



BMW iX5 HYDROGEN.

THE EV WITH FAST REFUELING.

DR. JÜRGEN GULDNER

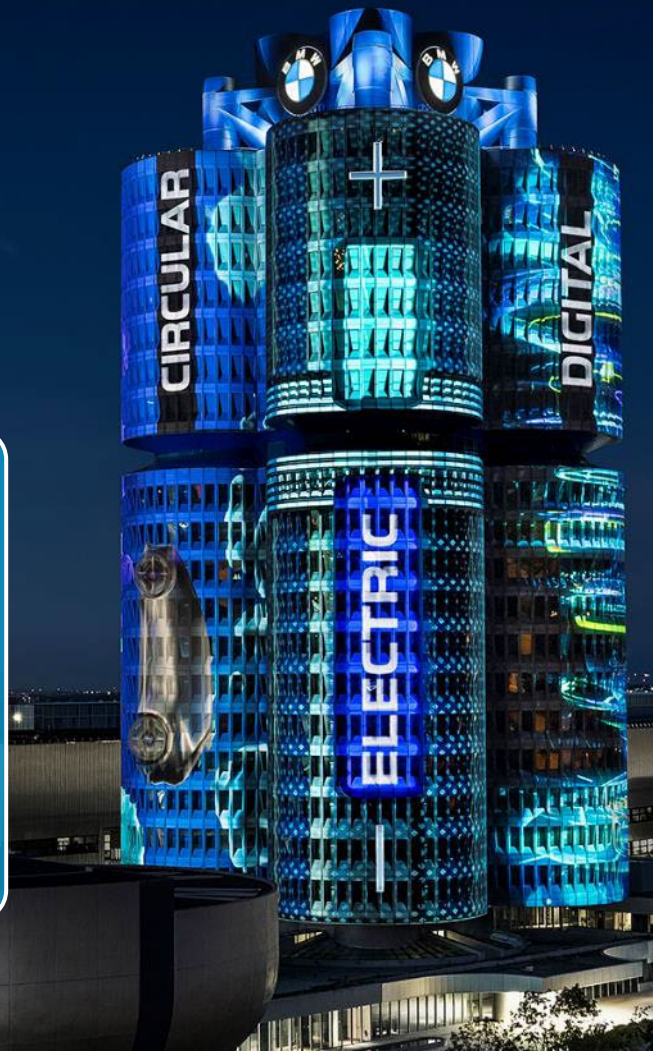
General Program Manager Hydrogen Technology

THE BMW GROUP IS COMMITTED TO THE PARIS AGREEMENT AND THE 1.5 °C TARGET.

- First German OEM to join the "Ambition for 1.5 °C".
- Goal: climate neutrality along the entire value chain by 2050.
- Also part of the UN "Race to Zero" program.

... this requires:

- The use of all available technologies, including BEVs and FCEVs.
- Decarbonization of the entire value chain and life cycle.



MSCI – IMPLIED TEMPERATURE RISE INDEX.
BMW GROUP aligned with Paris Agreement target.



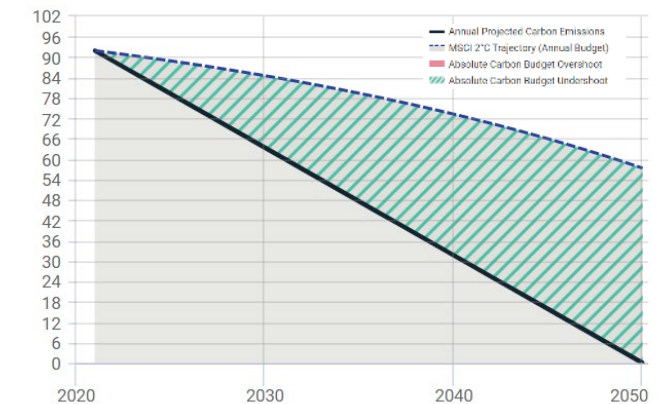
BMW
GROUP



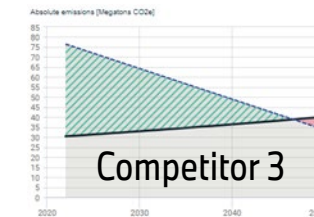
1.5°C

Decarbonisation data
from 4. January 2023

Absolute emissions [Megatons CO2e]



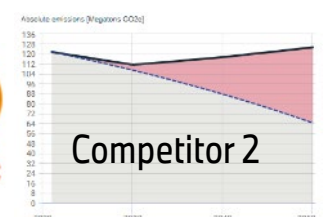
2.0°C



Competitor 3



2.5°C



Competitor 2

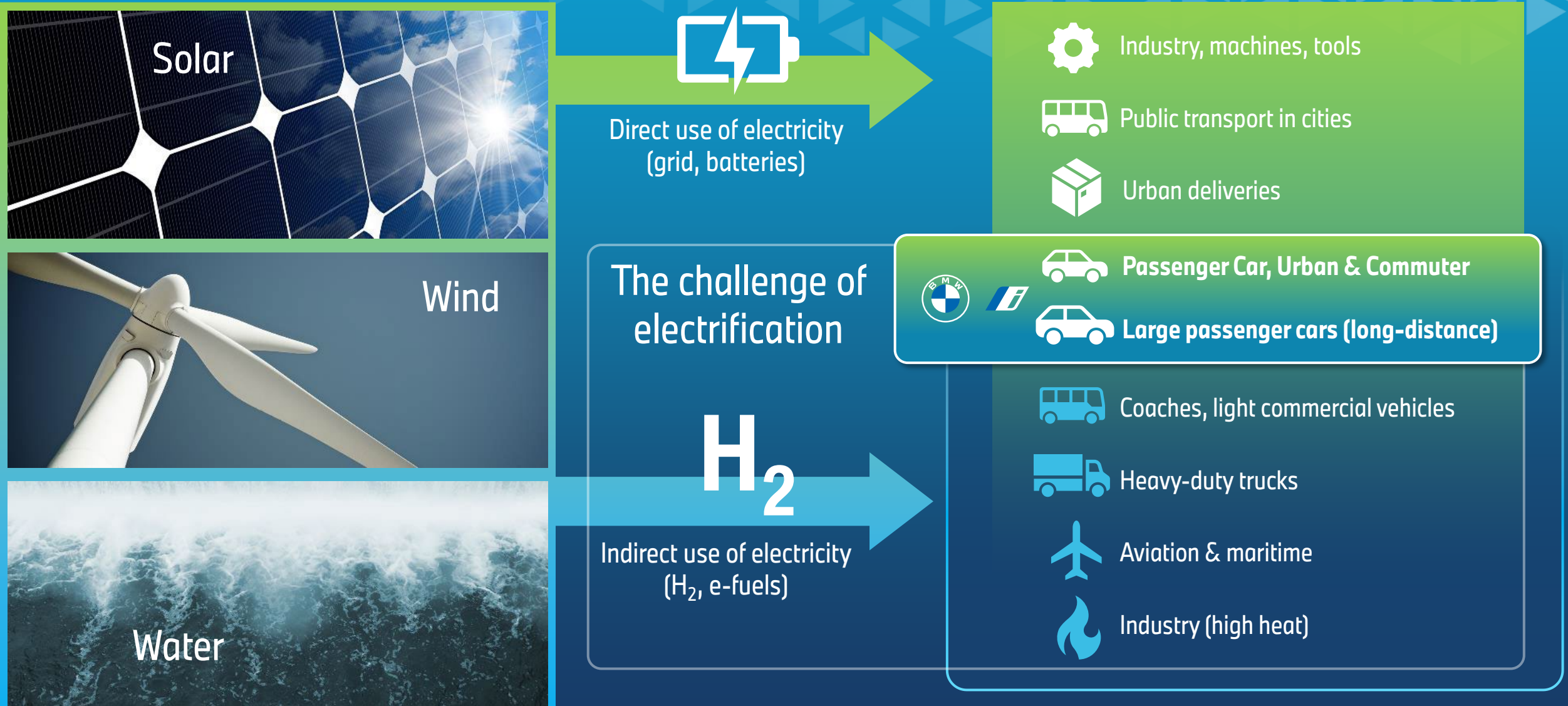


3.3°C



Competitor 1

THE DECARBONIZATION CHALLENGE.



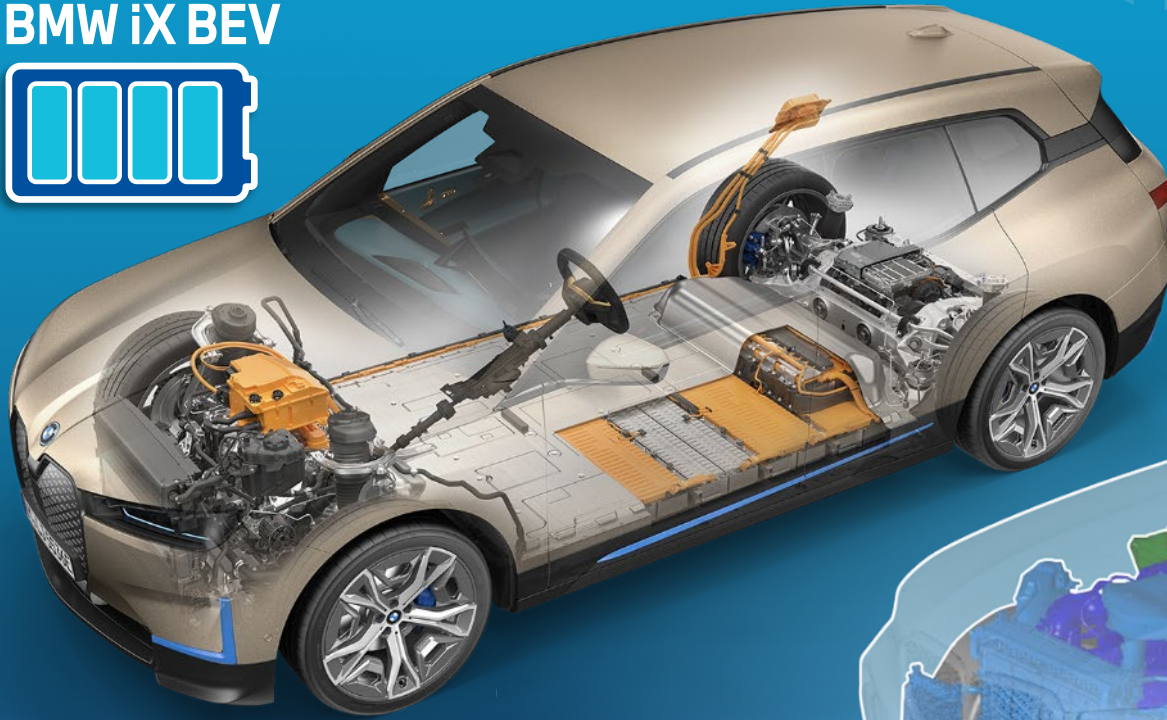
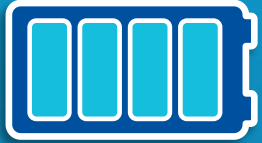
BEVS AND FCEVS COMPLEMENT EACH OTHER.

- **Technology:**
both are EVs – FCEV enables fast refueling.
- **Customer:**
BEVs fulfill most use cases – but not all.
FCEV and BEV combined can help to decarbonize faster.
- **Infrastructure:**
2 are cheaper than 1.
- **Energy system:**
Cost and feasibility are more important than efficiency.
- **Raw materials:**
diversity increases resilience.

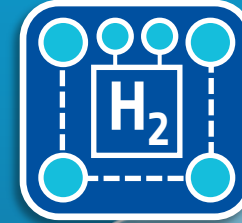


TWO ELECTRIC VEHICLES – DIFFERENT ENERGY STORAGE.

BMW iX BEV



BMW X5 FCEV



HYDROGEN FUEL CELL

CUSTOMER USE CASES OF HYDROGEN VEHICLES.

- > Customers **without convenient access to e-charging.**



- > Customers who require **high flexibility** or travel frequently.



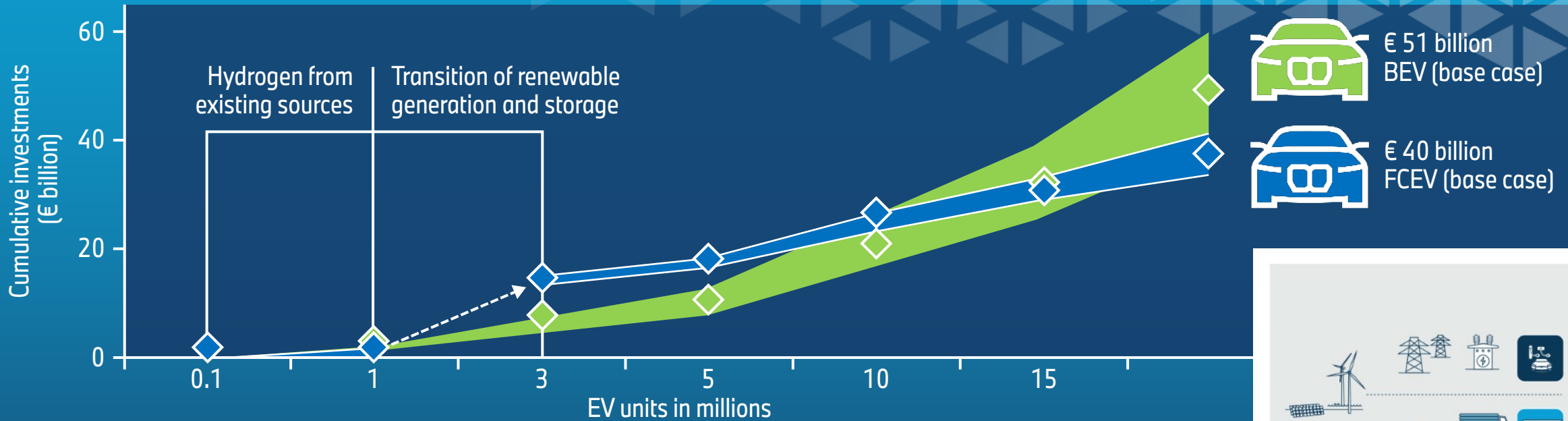
- > Customers in **cold climates** (no range reduction).



- > Customers with regular **towing use cases.**



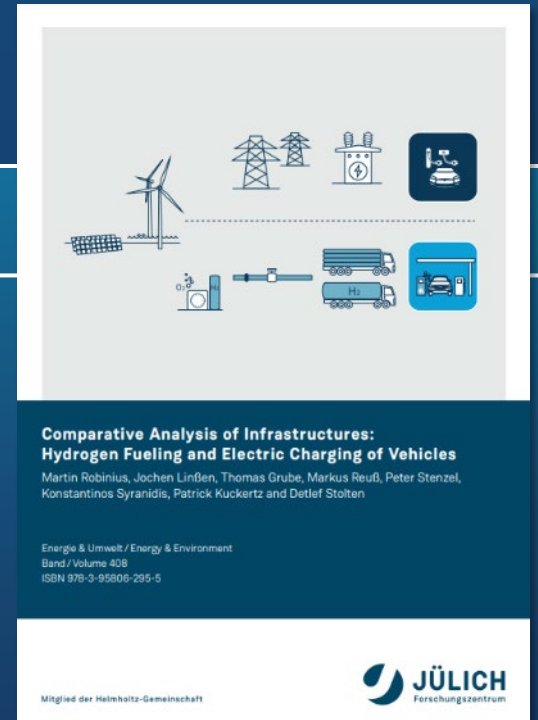
INFRASTRUCTURE PERSPECTIVE: 2 ARE MORE ECONOMICAL THAN 1. EXAMPLE: GERMANY.



» Conclusions

- Initial cost for **electric charging** is low – but it increases non-linearly with the number of vehicles.
- The cost for a hydrogen refueling station depends mainly on the size – and remains constant in the roll-out.

* Source: „Comparative Analysis of Infrastructures for Germany“ (FZ Jülich).



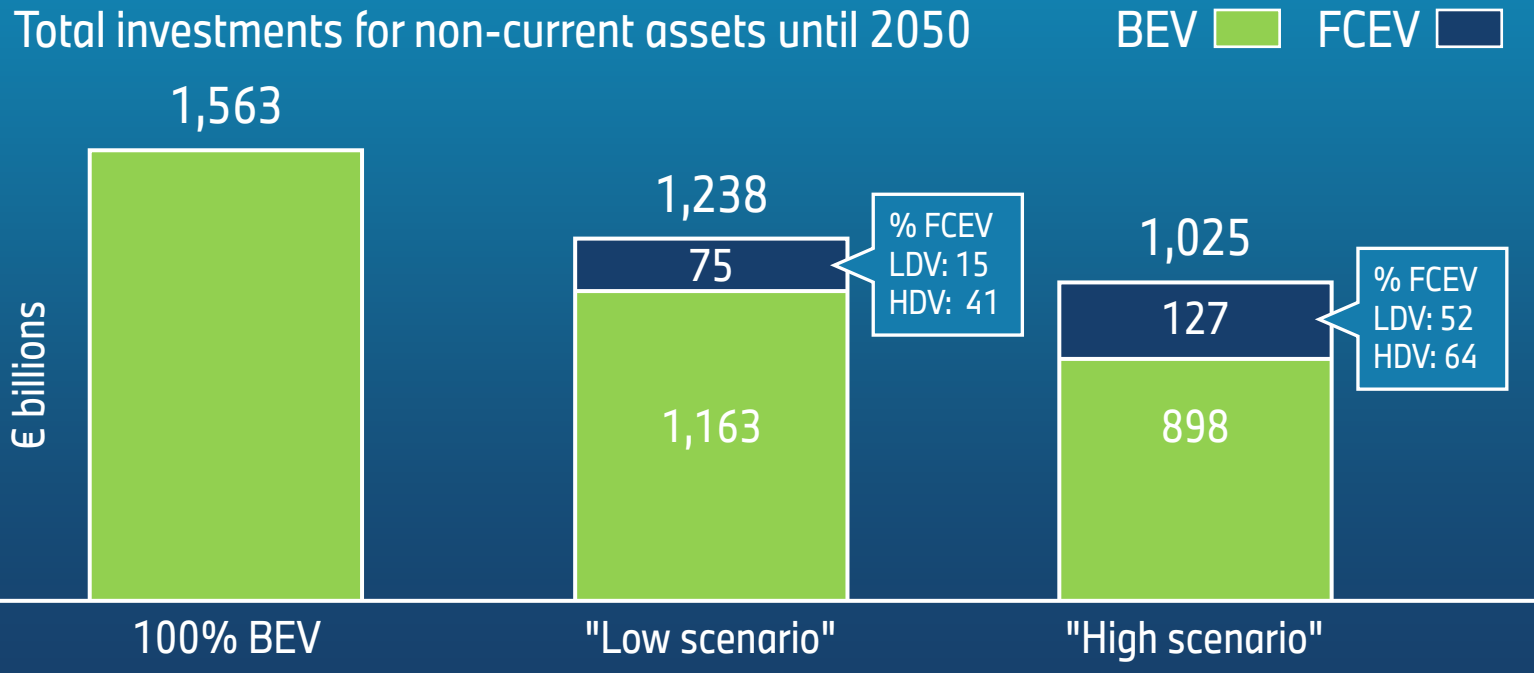
INFRASTRUCTURE PERSPECTIVE: 2 ARE MORE ECONOMICAL THAN 1. EXAMPLE: EUROPE.



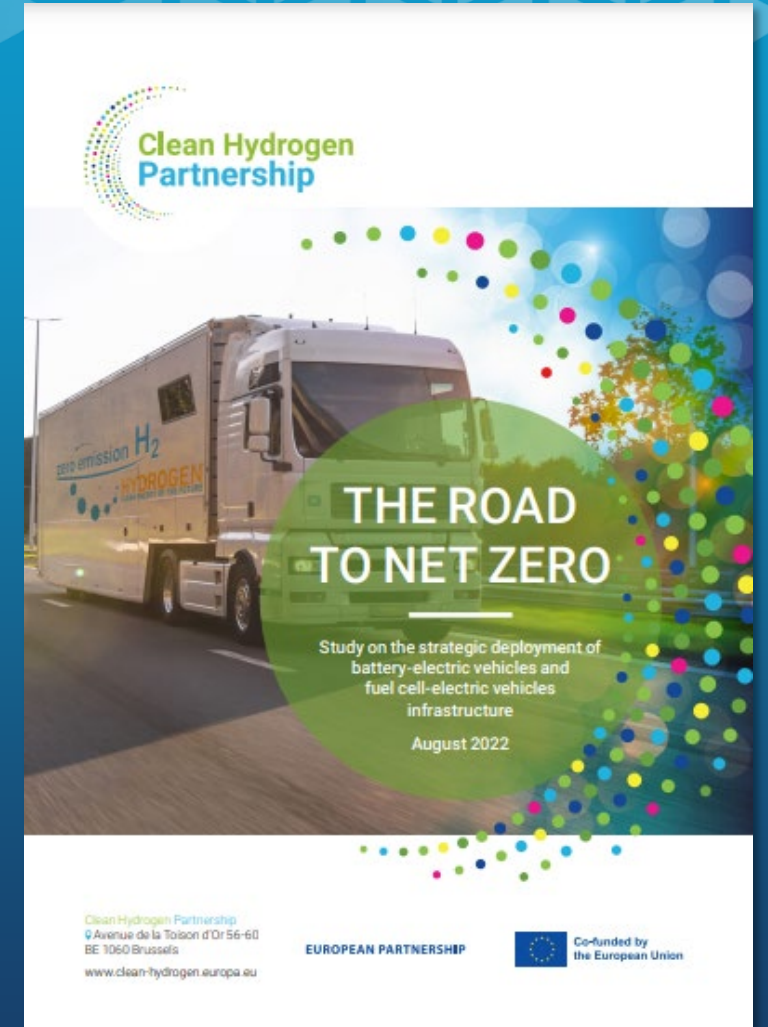
- "Low" scenario costs 20% less than 100% BEV.
- "High" scenario with costs 34% less than 100% BEV.

A combined H₂ refueling infrastructure for commercial vehicles and passenger cars is most cost efficient.

Total investments for non-current assets until 2050



Source: "The Road to net Zero" (McKinsey for Clean Hydrogen Partnership 2022).



A GLOBAL INFRASTRUCTURE NETWORK OF HYDROGEN REFUELING STATIONS IS DEVELOPING WORLDWIDE (AS OF 3/2023).




1000+ Total number of active stations

2020: 545
2021: 690
2022: 1070

+ 25%
+ 55%

276 Stations in Europe and the Middle East

116 Stations in America

-  America
-  Europe and the Middle East
-  Asia and Pacific
-  Total number of HRS in use

Hydrogen Council: H2 Insights, March 2023 Update
+ <https://h2tools.org/hyarc/hydrogen-data/international-hydrogen-filling-stations>

H₂
Hydrogen

650+ Stations in Asia and Pacific

300+

210

163

8
Canada

107
USA

Costa Rica 1

Brazil 1

2
Iceland

United Kingdom 12

Norway 8

Sweden 4

Latvia 1

Netherlands 7

Denmark 7

Belgium 5

Czech Republic 7

Austria 7

Hungary 1

Switzerland 13

France 56

Germany 105

Croatia 1

Spain 3

Italy 1

Saudi Arabia 1

India 2

Malaysia 1

Australia 5

China 300+

Taiwan 1

South Korea 210

Japan 163

INFRASTRUCTURE: EUROPEAN PERSPECTIVE.



- EU: Until end of 2030, hydrogen refueling stations will be built at intervals of 200 km and at every urban node. That includes 700 bar points for passenger cars. In total over 600 hydrogen refueling stations.
- Many modern European Hydrogen Refueling stations already feature:
 - ✓ 24/7 automated operation (refueling done by driver/customer)
 - ✓ High availability (shown online in H2-Mobility databank, with maintenance announced ahead)
 - ✓ New station or add-on to existing stations



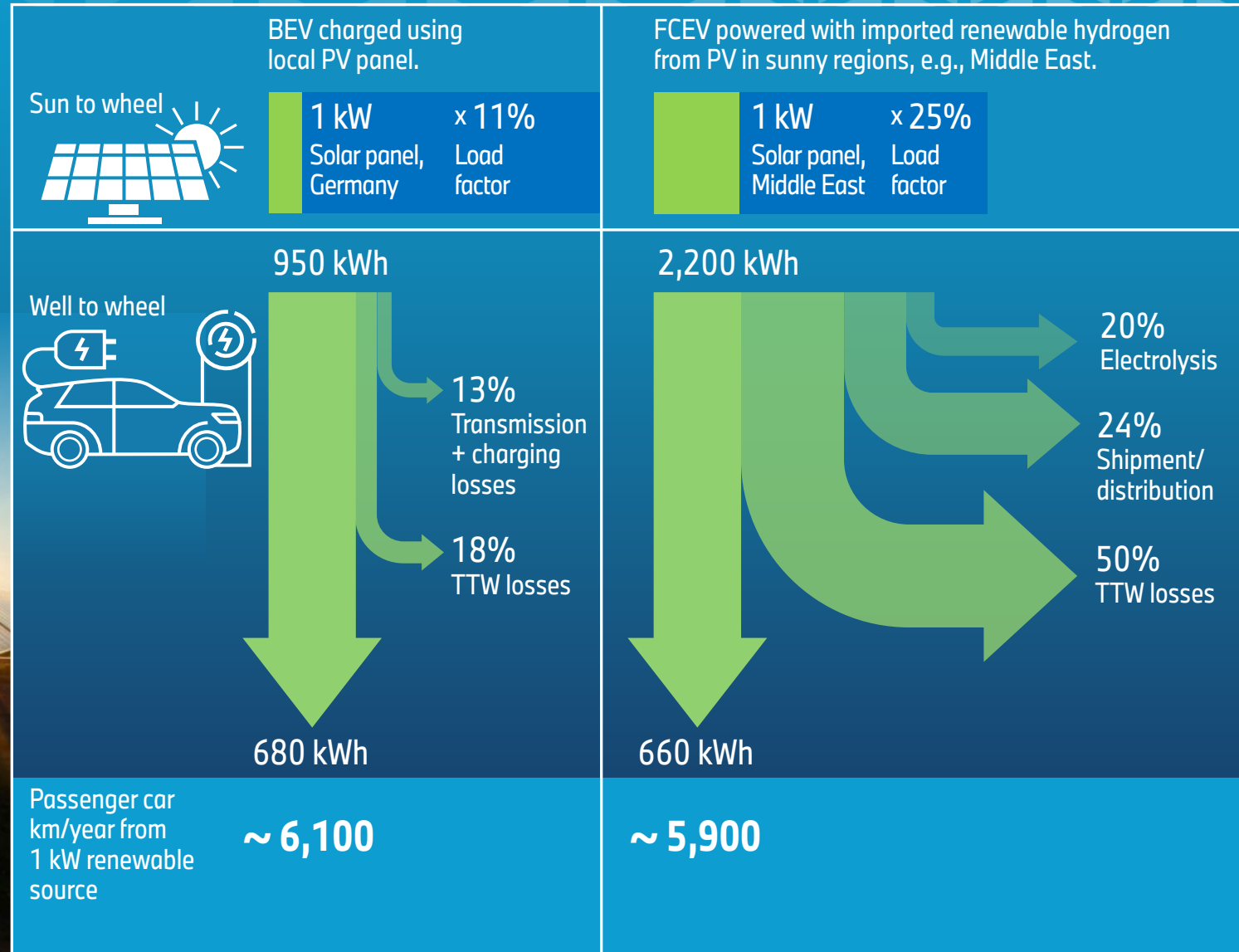
Cars & vans use 700 bar worldwide.
Depending on the manufacturer, buses and trucks use 350 bar or 700 bar.

ENERGY SYSTEM: "SUN-TO-WHEEL".

- BEVs are more efficient than FCEVs due to the conversion losses.
- Higher yield of renewable energy production in certain regions compensates for the losses.
- **Cost and feasibility are more important than efficiency.**



Source: "Roadmap towards zero emissions"
(McKinsey for Hydrogen Council 2021).



ENERGY SYSTEM. CURTAIL OR PRODUCE H₂?

- Renewable energy production fluctuates → more production capacity required than average consumption.
- Excess energy can be curtailed – or used to produce hydrogen.
- 10% extra is available at least – almost for free (after the investment).
- ~ 5,8 TWh not fed into the grid in 2022.
- ~ 100.000 tons of



<https://de.statista.com/statistik/daten/studie/617949/umfrage/einspeisemanagement-in-deutschland/>

BEV charged using local PV panel; peak supplies renewable hydrogen for FCEV fuelling.

1 kW	× 11 + 2%
Solar panel, Germany	Load factor

950 kWh

+ 200 kWh

13%
Transmission
+ charging
losses

18%
TTW losses

Curtailement
Renewable
curtailment at peak
times to prevent grid
overloading can be
offset by producing
hydrogen instead.

680 kWh

+ 70 kWh

~ 6,100

+ ~ 600



HIGHER PERSPECTIVE THAN EFFICIENCY: GREEN HOUSE GAS EMISSION LIFE CYCLE ANALYSIS.

- FCEV and BEV are similar in LCA, as several studies and assessments have shown.
- BEVs and FCEVs only help decarbonise road transport when produced and operated with renewable or low-carbon energy.
- Even when accounting for the additional emissions from long-distance LH₂ shipping, FCEV and BEV have similar lifecycle emissions.

Production



Use Phase



Recycling



¹ ADAC: <https://www.adac.de/verkehr/tanken-kraftstoff-antrieb/alternative-antriebe/klimabilanz/>

² Fraunhofer: https://www.ise.fraunhofer.de/content/dam/ise/de/documents/news/2019/ISE_LCA-BEV-FCEV-Results.pdf

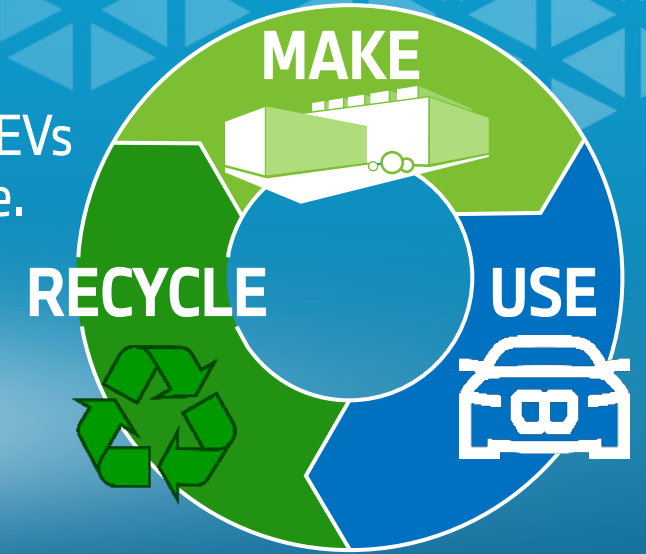
³ HydrogenCouncil: <https://hydrogencouncil.com/wp-content/uploads/2021/10/Transport-Study-Full-Report-Hydrogen-Council-1.pdf>

LIFE CYCLE AND RAW MATERIALS PERSPECTIVE: DIVERSITY INCREASES RESILIENCE.

➤ Diversity increases resilience
and decreases risk.



➤ Circularity is
important for BEVs
and FCEVs alike.



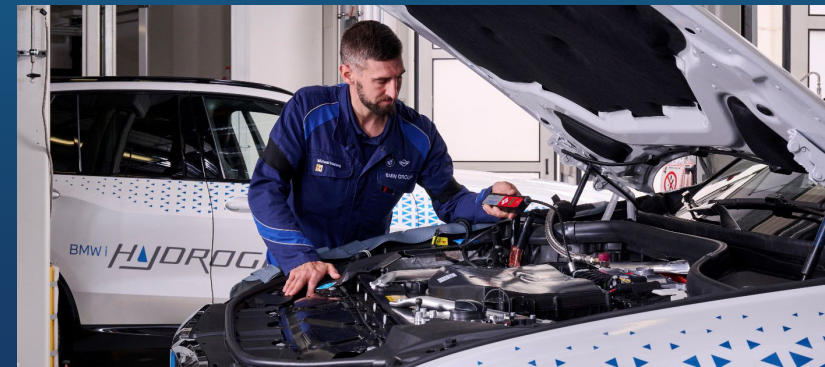
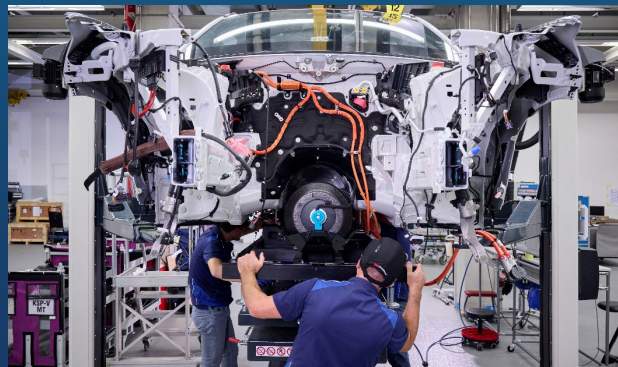
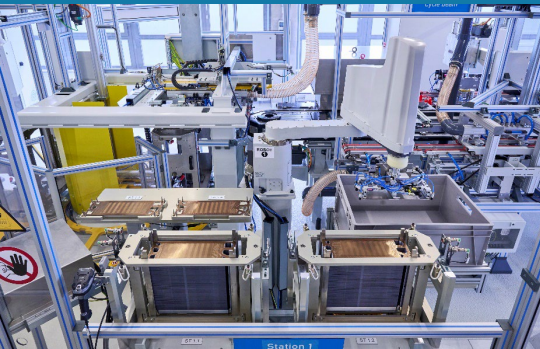
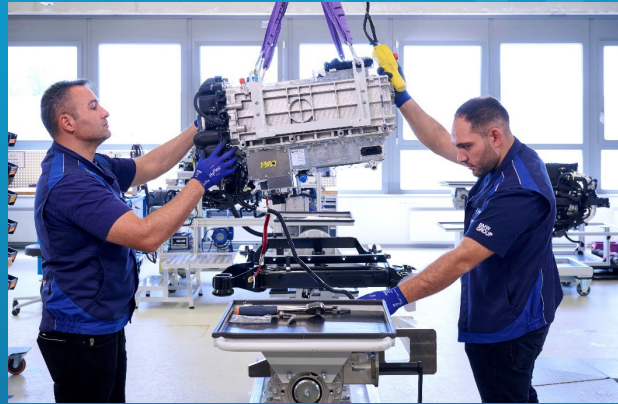
➤ FCEV need > **100kg**
less raw materials
than BEVs.

➤ FCEV batteries need **90% less** critical raw materials
than BEV batteries.

➤ Platinum (main raw material for fuel cells)
already has high recycling rate, which will
increase with phase-out of combustion engines.



PRODUCTION OF THE BMW iX5 HYDROGEN AND THE BMW-DEVELOPED FUEL CELL SYSTEMS TAKES PLACE IN-HOUSE.



BMW
GROUP



BMW iX5 HYDROGEN.

THE EV WITH FAST REFUELING.

ROBERT HALAS

Project Manager iX5 Hydrogen

BMW iX5 HYDROGEN. ALL ADVANTAGES OF ELECTRIC DRIVING.



➤ Hydrogen fuel cell technology provides all advantages of electric driving.

➤➤ Great acceleration ➤➤ Zero emission ➤➤ Smooth, silent ride

BMW i **HYDROGEN**
FUEL CELL

BMW iX5 HYDROGEN. REFUELING WITH HYDROGEN IS EASY.

- The main advantage of a hydrogen powertrain is fast refueling.
- Filling up the hydrogen tanks only takes three to four minutes.



BMW iX5 HYDROGEN.
BMW DRIVING DYNAMICS.

WORLD'S MOST POWERFUL
PASSENGER VEHICLE
FUEL CELL SYSTEM



HIGH POWER
BATTERY



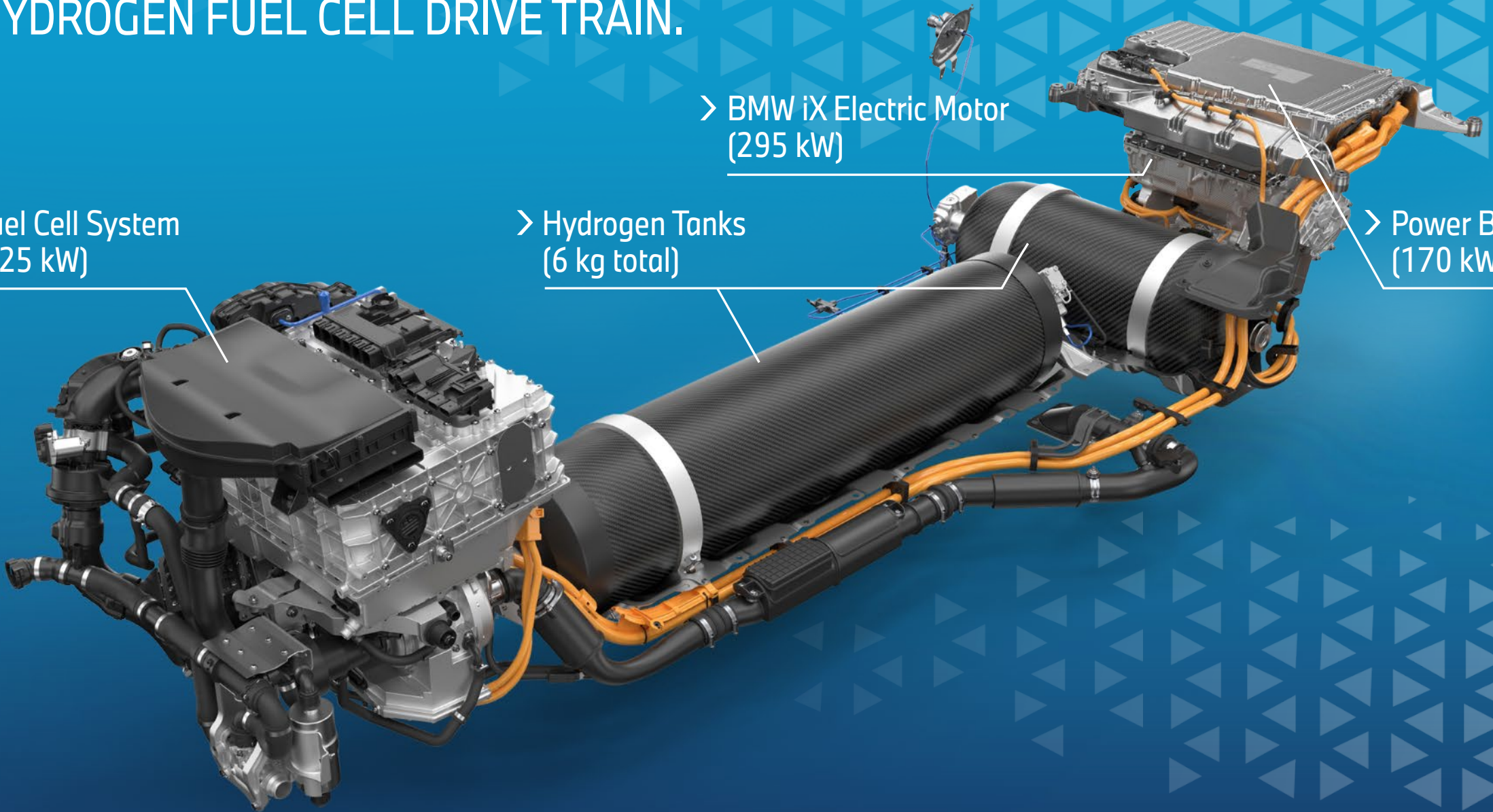
BMW iX5 HYDROGEN. HYDROGEN FUEL CELL DRIVE TRAIN.

> Fuel Cell System
(125 kW)

> Hydrogen Tanks
(6 kg total)

> BMW iX Electric Motor
(295 kW)

> Power Battery
(170 kW)



BMW iX5 HYDROGEN. HYDROGEN FUEL CELL SYSTEM.

Cooling system

High-voltage coolant pump

Media interface unit

Control unit

Hydrogen line

Fuel cell stack

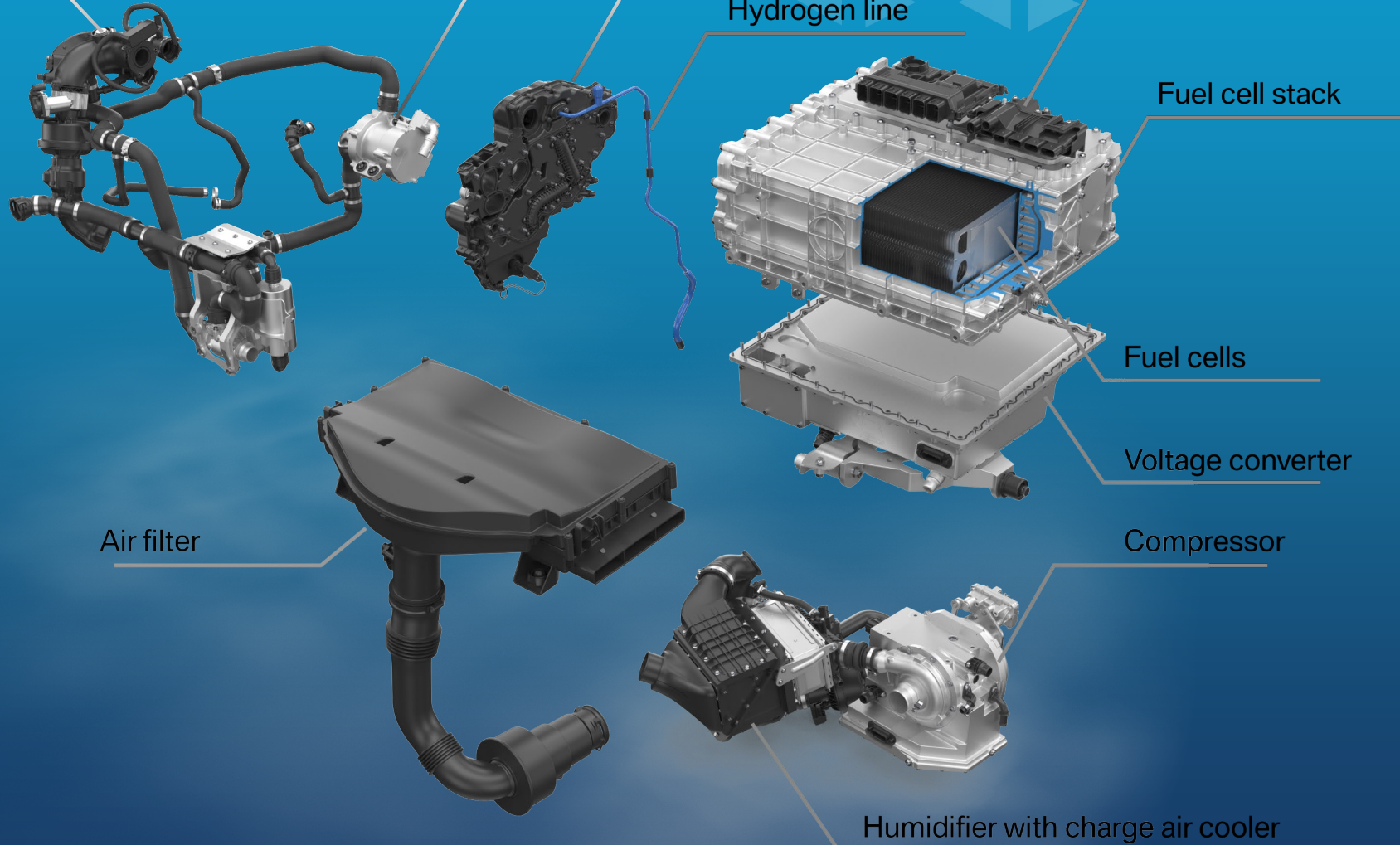
Fuel cells

Voltage converter

Compressor

Humidifier with charge air cooler

Air filter



BMW iX5 HYDROGEN. TECHNICAL DATA.

Electrical power fuel cell	125 kW / 170 hp
Total power output	295 kW / 401 hp
Hydrogen tank capacity	≈ 6 kg
Range (WLTP)	≈ 500 km
Maximum speed	≈ 185 km/h
Acceleration (0-100 km/h)	< 6 s
Vehicle weight	≈ comparable PHEV < comparable BEV

HYDROGEN FUEL CELL



BMW iX5 HYDROGEN. SPECIFIC EXTERIOR AND INTERIOR DESIGN ELEMENTS.



BMW iX5 HYDROGEN EXTENSIVE TESTING OVER THE PAST 4 YEARS HAS BEEN SUCCESSFULLY COMPLETED.

