BMW GROUP

BMW iX5 HYDROGEN.

THE EV WITH FAST REFUELING.

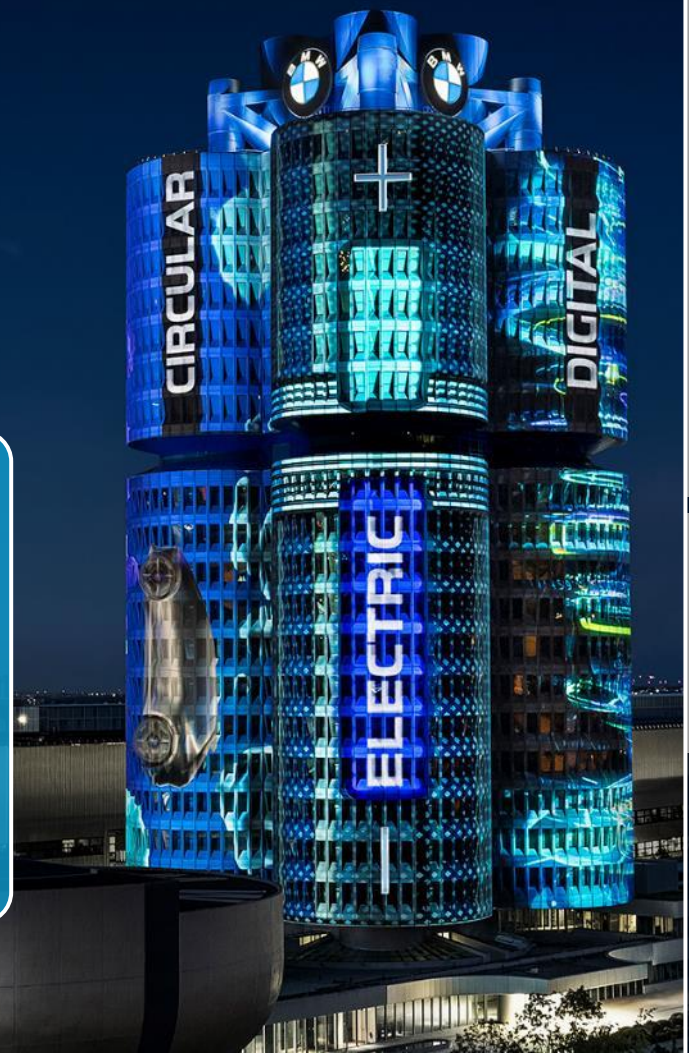
DR. JÜRGEN GULDNER
General Program Manager Hydrogen Technology

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.

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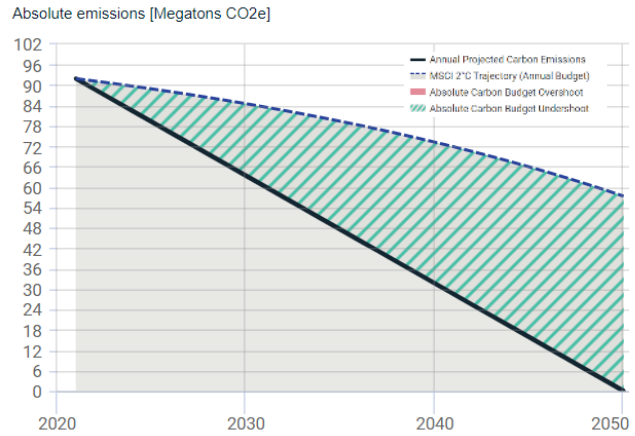
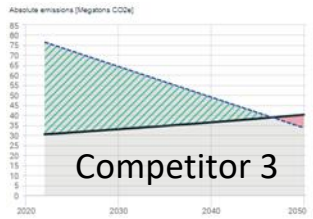
1.5°C

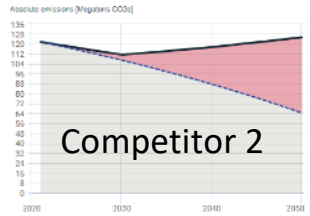
Decarbonisation data from 4. January 2023



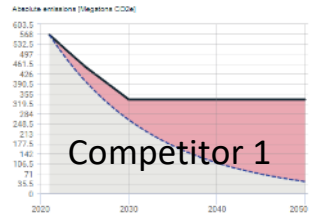
2.0°C



2.5°C



3.3°C



THE DECARBONIZATION CHALLENGE.

Direct use of electricity
(grid, batteries)

The challenge of electrification

H_2

Indirect use of electricity
(H_2, e-fuels)

- Industry, machines, tools
- Public transport in cities
- Urban deliveries
- **Passenger Car, Urban & Commuter**
- **Large passenger cars (long-distance)**
- Coaches, light commercial vehicles
- Heavy-duty trucks
- Aviation & maritime
- Industry (high heat)

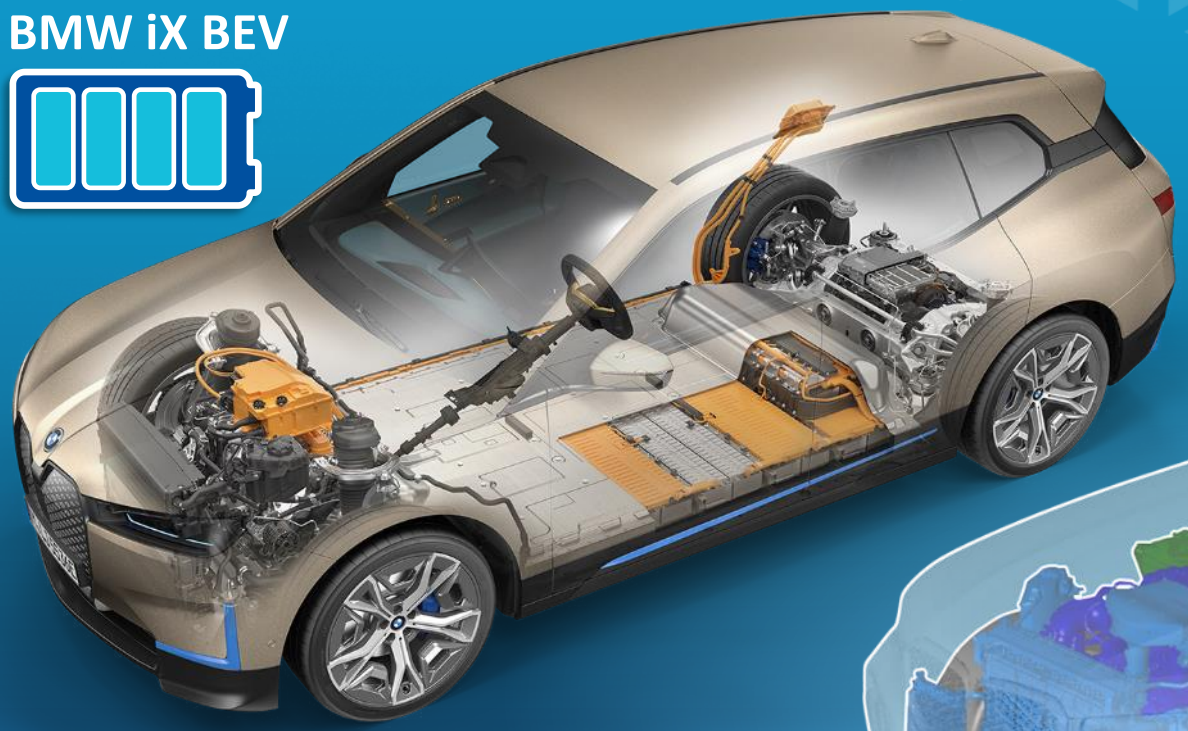
BEVS AND FCEVS COMPLEMENT EACH OTHER.

- **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.

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

TWO ELECTRIC VEHICLES – DIFFERENT ENERGY STORAGE.

BMW iX BEV



BMW X5 FCEV

HYDROGEN FUEL CELL

CUSTOMER USE CASES OF HYDROGEN VEHICLES.

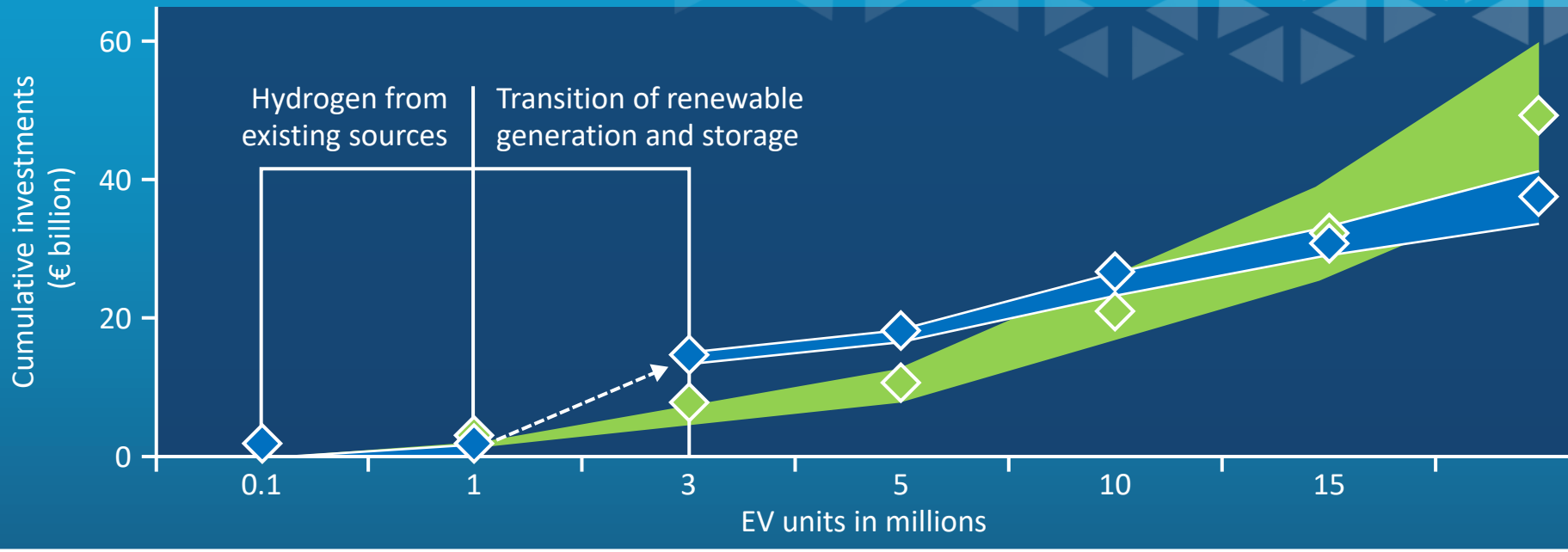
- Customers **without convenient access to e-charging**.

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

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

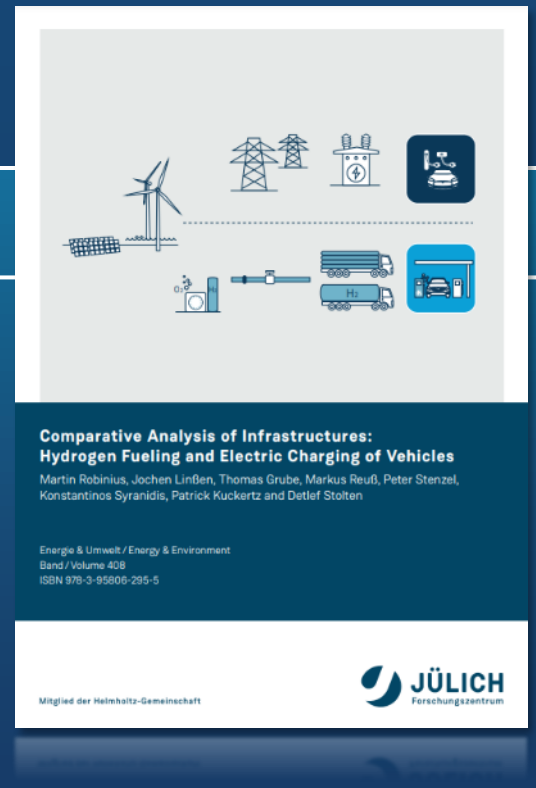
- Customers with regular **towing use cases**.

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



€ 51 billion
BEV (base case)

€ 40 billion
FCEV (base case)



Conclusions

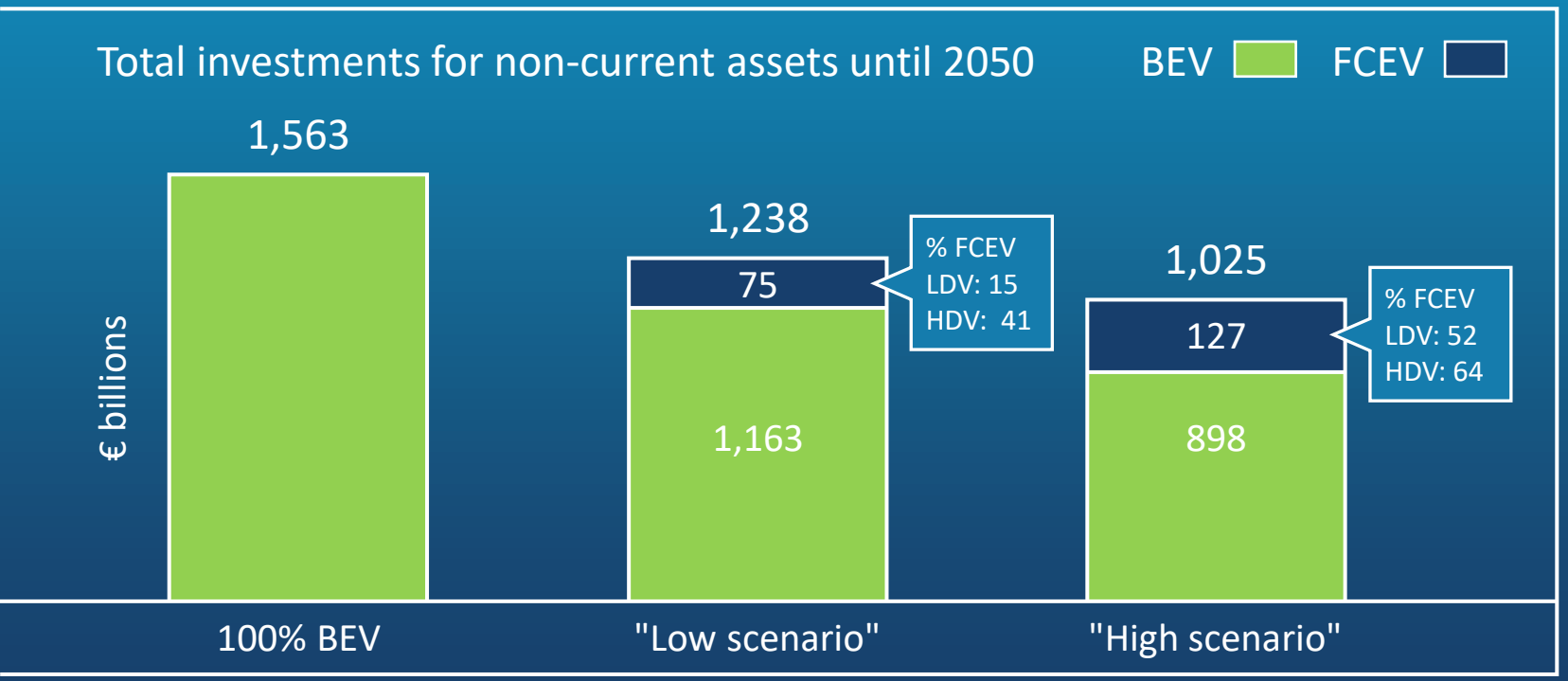
- Initial cost for **electric charging** is low – but it increases non-linearly with the number of vehicles.
- The cost for a hydrogen refueling station depends mainly on the size – and remains constant in the roll-out.

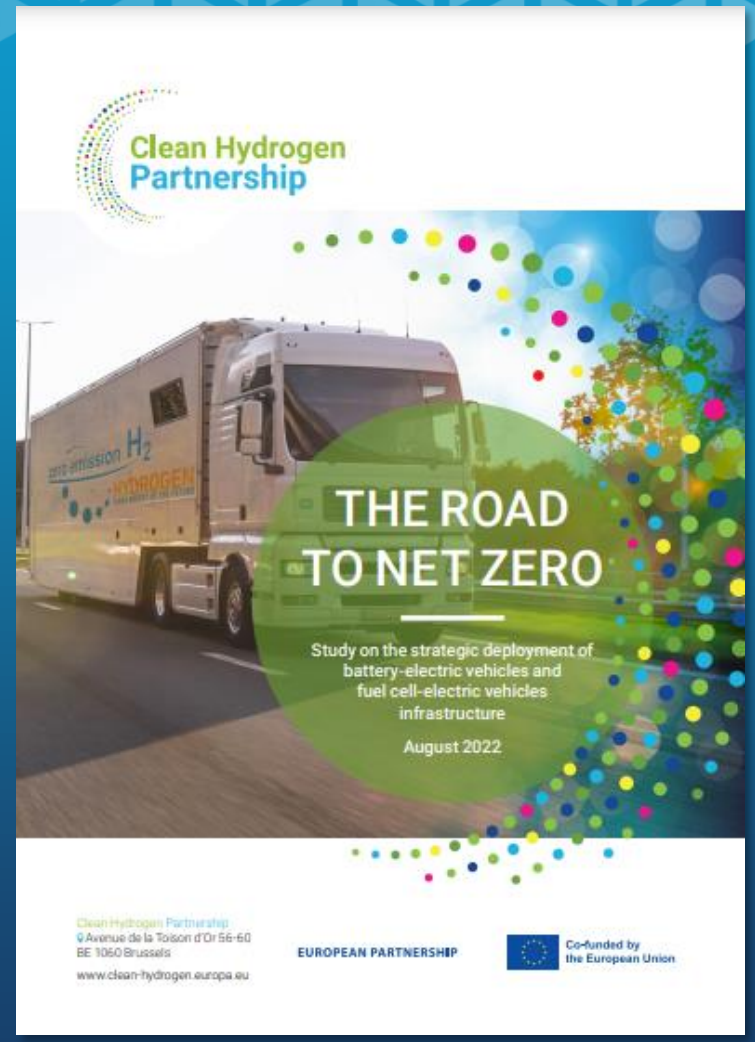
* Source: „Comparative Analysis of Infrastructures for Germany“ (FZ Jülich).

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 H_2 refueling infrastructure for commercial vehicles and passenger cars is most cost efficient.





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** + 25%
2021: **690** + 55%
2022: **1070**

276 Stations in Europe and the Middle East

116 Stations in America

650+ Stations in Asia and Pacific

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

Iceland 2
Canada 8
USA 107
Costa Rica 1
Brazil 1
United Kingdom 12
Norway 8
Sweden 4
Latvia 1
Netherland s 37
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
China 300+
Taiwan 1
South Korea 210
Japan 163
Malaysia 1
Australia 5

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

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).

	BEV charged using local PV panel.	FCEV powered with imported renewable hydrogen from PV in sunny regions, e.g., Middle East.
Sun to wheel	1 kW Solar panel, Germany x 11% Load factor	1 kW Solar panel, Middle East x 25% Load factor
Well to wheel	950 kWh → 13% Transmission + charging losses; 18% TTW losses → 680 kWh	2,200 kWh → 20% Electrolysis; 24% Shipment/ distribution; 50% TTW losses → 660 kWh
Passenger car km/year from 1 kW renewable source	**~ 6,100**	**~ 5,900**

ENERGY SYSTEM. CURTAIL OR PRODUCE H_2?

- 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** H_2

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

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

950 kWh → 680 kWh

+ 200 kWh → + 70 kWh

13% Transmission + charging losses

18% TTW losses

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

~ 6,100 | **+ ~ 600**

Sources:
"Roadmap towards zero emissions" (McKinsey for Hydrogen Council 2021).
https://de.statista.com/statistik/daten/studie/617949/umfrage/einspeisemanagement-in-deutschland/

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 LH_2 shipping, FCEV and BEV have similar lifecycle emissions.

Production

Use Phase

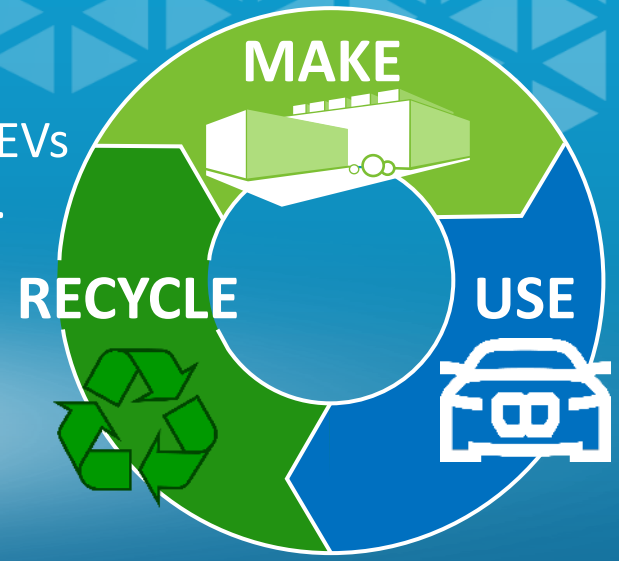
Recycling

[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.

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BMW iX5 HYDROGEN.

THE EV WITH FAST REFUELING.

ROBERT HALAS
Project Manager iX5 Hydrogen

BMW iX5 HYDROGEN.
ALL ADVANTAGES OF ELECTRIC DRIVING COMBINED WITH FAST FUELING.

- Great acceleration
- Zero emission
- Smooth, silent ride
- 3-4 minutes fueling

BMW i HYDROGEN FUEL CELL

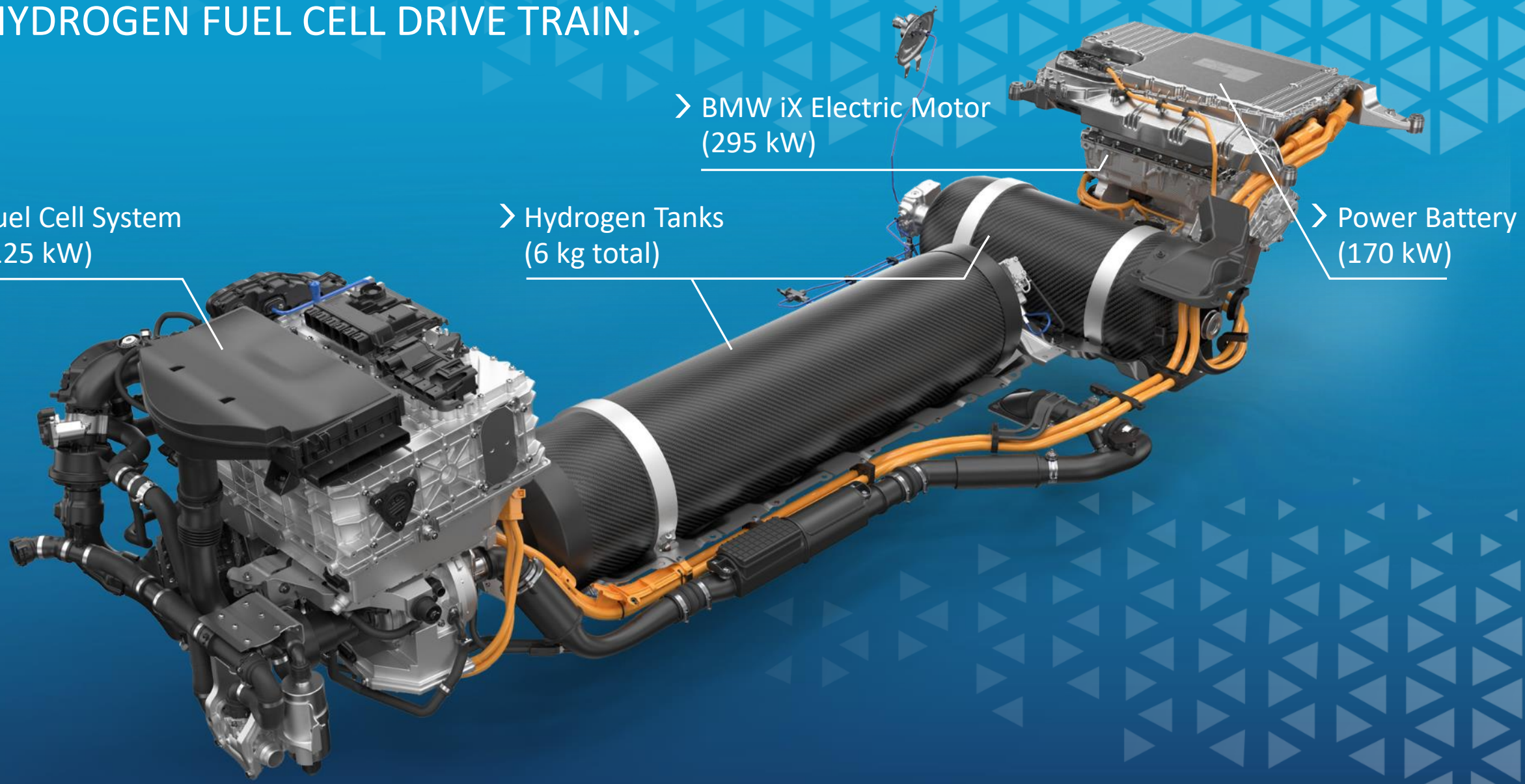
BMW iX5 HYDROGEN.
BMW DRIVING DYNAMICS.

WORLD‘S MOST POWERFUL PASSENGER VEHICLE FUEL CELL SYSTEM

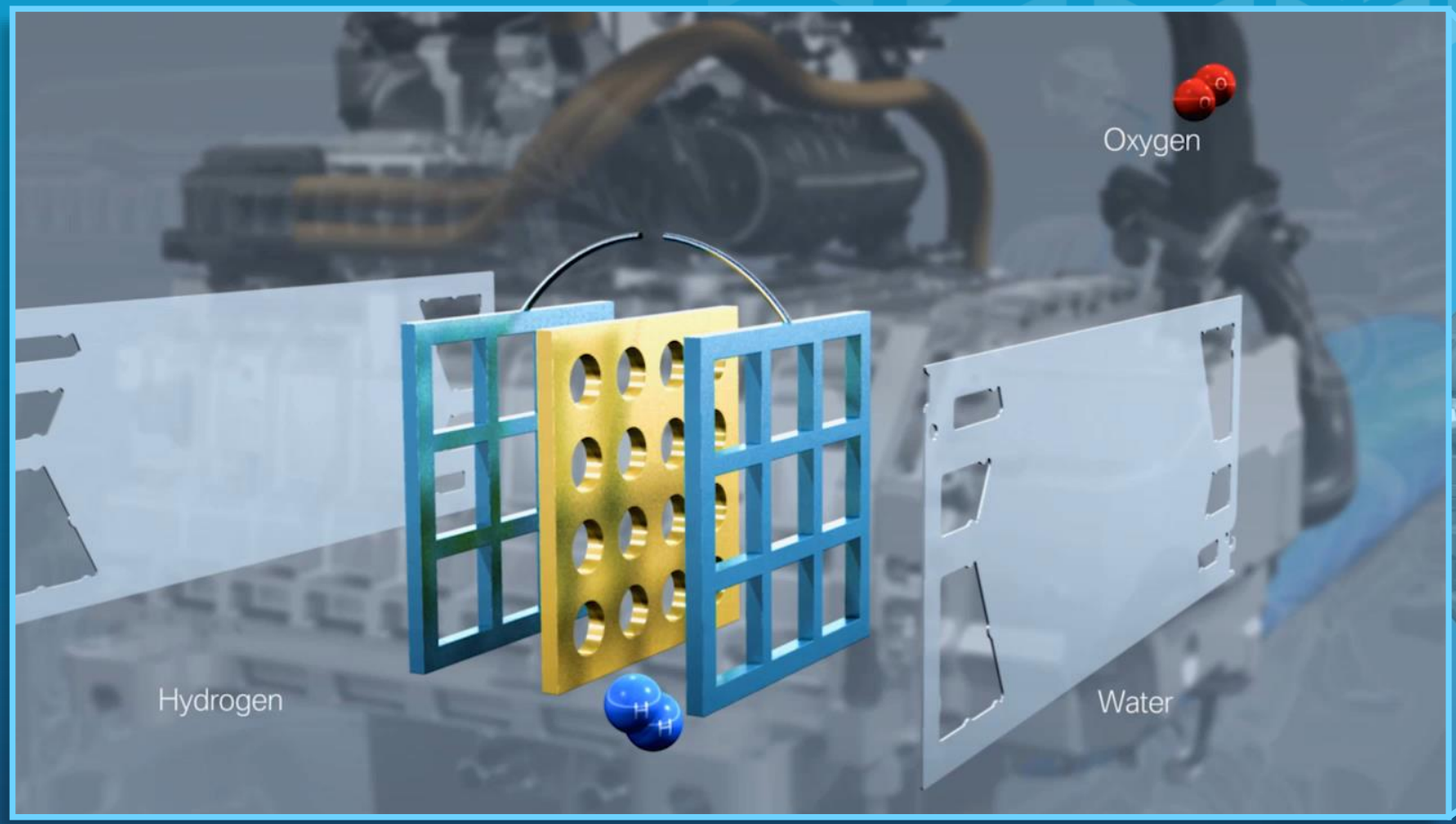
+

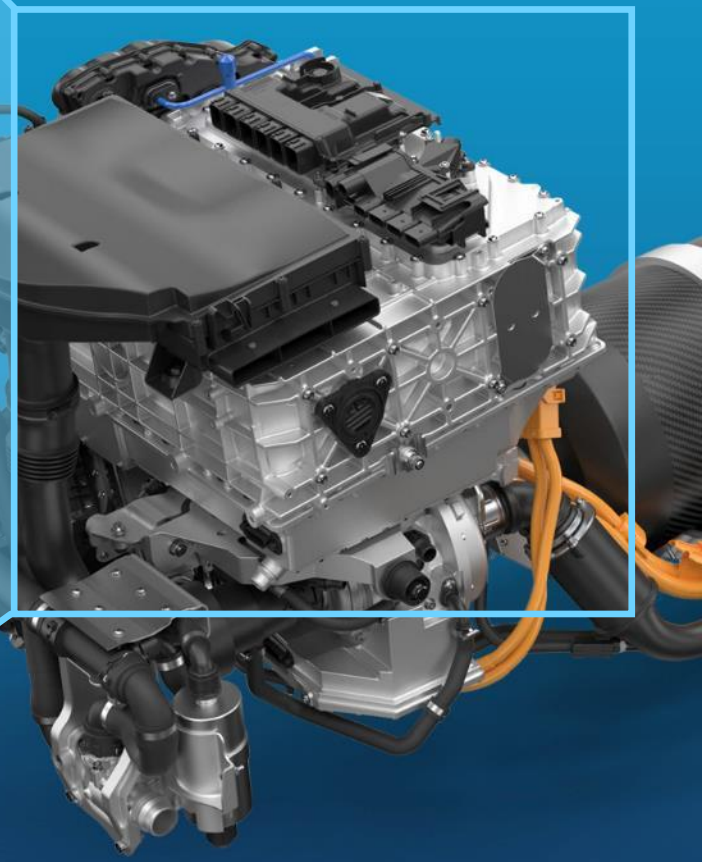
HIGH POWER BATTERY

BMW iX5 HYDROGEN.
HYDROGEN FUEL CELL DRIVE TRAIN.



BMW iX5 HYDROGEN.
FUEL CELL TECHNOLOGY.





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.

THE BMW iX5 HYDROGEN PILOT FLEET VEHICLES FULFILL ALL SAFETY STANDARDS REQUIRED.

- The iX5 Hydrogen fulfills highest safety standards as any other vehicle of the BMW Group like:
  - Crash tests.
  - Hydrogen leakage tests.
  - Cold and hot climate tests.
  - Vehicle life time endurance and stress tests.

- Rigorous certification according to international regulations for H_2-components (GTR, R 134 etc.) implemented, e.g:
  - Pressure tests.
  - Life time cycling tests.
  - Fire tests.

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