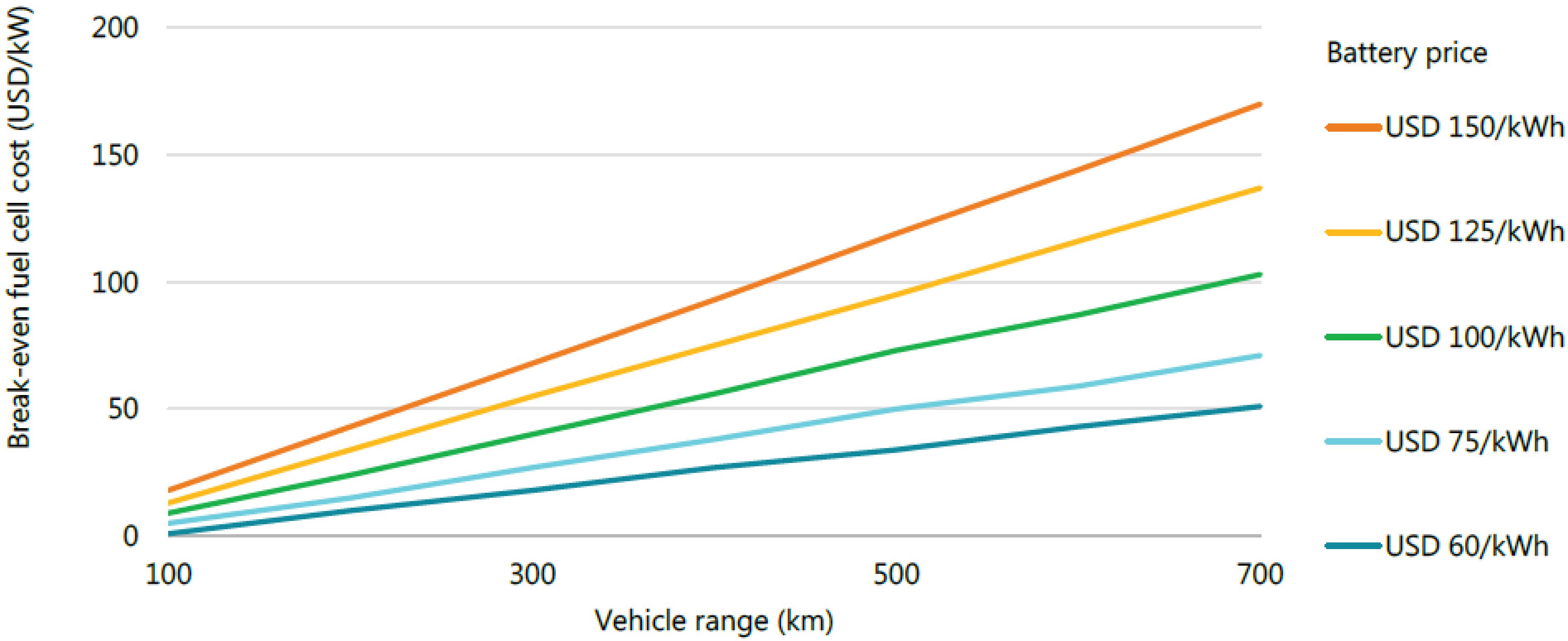


Costi di acquisto



Notes: ICE = internal combustion engine. The y-axis intercept of the figure corresponds to base vehicle "glider" plus minor component costs, which are mostly invariant across powertrains. More information on the assumptions is available at www.iea.org/hydrogen2019.

Condizioni di pareggio



Note: More information on the assumptions is available at www.iea.org/hydrogen2019.

Source: IEA 2019.

Soluzioni no-regret

Green molecules needed?	Industry	Transport	Power sector	Buildings
No-regret	· Reaction agents (DRI steel) · Feedstock (ammonia, chemicals)	· Long-haul aviation · Maritime shipping	· Renewable energy back-up depending on wind and solar share and seasonal demand structure	· Heating grids (residual heat load *)
Controversial	· High-temperature heat	· Trucks and buses ** · Short-haul aviation and shipping · Trains ***	· Absolute size of need given other flexibility and storage options	
Bad idea	· Low-temperature heat	· Cars · Light-duty vehicles		· Building-level heating

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and buses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

*** Depending on distance, frequency and energy supply options

Agora Energiewende (2021)

Conclusioni

- I veicoli ad idrogeno e fuel cell sono una realtà. Esistono modelli in vendita ormai consolidati. Altre case hanno anticipato l'uscita di modelli FCEV
- Intensa attività già svolta (ed in corso) per migliorare le prestazioni e ridurre le criticità (peso dei serbatoi, sicurezza, durabilità, …)
- Lo sviluppo della tecnologia è fortemente legato alla presenza di infrastrutture di approvvigionamento (esempi di produzione in loco o ri-gassificazione)
- Dato lo sviluppo dei veicoli elettrici, probabilmente potrebbe essere vincente nel settore delle lunghe percorrenze o in nicchie specifiche. Possibile utilizzare vettori di idrogeno alternativi (metanolo, ammoniaca, …)
- L'idrogeno è ecologico tanto quanto lo è il processo da cui si produce
- L'idrogeno costa energia e capitale, non va considerata come panacea, va usato dove può fare la differenza

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