McKinsey & Company

Hydrogen

Eine Roadmap zur wettbewerbsfähigen Dekarbonisierung von Transport, Industrie und Energie

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Hydrogen can play seven roles in the energy transition

Roles of hydrogen in the energy transition

Enable the renewable energy system

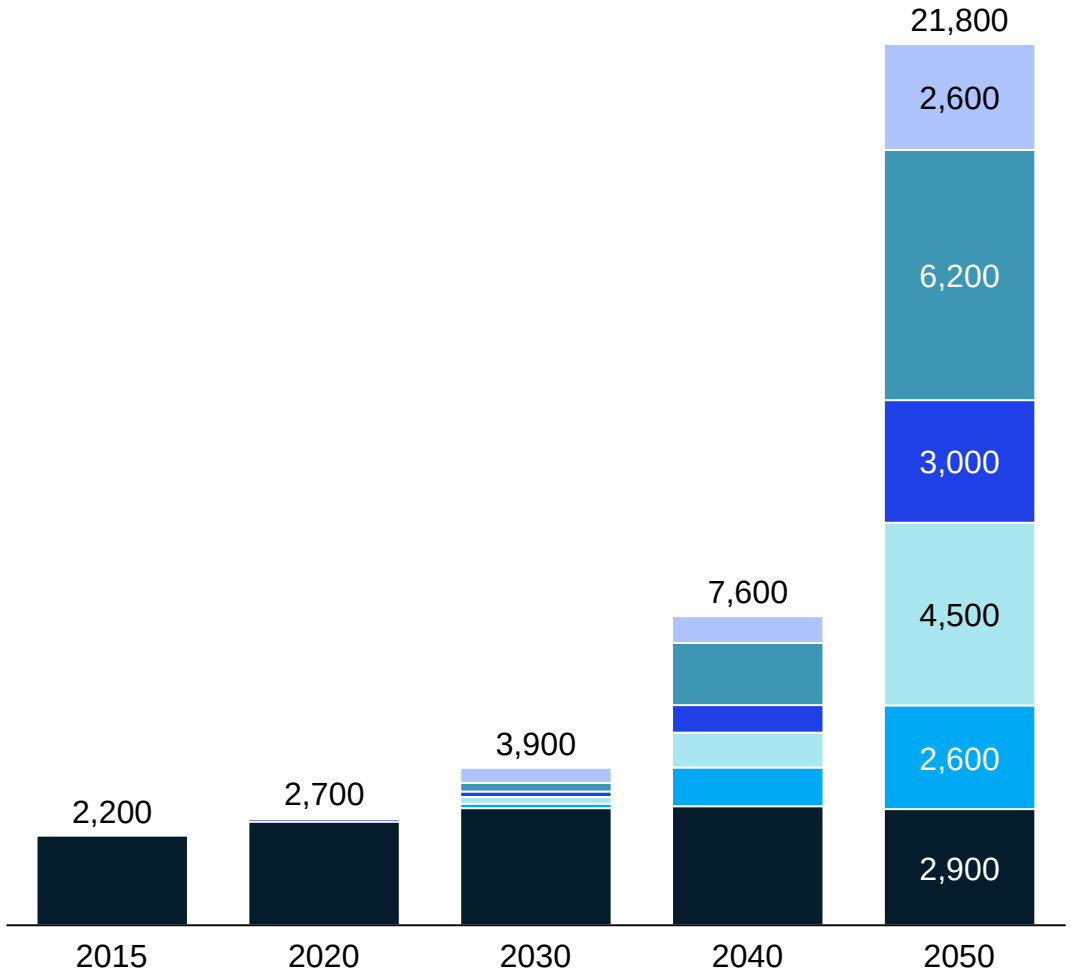
- Enable large-scale renewables integration and power generation
- Distribute energy across sectors and regions
- Buffer to increase system resilience

Decarbonize end uses, especially in hard-to-abate sectors

- Decarbonize transportation
- Help decarbonize building heating and power
- Decarbonize industry energy use
- Serve as renewable feedstock

Across all applications, global hydrogen demand could grow 10-fold

Global energy demand supplied with hydrogen, TWh



Power generation, buffering

Transportation

Building heating and power

Industry energy

New feedstock (CCU, DRI)

Existing feedstock uses

18%

of final energy demand

6 Gt

annual CO_2 abatement

$2.5 tn

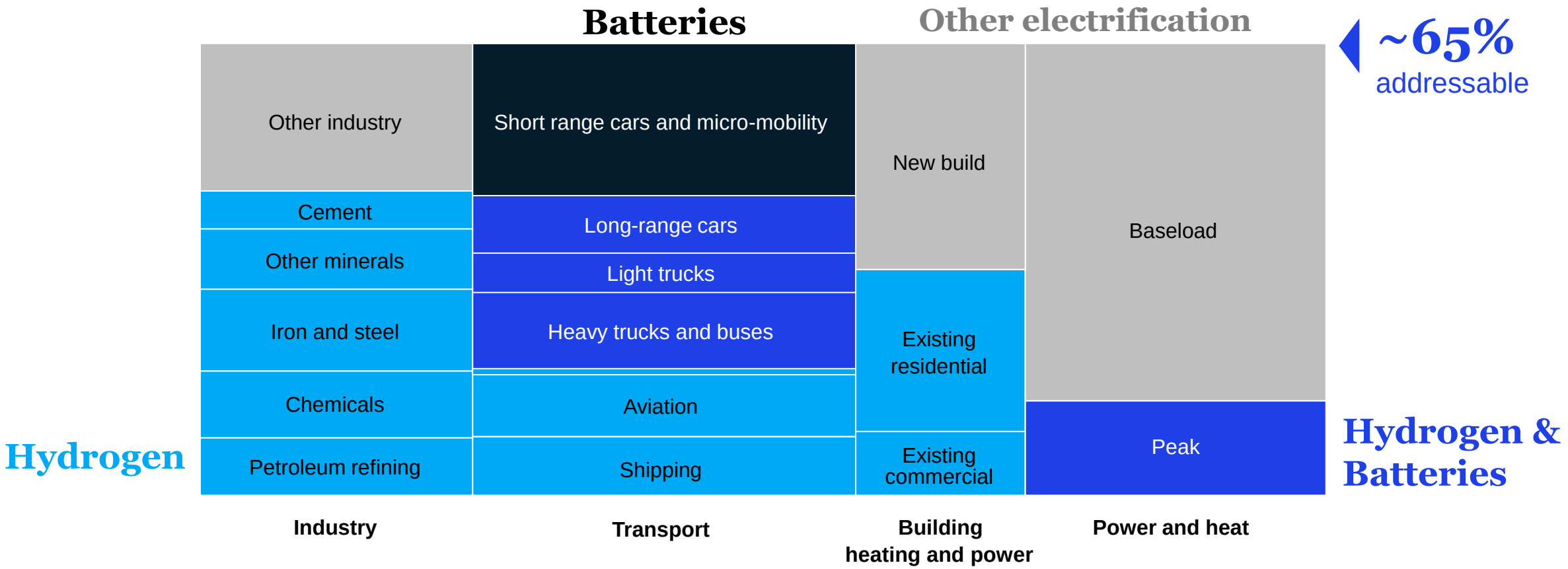
annual sales (hydrogen and equipment)

30 m

jobs created

Hydrogen is required to achieve far-reaching electrification

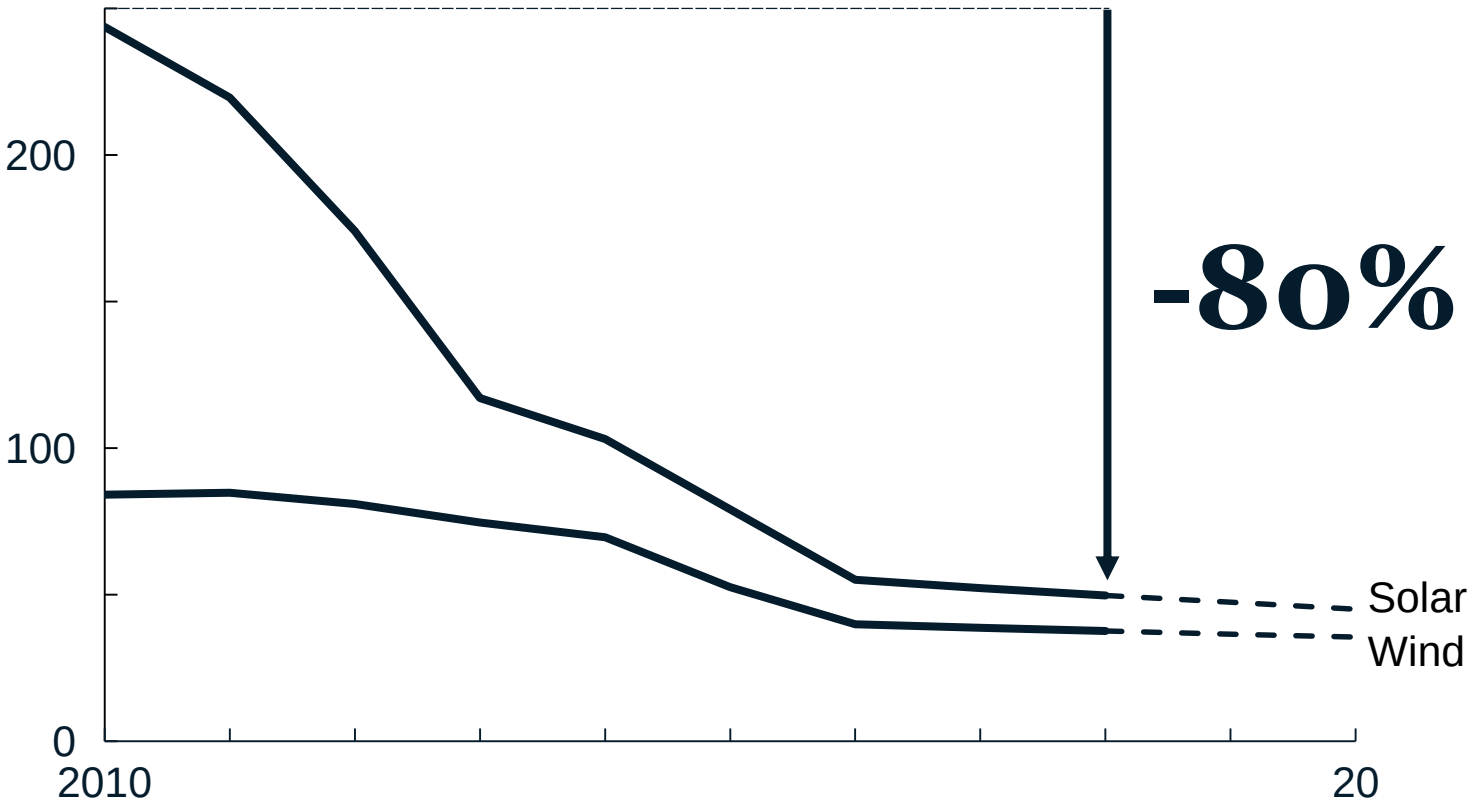
Energy-related CO_2 emissions by sector, European Union, MtCO2e (total: 3.8 GT CO_2e)



Renewables costs have fallen faster than projected…

Global average power prices

USD/MWh, 2010-20E



… leading to an increase in global capacity and lower electrolysis costs

14x

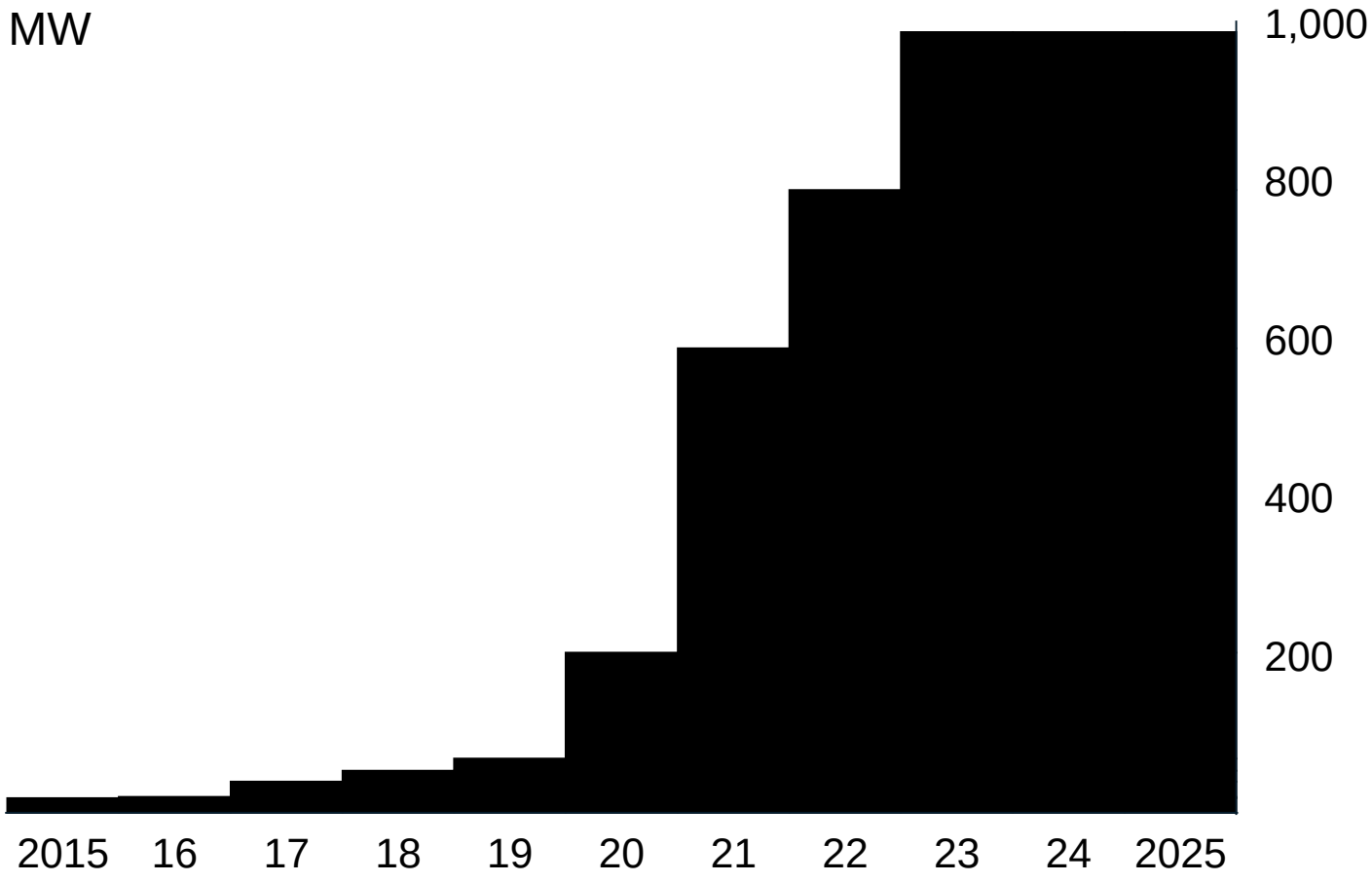
Global cumulative installed PV capacity forecast for 2030 in 2017 versus 2006

70%+

Share of electrolysis-based H2 production costs dependent on energy price

…leading to a steep increase in expected electrolyzer capacities

Global installed/expected capacity of electrolyzers (announced projects)



1 GW+

Electrolysis capacity in already announced projects by 2025

10 GW+

Government targets for Europe alone

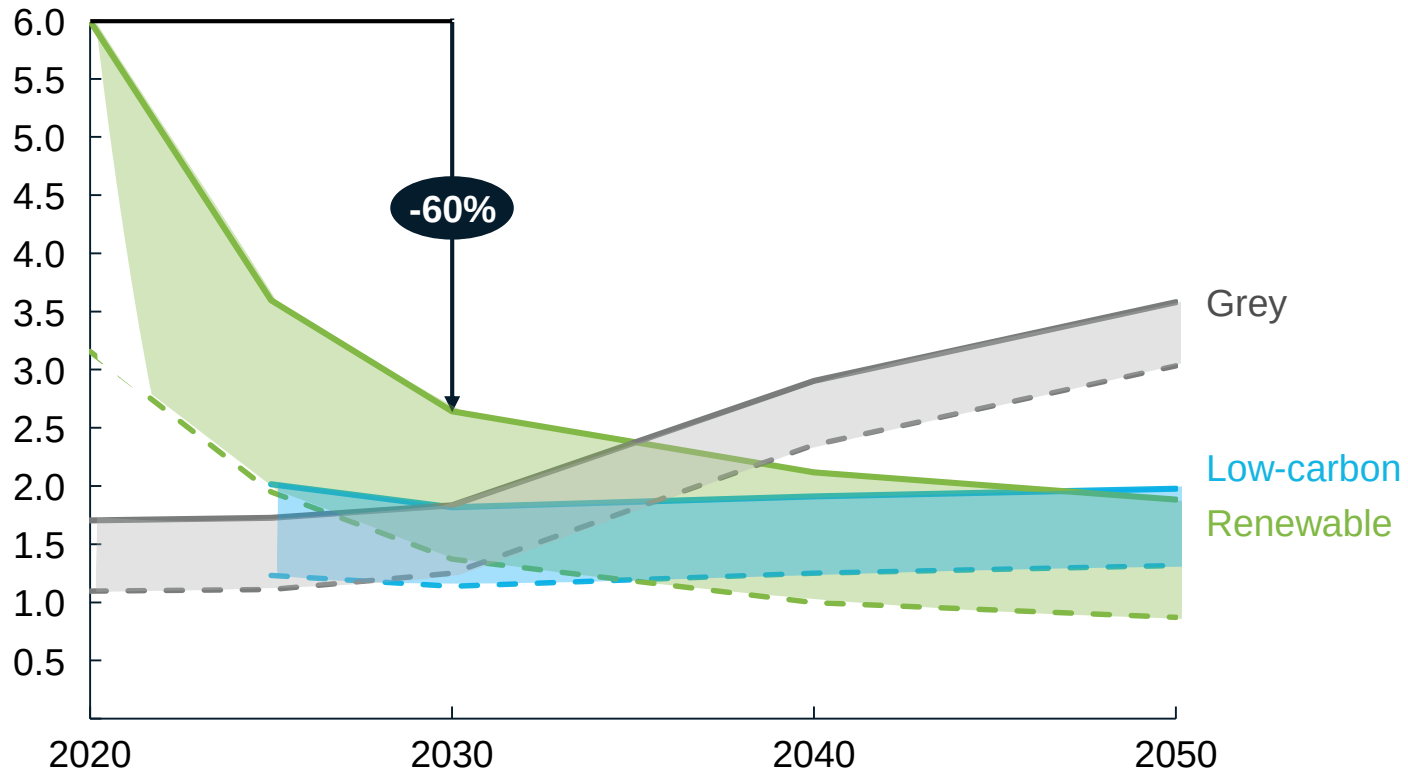
70 GW

To get to green hydrogen to 2 USD/kg

Renewable hydrogen production costs can be reduced by 60% through 2030

Production cost of hydrogen

USD/kg



Drivers of cost reduction

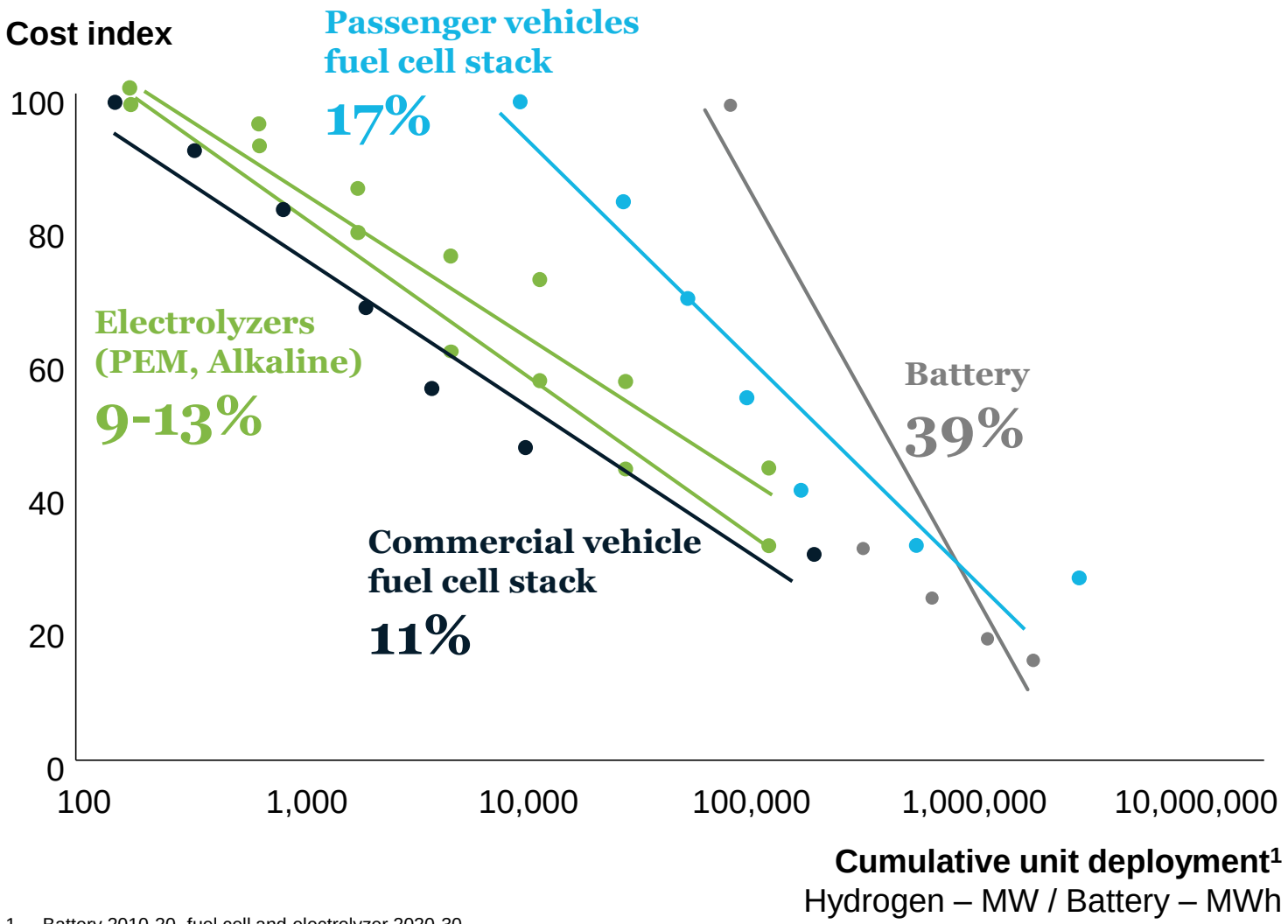
-75%

Capex decline of electrolyzer

-45%

Lower energy costs and higher efficiency

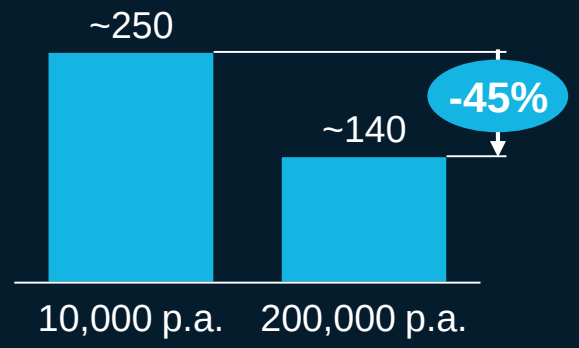
Manufacturing scale up will drive down costs



1. Battery 2010-20, fuel cell and electrolyzer 2020-30

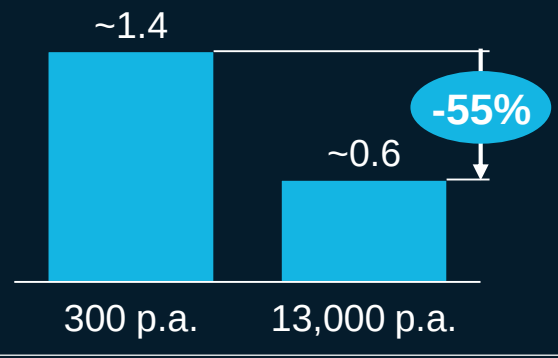
Fuel cell system cost

USD/kW



Electrolyzer system cost

USD million/MW

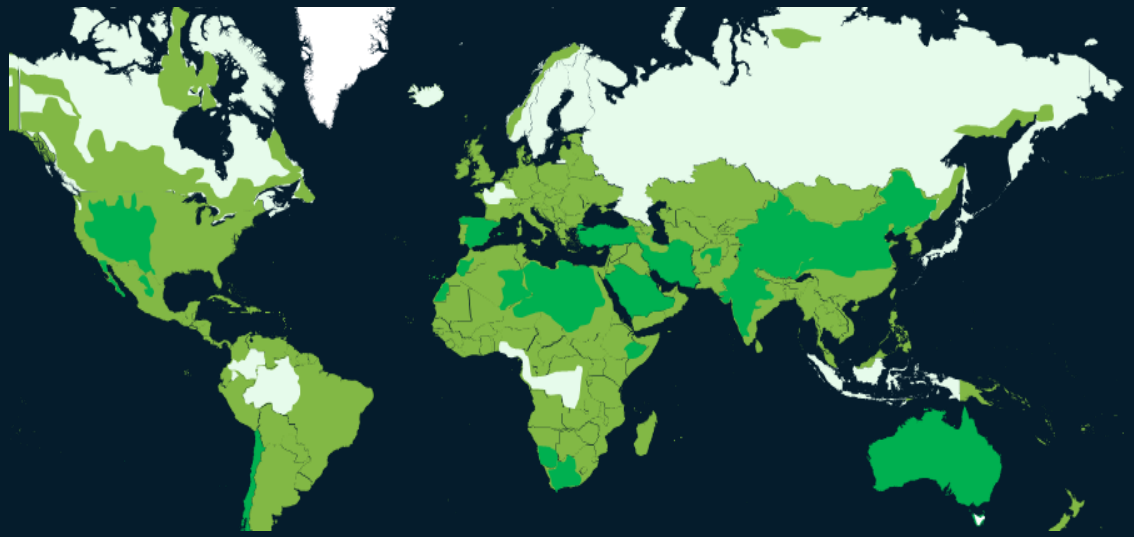


International trade of green and blue hydrogen can further lower hydrogen costs

Availability and economy of resources for green and blue hydrogen production

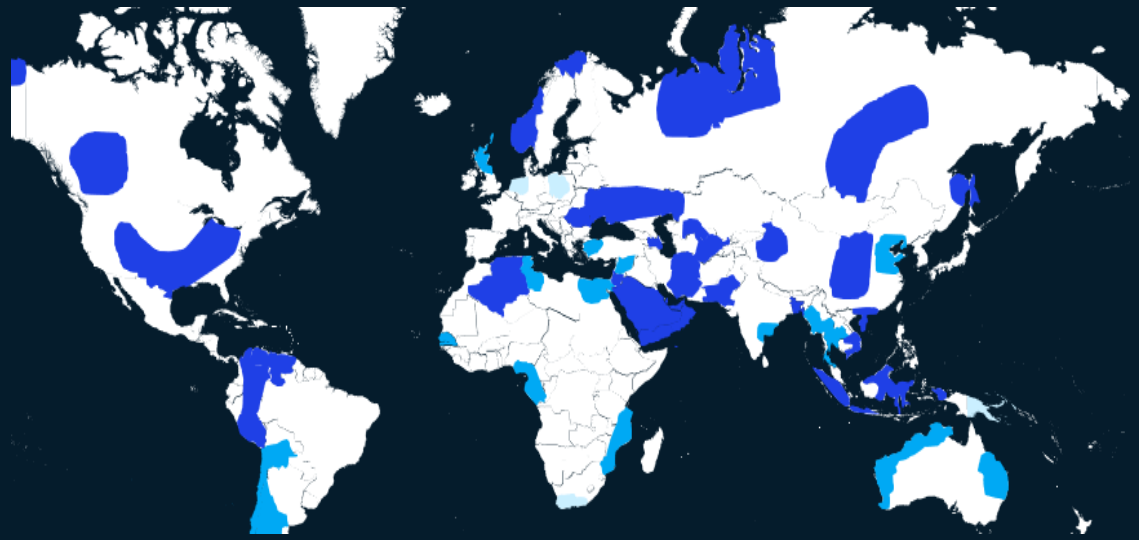
Most optimal resources | Less optimal resources | Least optimal resources

Wind and solar power resources for green hydrogen production costs



Limited resources for green hydrogen production in Japan, Korea, central Europe and large parts of US

Natural gas resources for blue hydrogen production

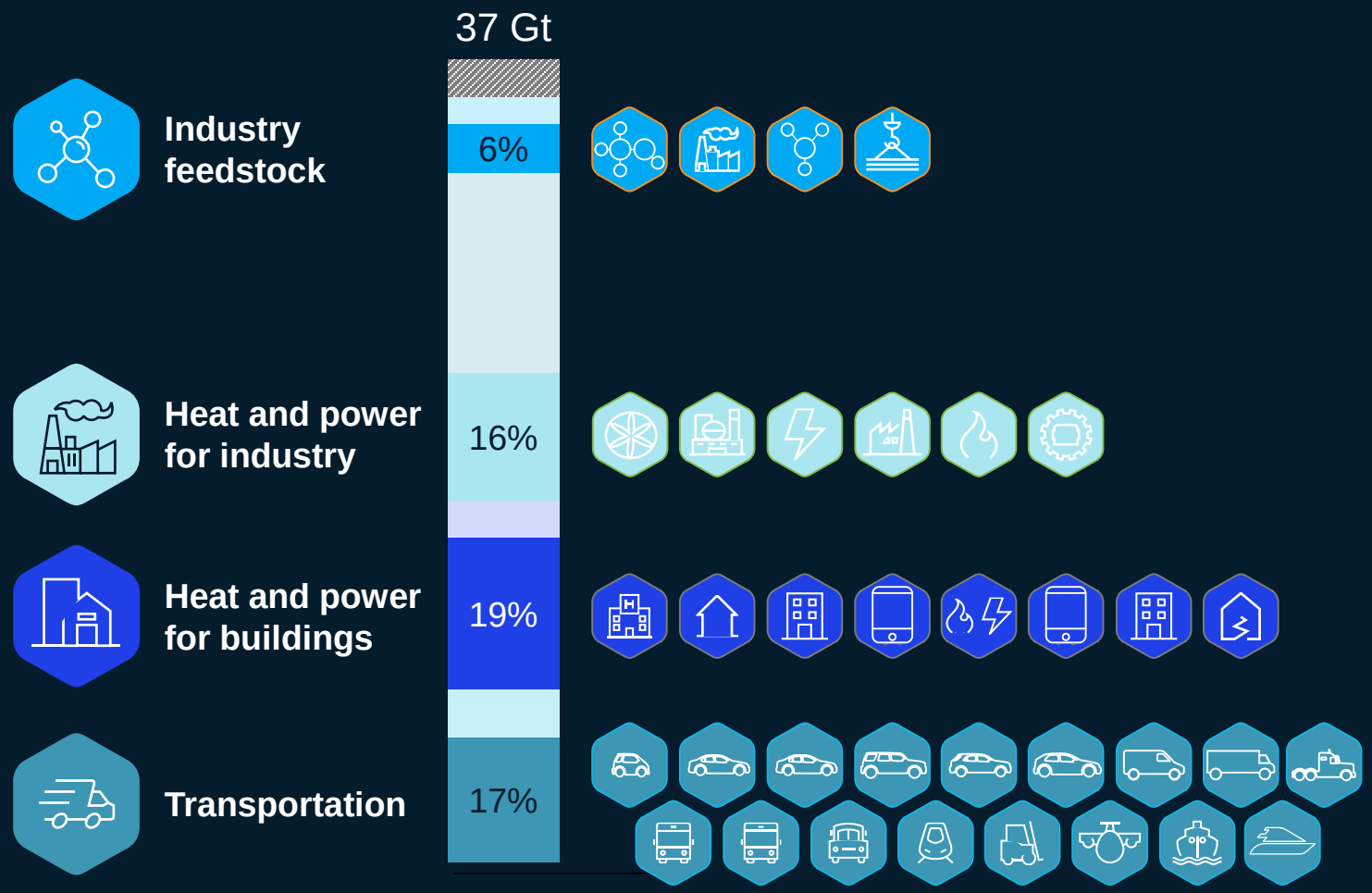


Optimal resources for both green and blue hydrogen production in the Middle East

Source: IEA, McKinsey

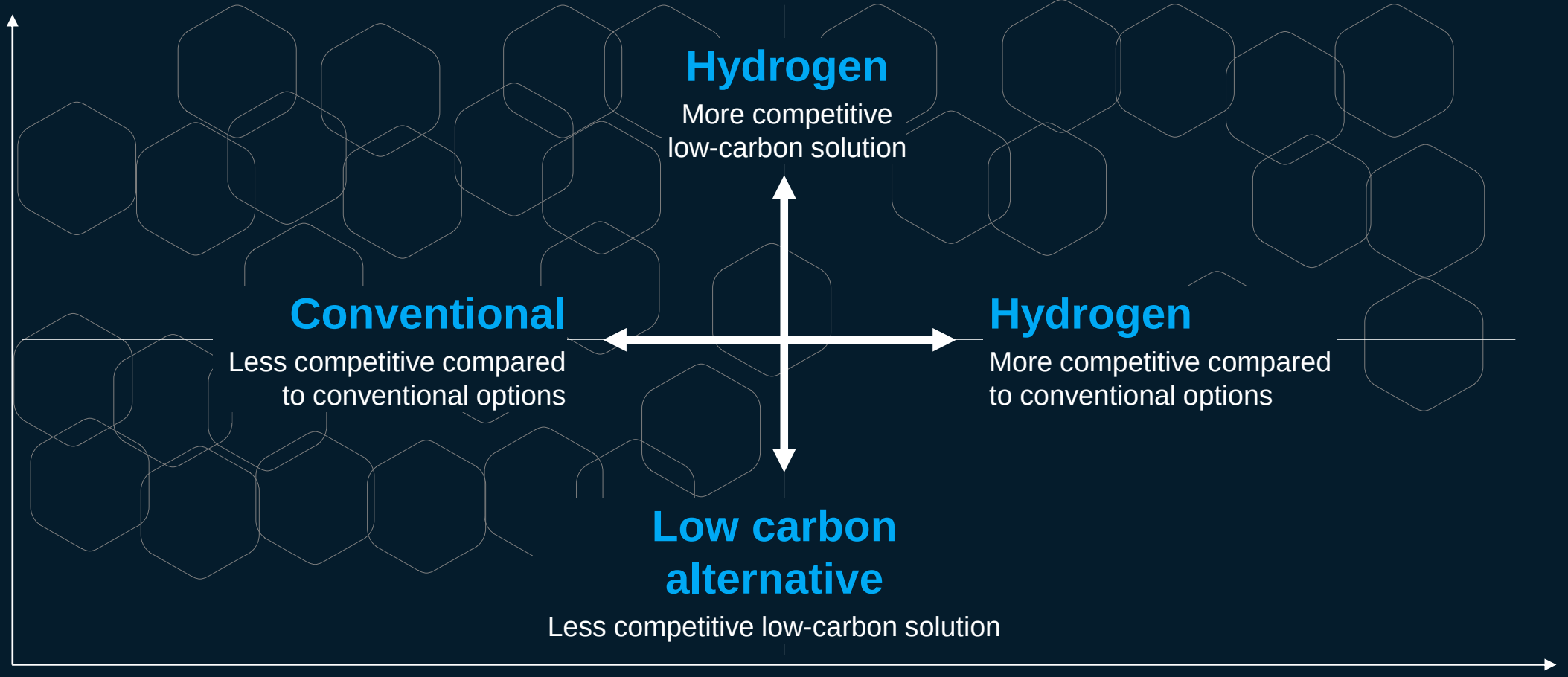
We have modelled 35 hydrogen applications addressing 58% of today's global CO_2 emissions

Global CO_2 emissions

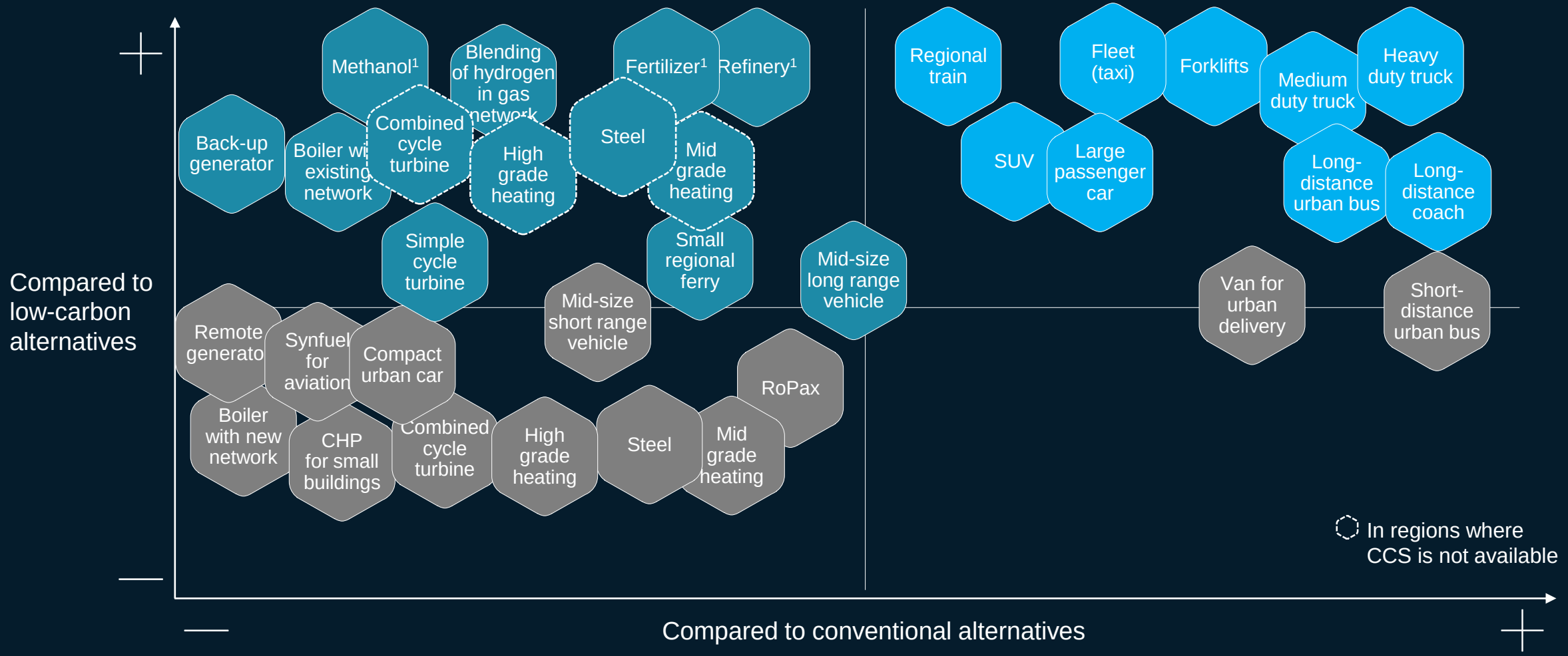


Results: Competitiveness of hydrogen applications by 2030

Analysis of 35 hydrogen applications across sectors



Competitiveness of hydrogen applications by 2030



1. Clean hydrogen is the only alternative

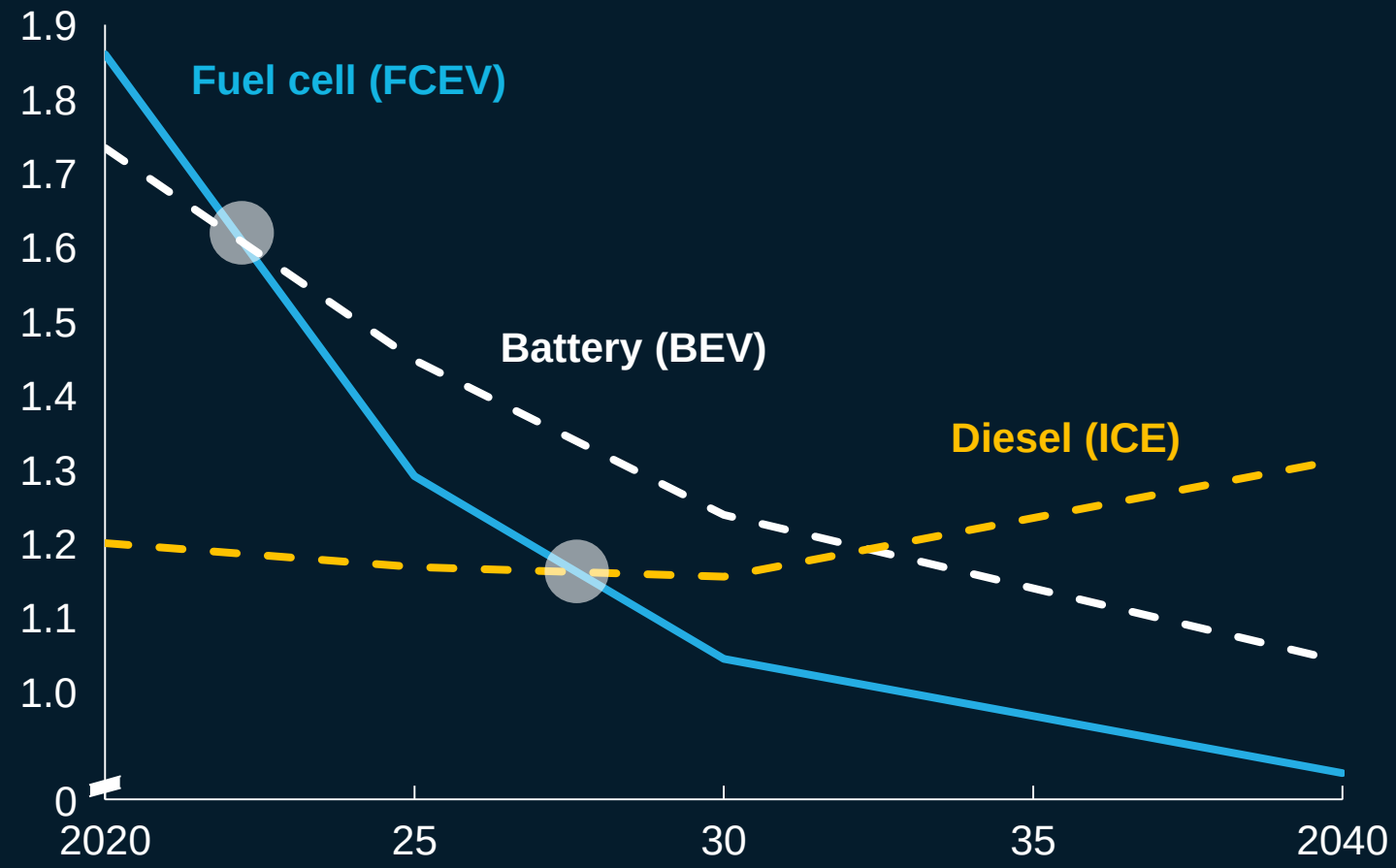
HDT: Commercial heavy duty transport can become cost competitive by 2030

-75%
Fuel cell system

-40%
Distribution and refueling infrastructure

Total cost of ownership (TCO)[1]

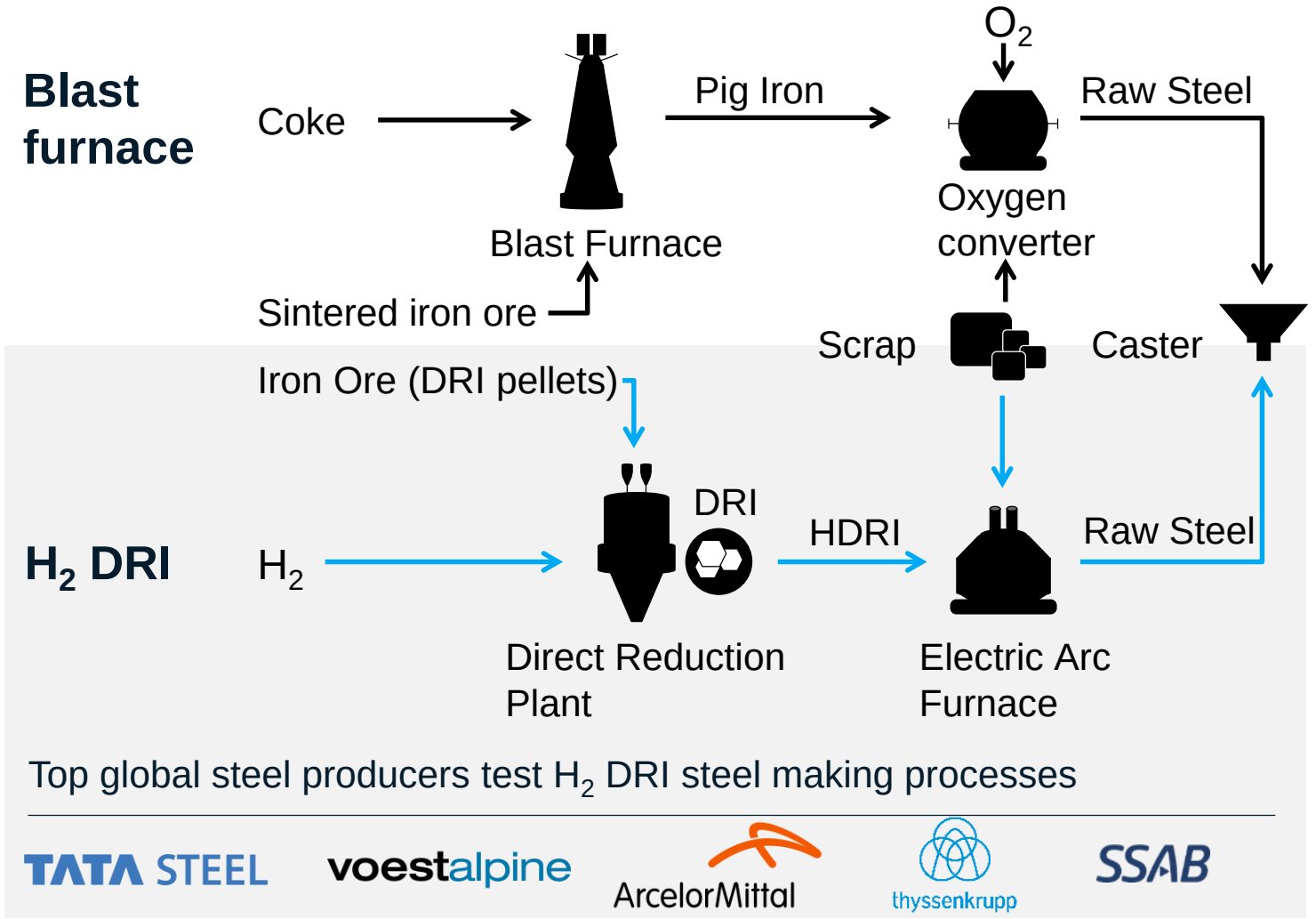
EUR / km



1. HDT / Class 8 truck, with 35 t gross weight

H2 DRI steel production can be cost competitive by 2030, compared to blast furnace

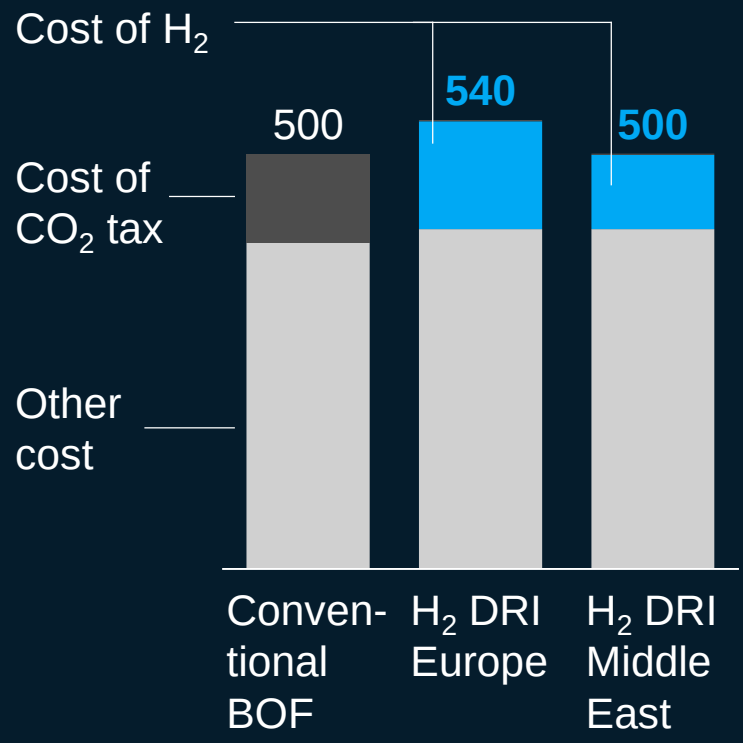
Comparison of blast furnace and H_2-based direct reduced iron steel making



Top global steel producers test H_2 DRI steel making processes

TATA STEEL voestalpine ArcelorMittal thyssenkrupp SSAB

Cost of steel making, in USD/ton



H_2 DRI steel making can be cost competitive in 2030 with blue H_2 in the Middle East

5 levers to create markets and accelerate the path to competitiveness

Scale up of solutions with biggest improvement for investment

(e.g., push of national industry into fuel cells for vehicles)

Prioritization of infrastructure build-out and utilization

(e.g., pipeline network build-up along natural gas trading corridors; infrastructure build-out centered around trucking routes in Germany)

Reduction of demand uncertainty

(e.g., offtake agreements, private-public partnerships)

Deployment of complementary solutions

(e.g., regional hydrogen hubs near Northern German wind parks)

Investment in cost-efficient H_2 production

(e.g., electrolysis ramp-up roadmap in Germany and/or Northern Africa; blue H_2 from Russia)

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