Hydrogen Council

Hydrogen Council

Update, ambition, latest reports

APRIL 2020

WHO WE ARE

HYDROGEN COUNCIL

A global CEO-led initiative

Founded at

WORLD ECONOMIC FORUM

Davos 2017

Grown from 13 to

81

Companies

18

Countries

4

Continents

Representing

6

MILLION jobs

€18.7

TRILLION

in revenues

ONE SHARED VISION

A STRONG & DIVERSE GROUP

3M
AIRBUS
Air Liquide
AIR PRODUCTS
ALSTOM
AngloAmerican
aramco
BMW GROUP
BOSCH
bp
国家能源集团 CHN ENERGY
CNH INDUSTRIAL
Cummins
DAIMLER
EDF
ENGIE
equinor
faurecia
GM
Great Wall
HONDA
HYUNDAI
Iwatani
JM Johnson Matthey Inspiring science, enhancing life
JXTG Nippon Oil & Energy
Kawasaki
KOGAS
Linde
MICHELIN
PLASTIC OMNIUM
SCHAEFFLER
SIEMENS Ingenuity for life
SINOPEC
thyssenkrupp
TOTAL
TOYOTA
WEICHAI 潍柴

AFC Energy
AVL
BALLARD
CHART
Chevron
elringklinger
Faber CYLINDERS
Fortescue
galp
GORE
HEXAGON
ILJIN
ITOCHU
LIEBHERR
MANN+HUMMEL
Marubeni
MCDERMOTT
McPhy
Mitsubishi Corporation
MITSUBISHI HEAVY INDUSTRIES
MITSUI&CO.
nel
NGK NTK
NIKOLA
PLUG POWER
Power Assets Holdings Ltd.
REFIRE
中自催化 SINOCAT
亿华通 SinoHytec
SMBC
snam
SoCalGas
Sumitomo Corporation
TOYOTA TSUSHO
TRUE ZERO
Vopak
Woodside

ANTIN INFRASTRUCTURE PARTNERS
BNP PARIBAS
CRÉDIT AGRICOLE
John laing making infrastructure happen
SOCIETE GENERALE

ENGAGED AT THE HIGHEST LEVEL

Hydrogen Council

"The new hydrogen economy is not just a dream – it's quickly becoming a reality."

TAKESHI UCHIYAMADA
Chairman of the Board of Directors, Toyota Motor Corporation

Hydrogen Council

"We are responding to public demand for a clean future by raising the understanding of hydrogen's key role across different sectors."

BENOÎT POTIER
Co-Chair of the Hydrogen Council & Chairman and CEO of Air Liquide

Hydrogen Council

"Our gas pipeline and storage system could be used to store excess power in the form of green hydrogen, serving as a long-term storage that a low-carbon energy system will need in addition to batteries and other technologies."

MARYAM BROWN
President of SoCalGas

Hydrogen Council

"We believe that a hydrogen-powered society is the most viable way to achieve a successful energy transition."

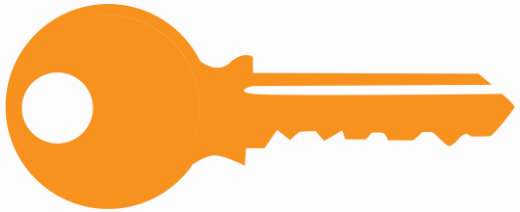
EUISUN CHUNG
Co-Chair of the Hydrogen Council & Executive Vice Chairman of Hyundai Motor Group

More statements by Hydrogen Council CEOs & executives

WHY WE ARE HERE

OUR VISION

Hydrogen has a key role to play in the energy transition



Based on **real industry data**, the Council sees hydrogen as an enabler of the future energy system, growing its role over time and delivering tangible benefits:

By 2030

H_2 scales up to achieve competitiveness

- ✓ Cost falls sharply, making hydrogen a competitive low-carbon option across 22 applications – equivalent to 15% of annual global energy demand

By 2050

H_2 reaches full potential

- ✓ 6 GT of CO_2 abatement annually
- ✓ 30 million jobs
- ✓ $2.5 trillion market

Sources:

"Hydrogen, Scaling Up" report, 2017
"Path to Hydrogen Competitiveness" report, 2020

OUR RESULTS

ADVOCATING ON THE GLOBAL STAGE

The Hydrogen Council has accomplished the following:

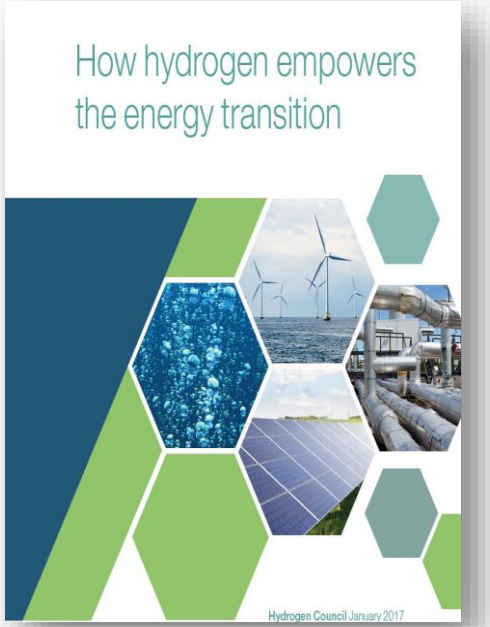
- Built relationships with key governments
- Created a roadmap to competitiveness based on scale & cost
- Established partnerships with international organisations
- Launched Investor Group to engage financial community
- Quantified hydrogen's potential contribution to deep decarbonisation

The Council is now working to provide a clear vision to governments on:

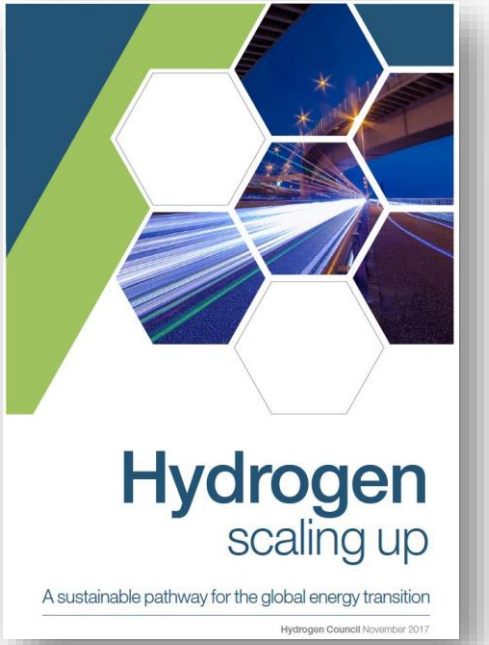
- Financing tools *(best practices & innovative ideas)*
- Flagship projects ready for large-scale investment
- Increasing awareness of hydrogen globally
- Policy tools *(best practices)*

USING RESEARCH…

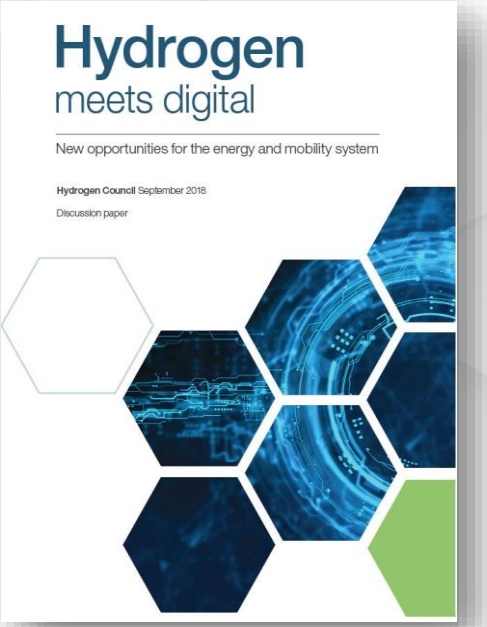
The Council creates studies on the use, development and deployment of hydrogen across sectors and industries. These studies further our understanding of **how to make the hydrogen economy a reality through concrete data provided by Council members** and informed conversations with key stakeholders around the globe. All studies are available **here**.



Explores the role of hydrogen in the energy transition and offers recommendations to help accelerate deployment



Discusses the feasibility of our 2050 hydrogen vision and proposes tangible steps to get there



Considers how digitization and hydrogen could complement each other in the energy transition

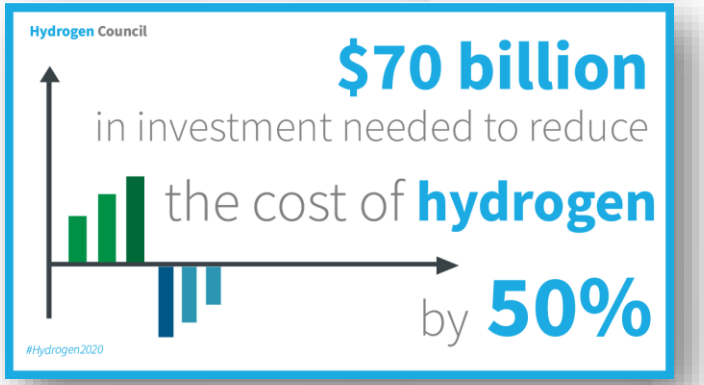
Presents a cost trajectory for hydrogen to become cost competitive to other low carbon and conventional alternatives by 2030

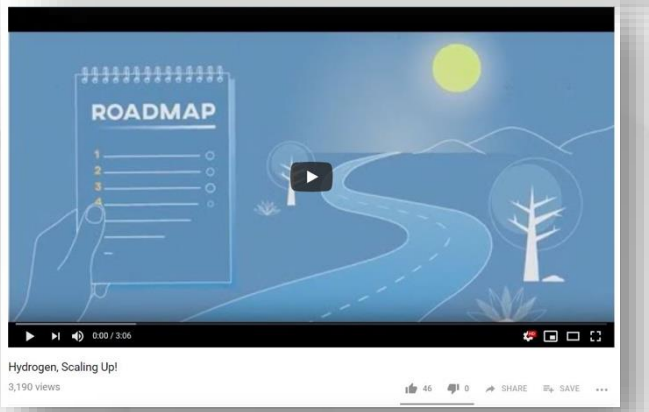
...AND COMMUNICATIONS TO SUPPORT ADVOCACY

AN INTEGRATED APPROACH TO COMMUNICATIONS & ADVOCACY

- **Boost awareness of and support for hydrogen in the energy transition** by creating common messaging to demonstrate hydrogen's benefits and impacts and show a clear commitment and pathways to scale

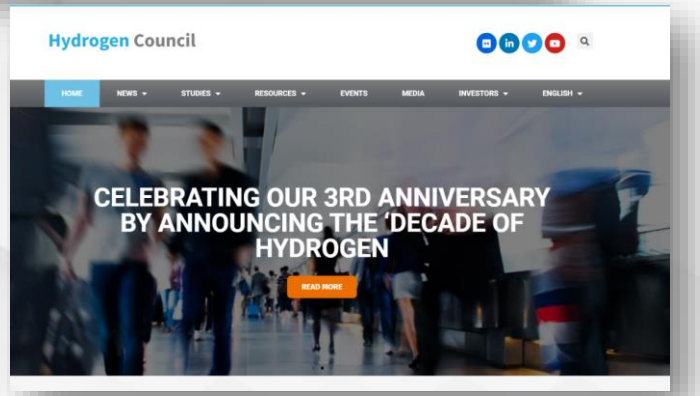
- **Support advocacy efforts at the highest level** through engagement of Hydrogen Council member CEOs and targeted global campaigns



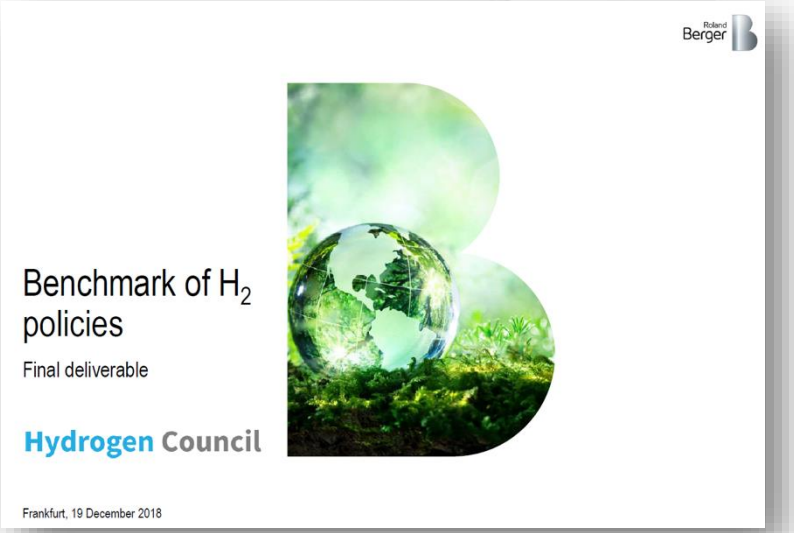


S&P Global
Platts

Fuel cell EVs set to top 13 million by 2030 as hydrogen scales up: Hydrogen Council



… AND RELEVANT POLICY & FINANCIAL SCHEMES



TOOK STOCK OF POLICY AND FINANCING TOOLS

Delivered a comprehensive review of the hydrogen policy landscape and associated financial incentives in selected markets across the world.

This study is available exclusively for members

LAUNCHED COLABORATION WITH KEY INVESTORS

Brought together financing experts from member companies and key investor organisations to advance development of innovative financing schemes.

The Investor Group is open exclusively to members

MOVING FORWARD

2020 COUNCIL PRIORITIES

1. Bring together key stakeholders to enable investment & large scale projects
-Build a business marketplace
-Stimulate investment

2. Amplify the voice of hydrogen worldwide
-Understand hydrogen perception & challenges
-Address issues & leverage new/broader opportunities

3. Guide policymakers toward appropriate regulations
-Identify key policies & technical recommendations
-Influence through key organizations

4. Ensure transversal coverage of safety topics globally
-Closing safety/standards gaps
-Reputation management and crisis preparedness

Hydrogen Council

STAY CONNECTED!

www.hydrogencouncil.com

@HydrogenCouncil
#HydrogenNow

Hydrogen Council

Path to hydrogen competitiveness

A cost perspective

20 January 2020

Drivers of renewed interest in hydrogen

Stronger push to limit carbon emissions

10

Years remaining in the global carbon budget to achieve the 1.5°C goal

66

Countries that have announced net-zero emissions as a target by 2050

Falling costs of renewables and hydrogen technologies

80%

Decrease in global average renewable energy prices since 2010

55x

Growth in electrolysis capacity by 2025 vs. 2015

Indicators of hydrogen's growing momentum

Strategic push in national roadmaps

70%

Share of global GDP linked to hydrogen country roadmaps to date[1]

10 m

2030 target deployment of FCEVs announced at the Energy Ministerial in Japan

Industry alliances and momentum growing

60

Members of the Hydrogen Council today, up from 13 members in 2017

30+

Major investments announced[2] globally since 2017, in new segments, e.g. heavy duty and rail

1. Based on 18 country roadmaps announced as of publication
2. Not exhaustive

Leveraging the members' expertise

Analytical support

McKinsey & Company

For selected technical areas:

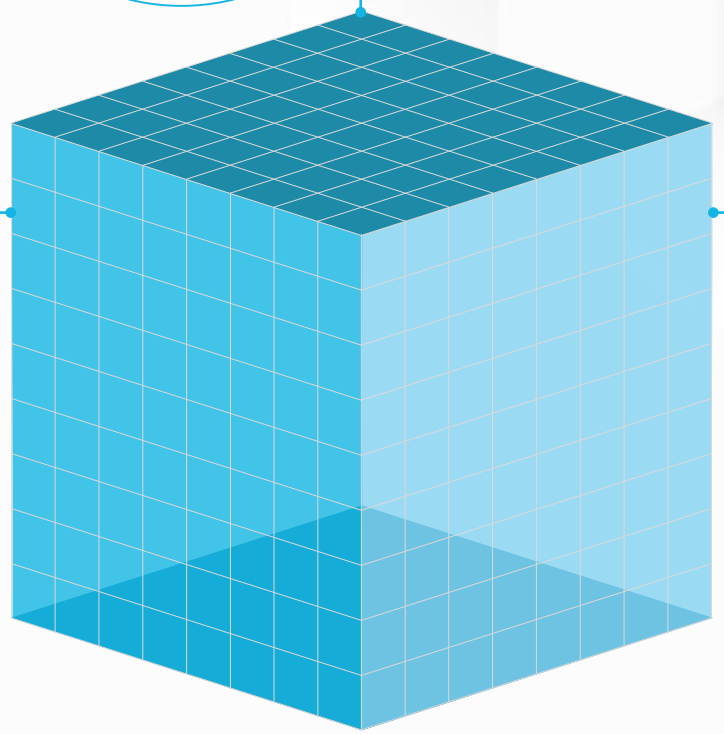
E4tech

40+
Technologies

Built cost trajectories for hydrogen supply chain from production to end use, compared them with cost targets relative to competing technologies, and identified gaps to close them

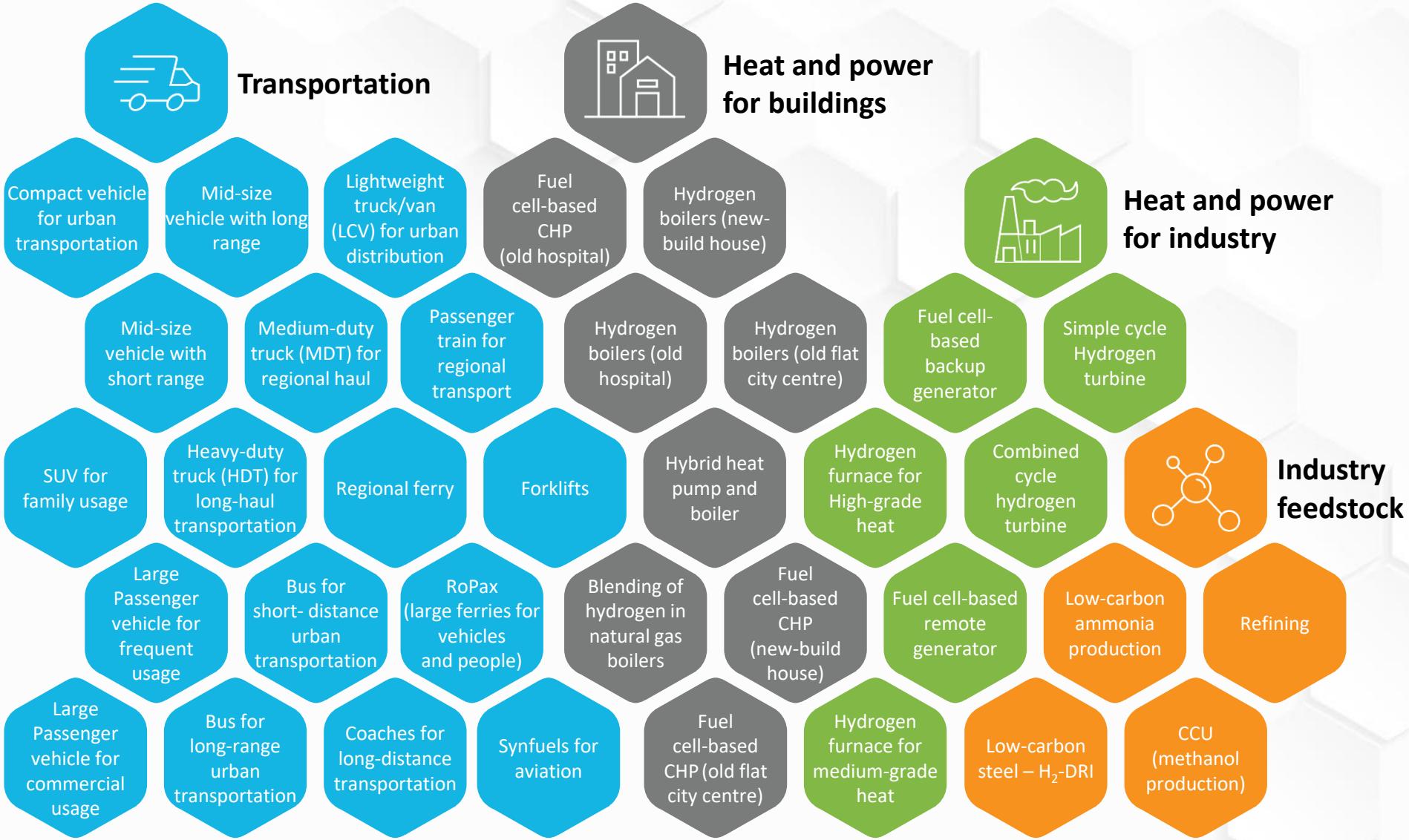
35
Applications

Modelled all end uses based on detailed total costs of ownership (TCO) across mobility, heating, power, and industrial feedstock applications



25,000
Data points

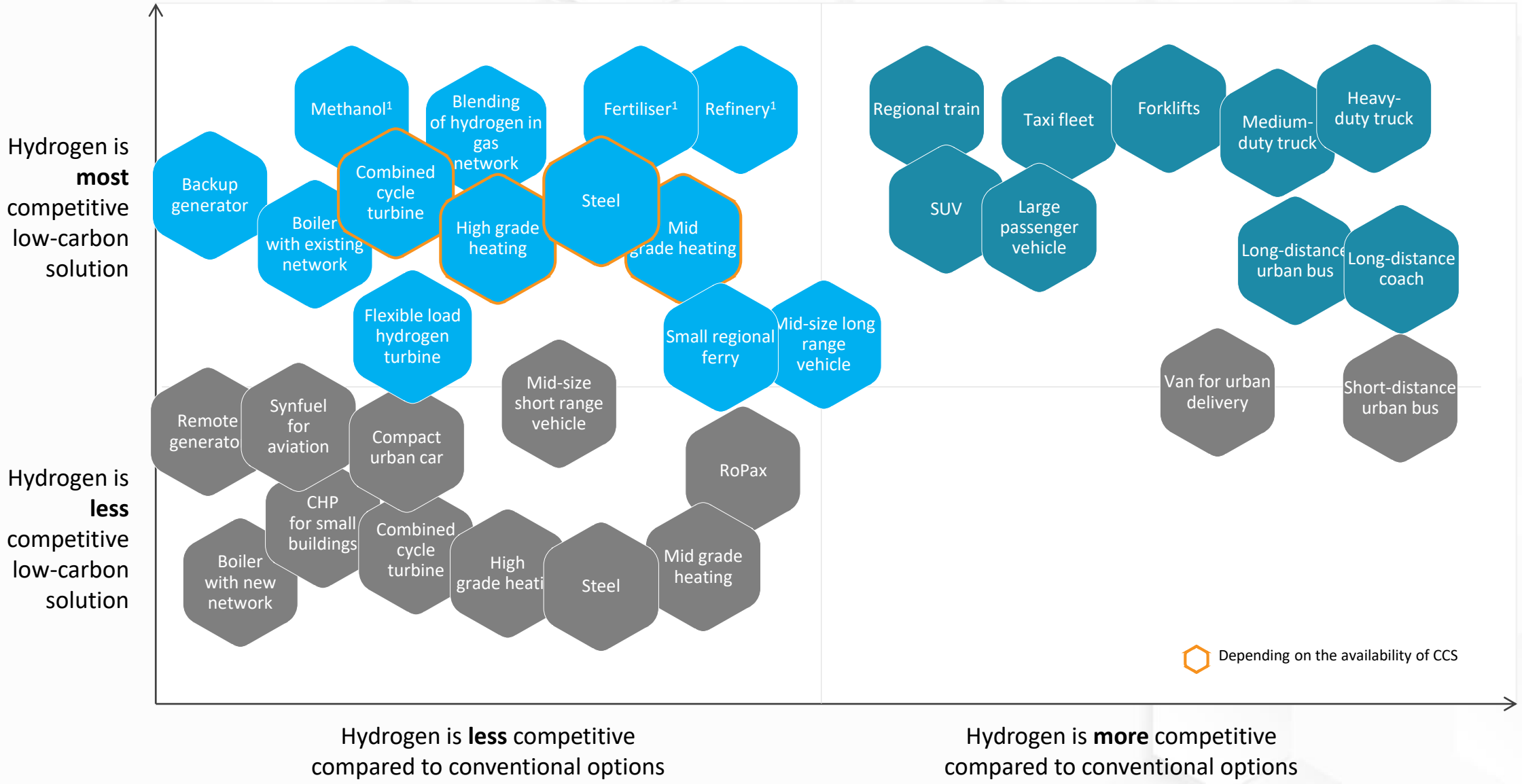
Aggregated and analysed clean team data from 30 companies across 4 regions (EU, US, Japan/Korea, China) on the cost/performance trajectory for hydrogen



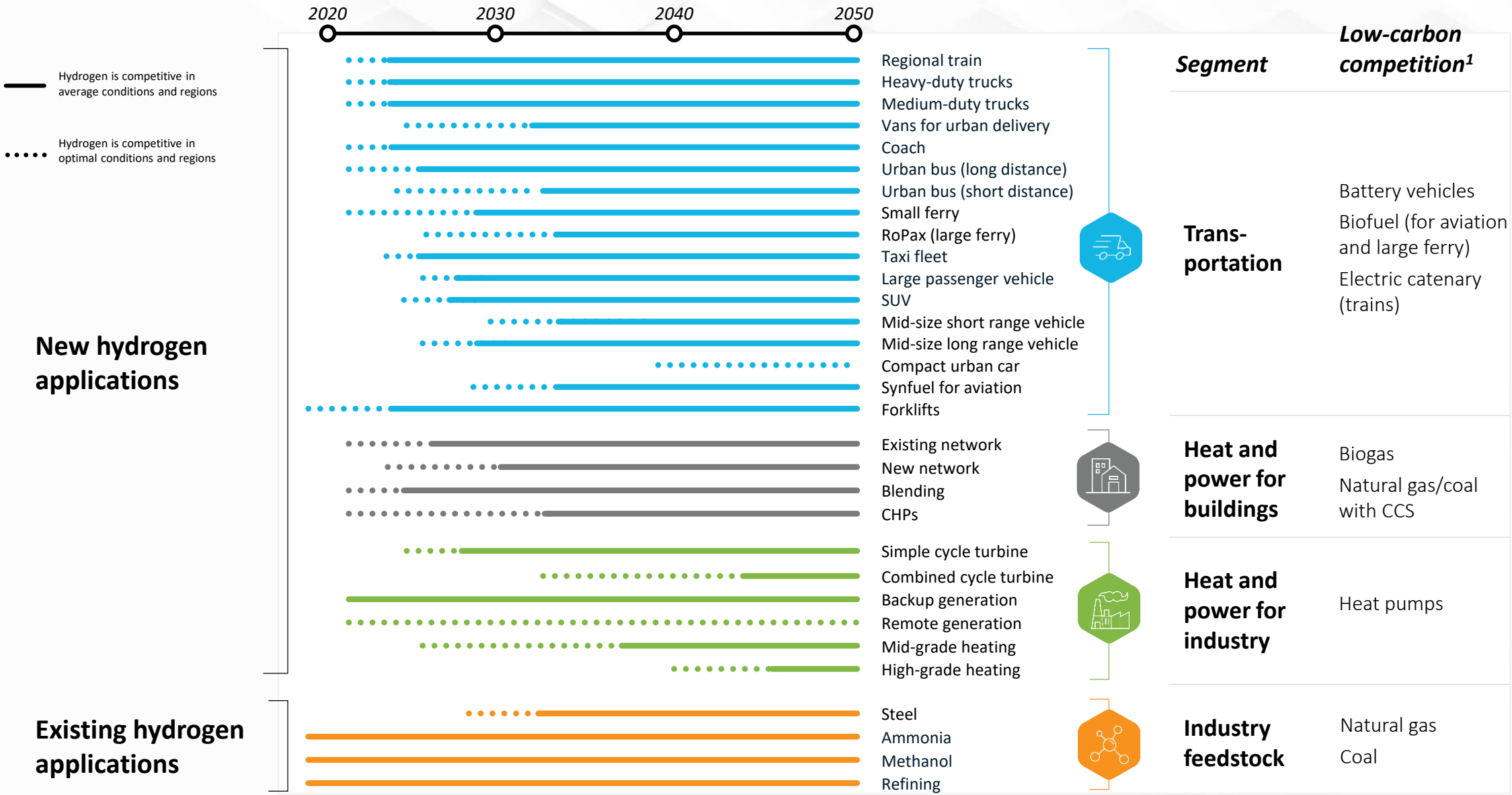
CO_2 global emissions 100% = 37 Gt

In addition, hydrogen can also be used in, e.g.

- **Mobility:** Container ships, tankers, tractors, container ships, motorbikes, tractors, off-road applications, fuel cell airplanes
- **Other:** Auxiliary power units, large scale CHP for industry, mining equipment, metals processing (non-DRI steel), etc.



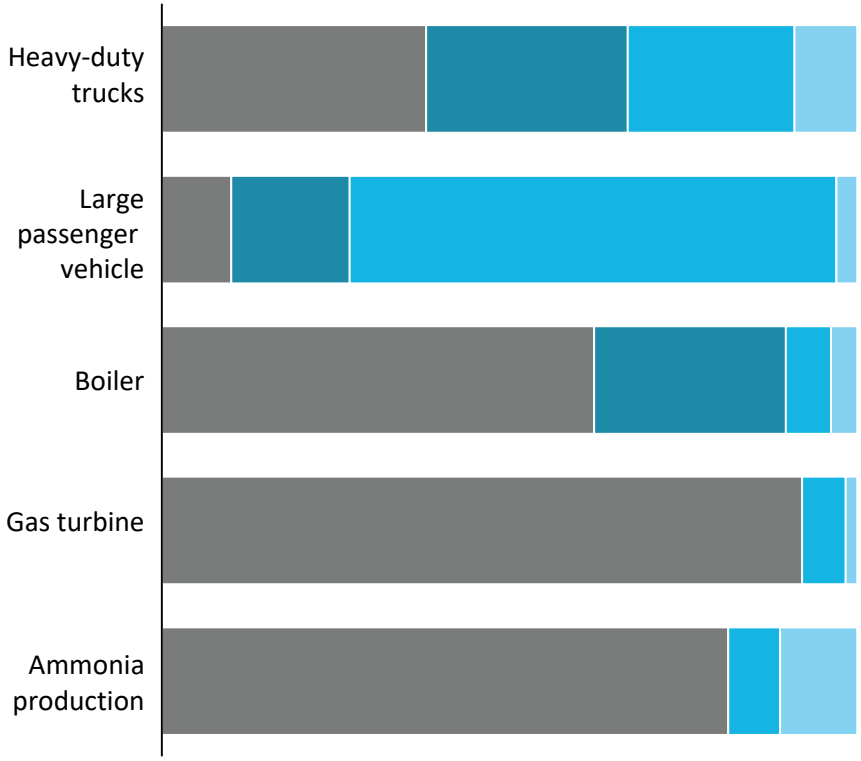
1. Hydrogen is the only alternative and low-carbon/renewable hydrogen competing with grey (optimal renewable or low-carbon shown)



1. In some cases hydrogen may be the only realistic alternative, e.g. for long-range heavy-duty transport and industrial zones without access to CCS

Cost breakdown of hydrogen applications

Percentage of total cost 2020



Cost drop 2020-30,

Percent

-50%	Scale-up of full supply chain Industrialisation of fuel cell and hydrogen tank manufacturing
-45%	Industrialisation of fuel cell and hydrogen tank manufacturing Scale-up and utilisation of HRS
-45%	Lower-cost hydrogen from renewables Higher pipeline network utilisation due to scale-up of demand
-35%	Scale-up of system size and manufacturing of electrolysers for green hydrogen production
-45%	

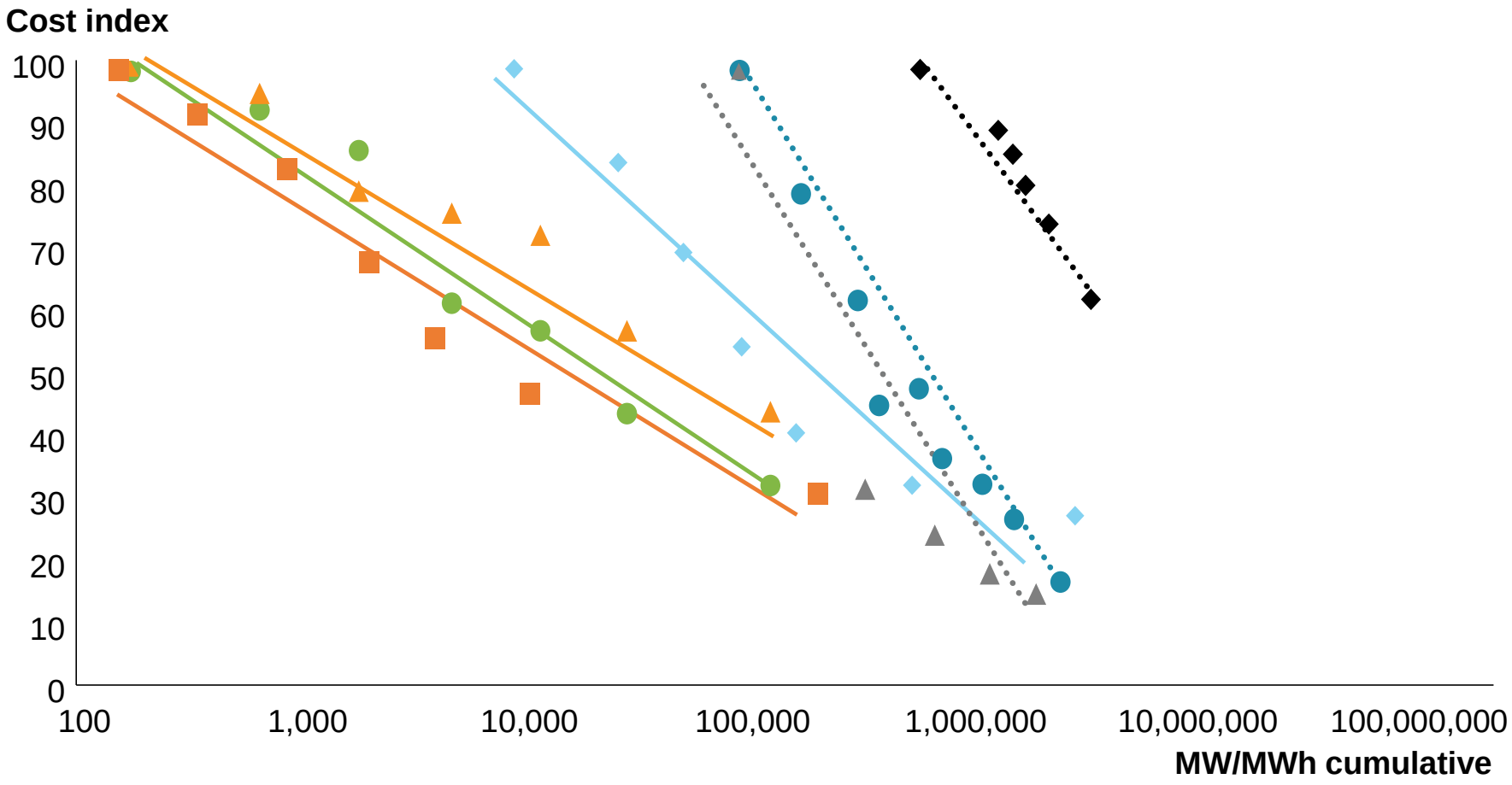
Cost reduction levers to reach target

Hydrogen production[1] | Hydrogen distribution | Equipment capex | Other opex

1. Assumes 50/50 blend of low-carbon and average renewable hydrogen

Capex development of selected technologies over total cumulative production

Indexed to 2020 values (2010 for comparative technologies)[1]



Learning rate

2020-30

13% PEM electrolysers

9% Alkaline electrolysers

17% Fuel cell stack for passenger vehicles

11% Fuel cell stack for commercial vehicles

Comparative technologies (2010-20)

35% Solar

39% Battery

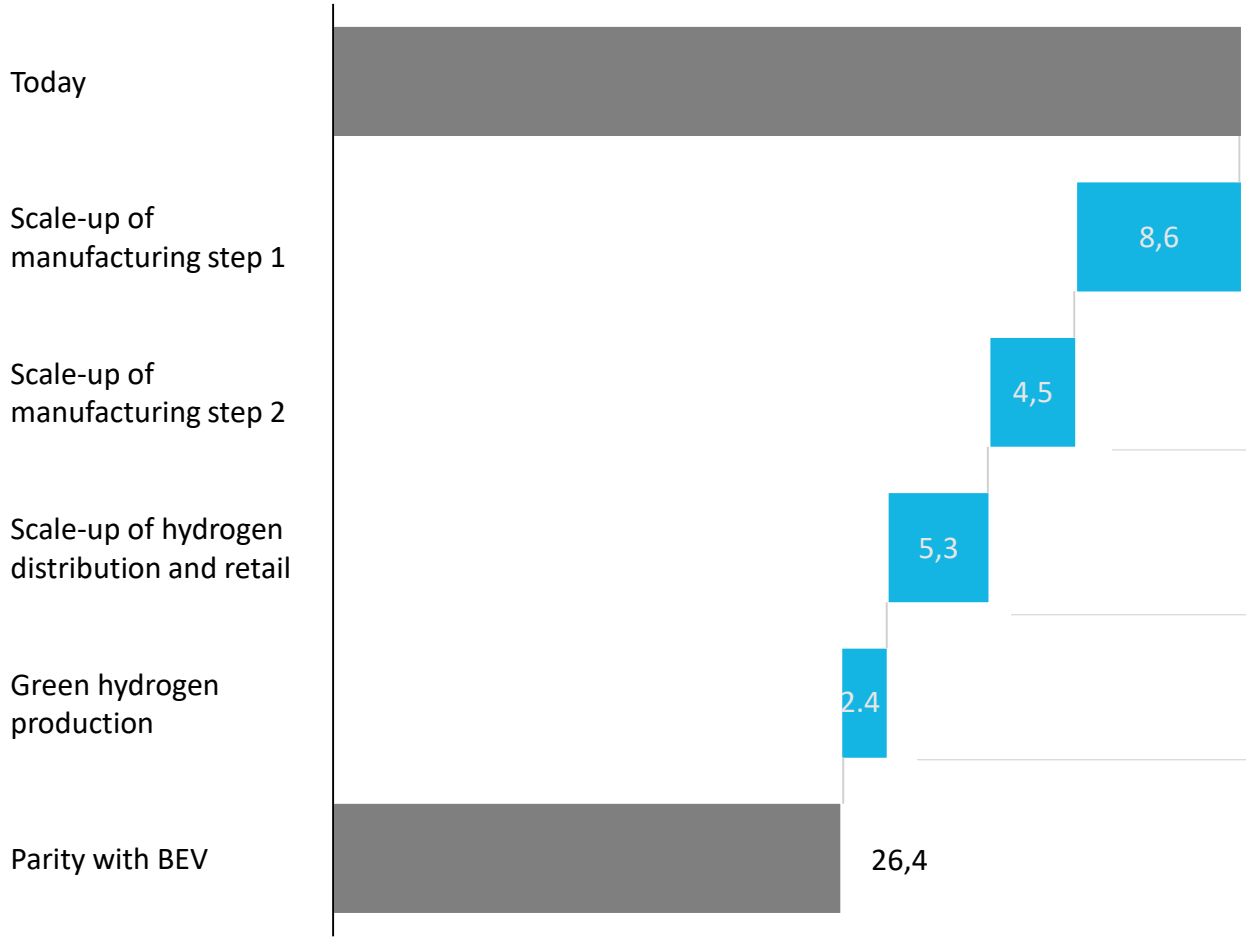
19% Wind onshore

Learning rates are highest for emerging technologies (PEM) and high volume FC for passenger vehicles
Learning rates for tanks are ~10-13%, somewhat lower than for fuel cells due to higher materials share of cost

1. Installed base: assuming 50/50 split of electrolysers volume with 50-75% utilisation; assuming 115 kW for PV, 250 kW for buses and 300 kW for trucks; LCOE used for solar cost; batteries in MWh

SOURCE: McKinsey; IRENA; BNEF; Ruffini & Wei (2018) (learning rates); DoE

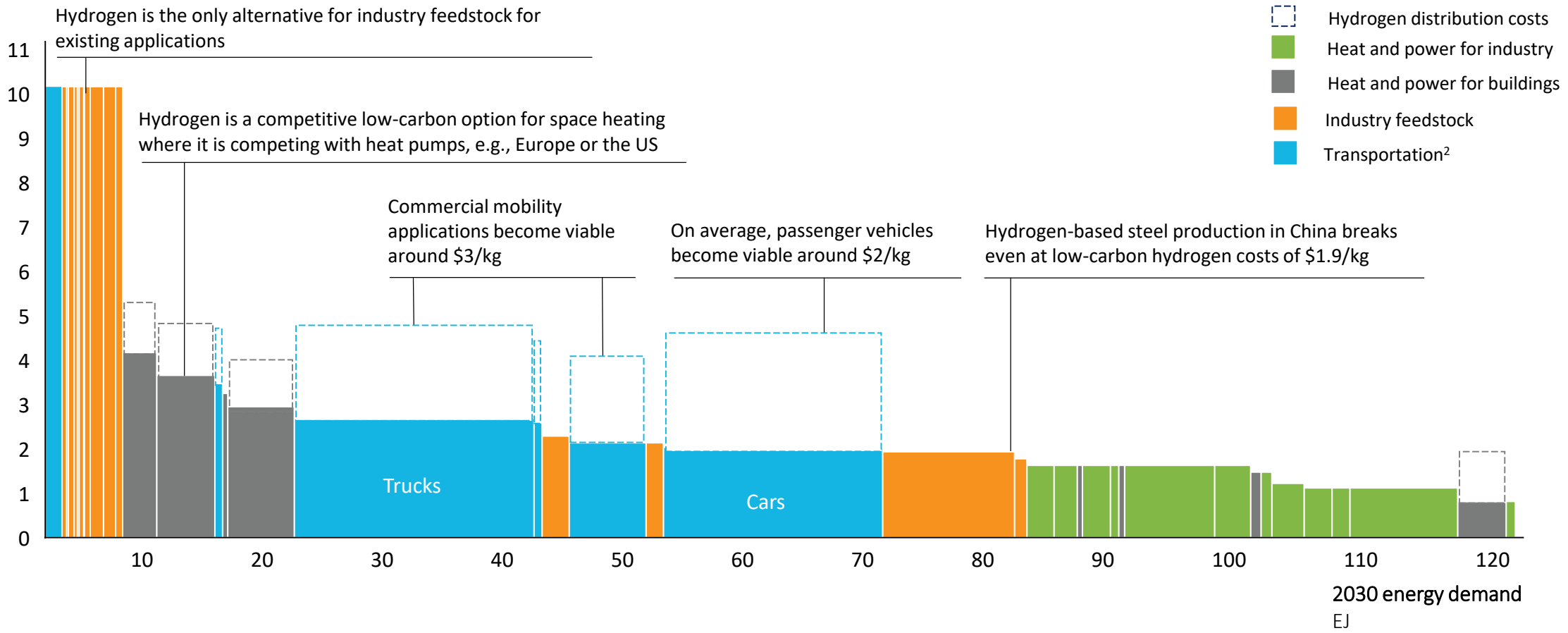
Total cost of ownership (USD cents/km)



-18%	Annual production of **200,000 vehicles**
-10%	Annual production of **700,000 vehicles**
-11%	Transition to 2.5x larger HRS and +40% trucking capacity
-5%	~50 GW electrolysis deployed and transition to ~100 MW production systems

Insight | Majority of cost reduction in vehicle capex comes from scaling up to 200k annual production; to reach fully parity with full battery vehicles 600k annual production volumes are required

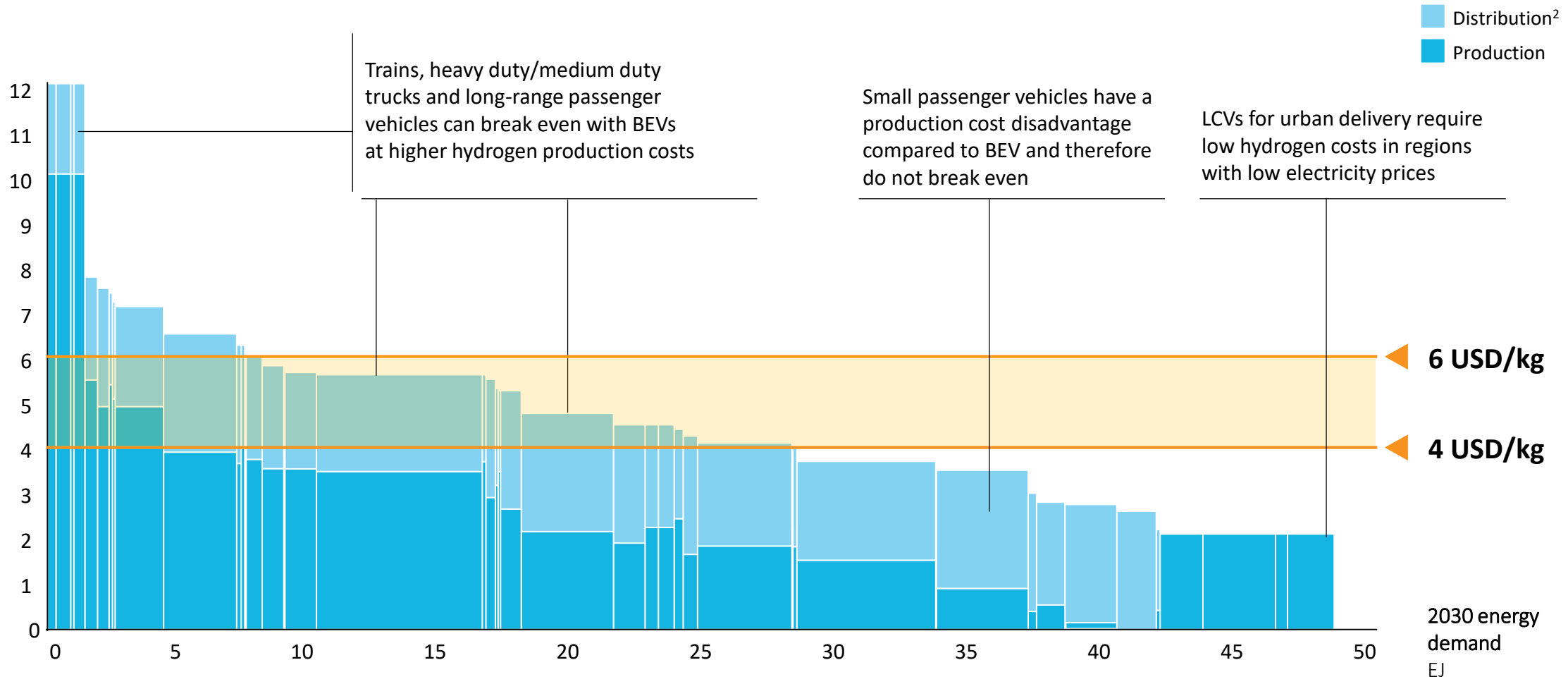
Breakeven hydrogen costs at which hydrogen application becomes competitive against low-carbon alternative in a given segment (USD/kg)



1. Regions assessed are the US, China, Japan/Korea, and Europe
2. Transportation segments breakeven calculated as weighted average

SOURCE: McKinsey; IHS; expert interviews; DoE; IEA

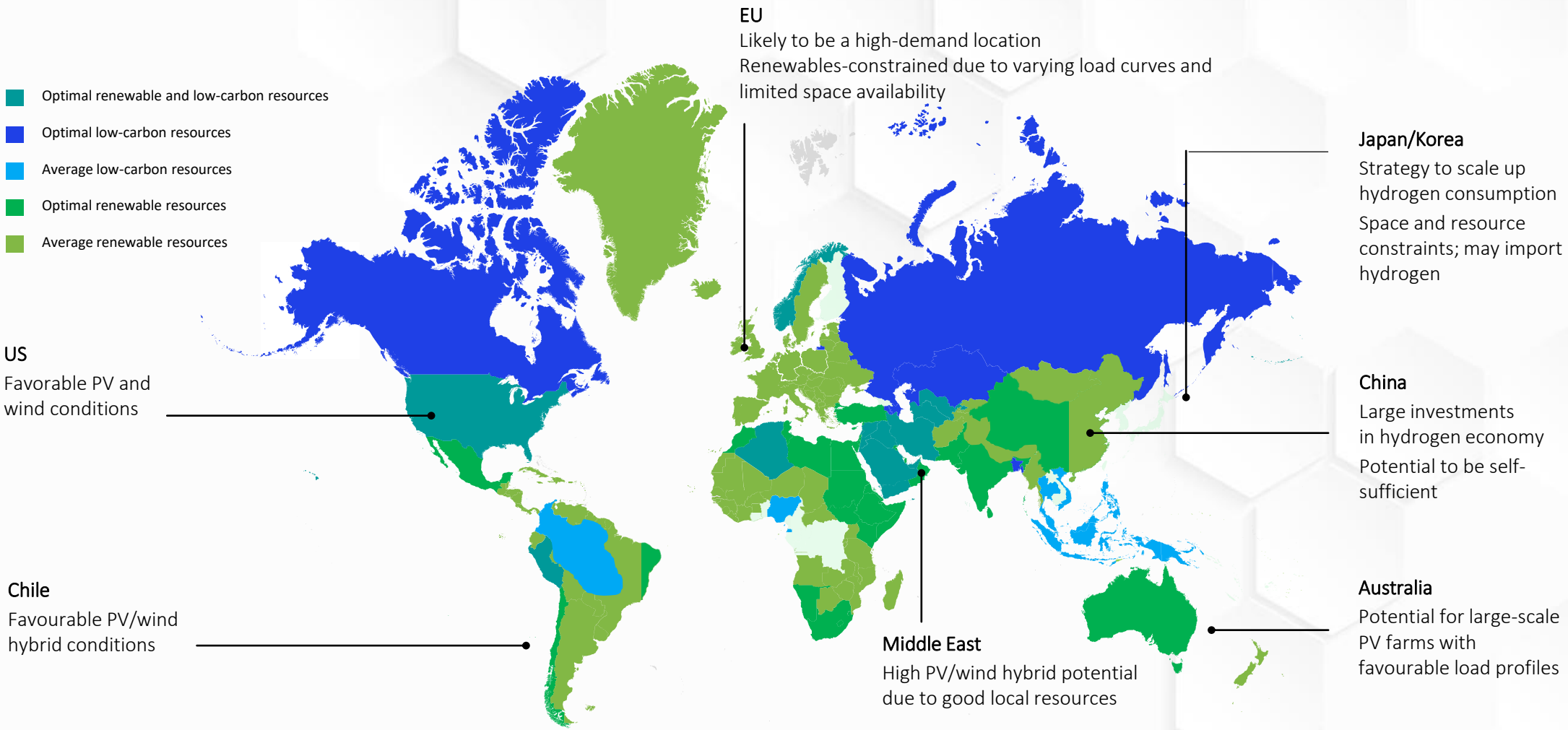
Breakeven hydrogen costs at which hydrogen mobility applications becomes competitive against low-carbon alternative in a given segment in focus regions[1] (USD/kg at nozzle)



1. Regions assessed are the US, China, Japan/Korea, and Europe
2. No distribution costs for aviation as it can be distributed as liquid fuel

SOURCE: McKinsey; IHS; expert interviews; DoE

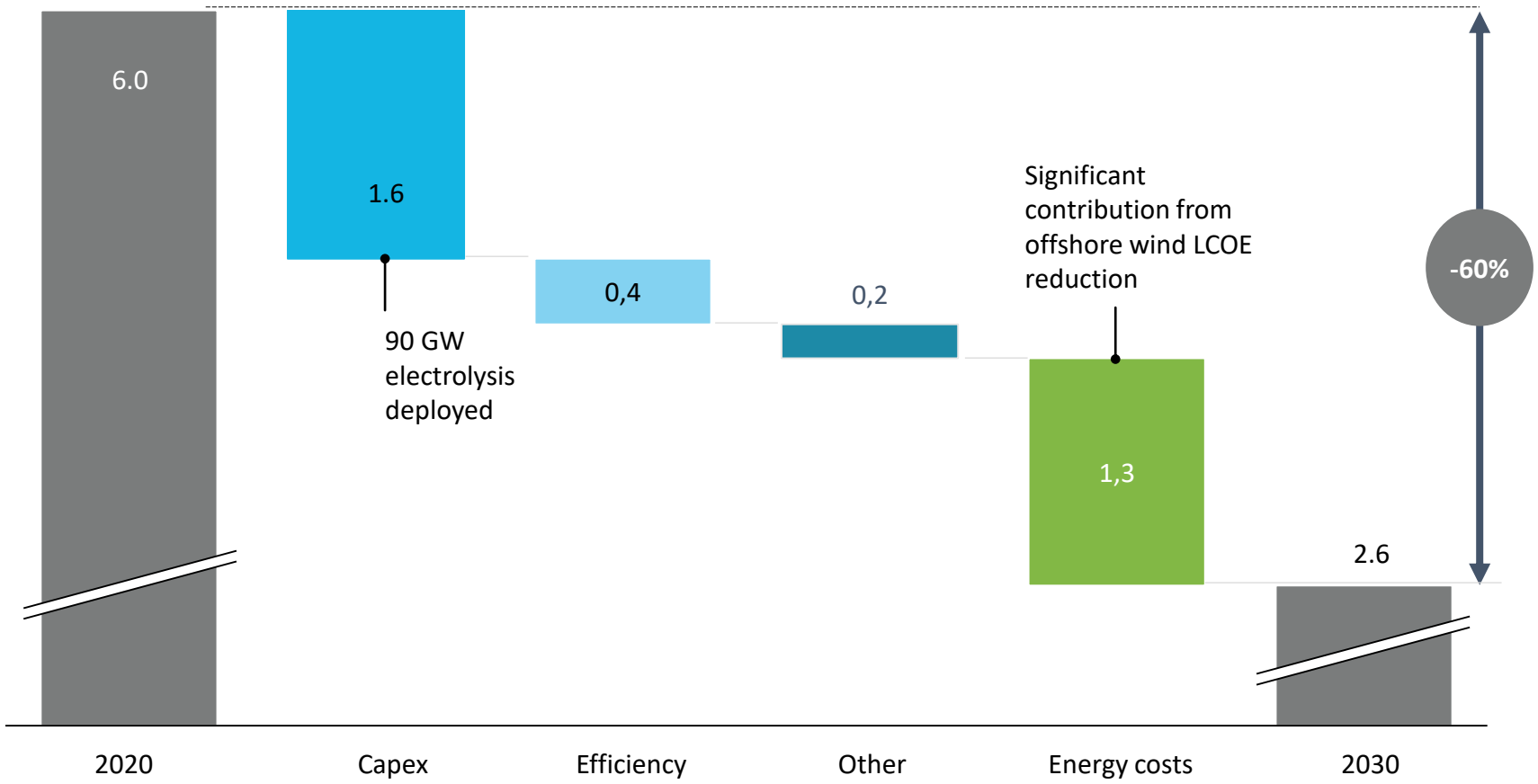
Best source of low-carbon hydrogen in different regions



Demand centres, e.g. EU, North-east Asia, are often constrained for resources, and may not be able to self-supply hydrogen
Countries with complementary load profiles of wind and PV can produce renewable hydrogen at very low prices
Regions like China and the US are both demand centres and have favourable RES

SOURCE: IEA; McKinsey

Cost reduction lever for hydrogen for electrolysis[1] connected to dedicated offshore wind in Europe (average case) (USD/kg hydrogen)



Capex decreases ~60% for the full system driven by scale in production, learning rate, and technological improvements
Increasing system size from ~2 MW to ~90MW
Efficiency improves from ~65% to ~70% in 2030
Other O&M costs go down following reduction in parts cost and learning to operate systems
Additionally, storage may become cheaper
(not included)
Energy costs[2] offshore wind LCOE decreases from 57 to 33 USD/MWh, and is assumed to be dedicated to hydrogen production
Grid fees decrease from ~15 to 10 USD/MWh
Load factor of 50%, i.e. ~4,400 full load hours equivalent

1. Assume 4,000 Nm3/h (~20 MW) PEM electrolysers connected to offshore wind, excludes compression and storage
2. Germany assumed

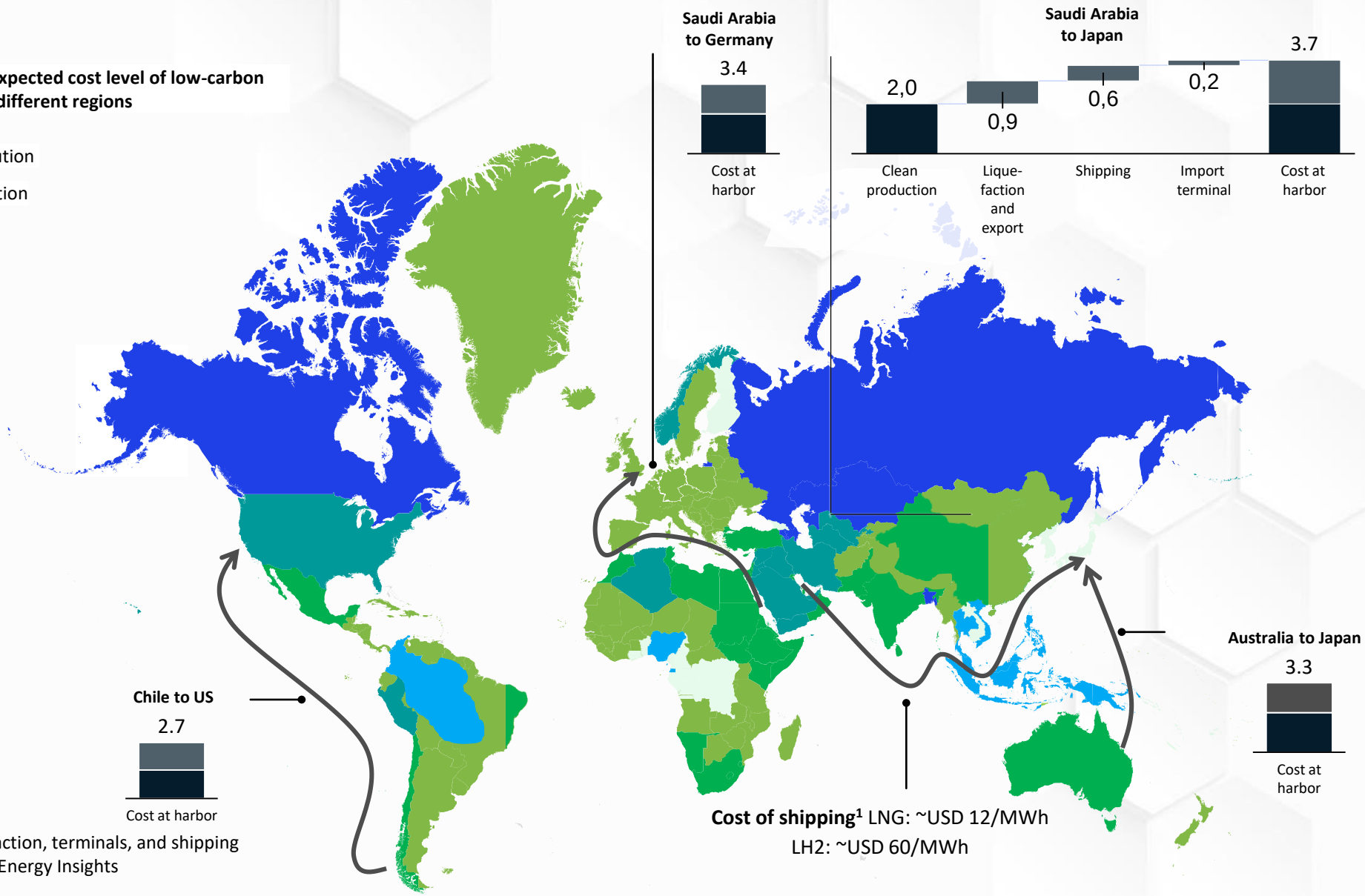
SOURCE: H21; McKinsey; Expert interview

Cost of shipping liquid hydrogen across regions, 2030 (USD/kg)

Source and expected cost level of low-carbon hydrogen in different regions

Distribution

Production



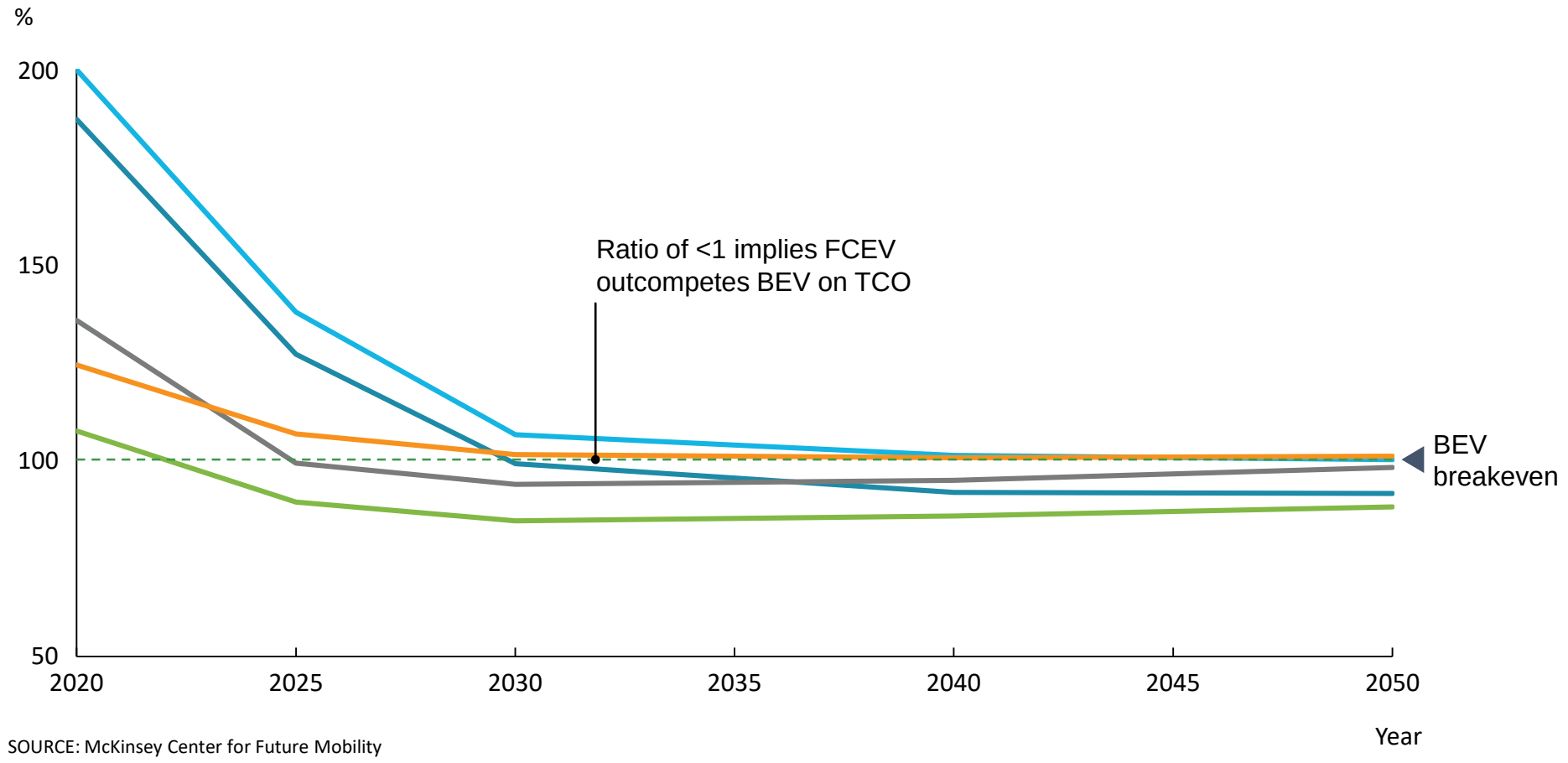
Cost of shipping[1] LNG: ~USD 12/MWh
LH2: ~USD 60/MWh

1. Includes liquefaction, terminals, and shipping

SOURCE: McKinsey Energy Insights

TCO ratio between FCEV/BEV vehicles

No.average of 5 car segments ranging from small and low usage to large and high usage



SOURCE: McKinsey Center for Future Mobility

FCEVs are generally better than BEV in use cases that require long tank range due to

- Lower cost of vehicle due to smaller battery
- Short refueling times made possible by Hydrogen

Longer charging time may imply fleets need to purchase a higher number of vehicles to provide same service

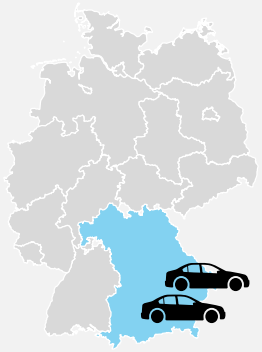
For fleets developing infrastructure, FC offers additional economies of scale vs. BEV, which scale more linearly

Urban car (A/B) – 200 km | Urban bus – 150 km | Family usage (C/D) – 400 km | Heavy duty truck (long-distance) - 600 km | Taxi fleet (E+) - 650 km

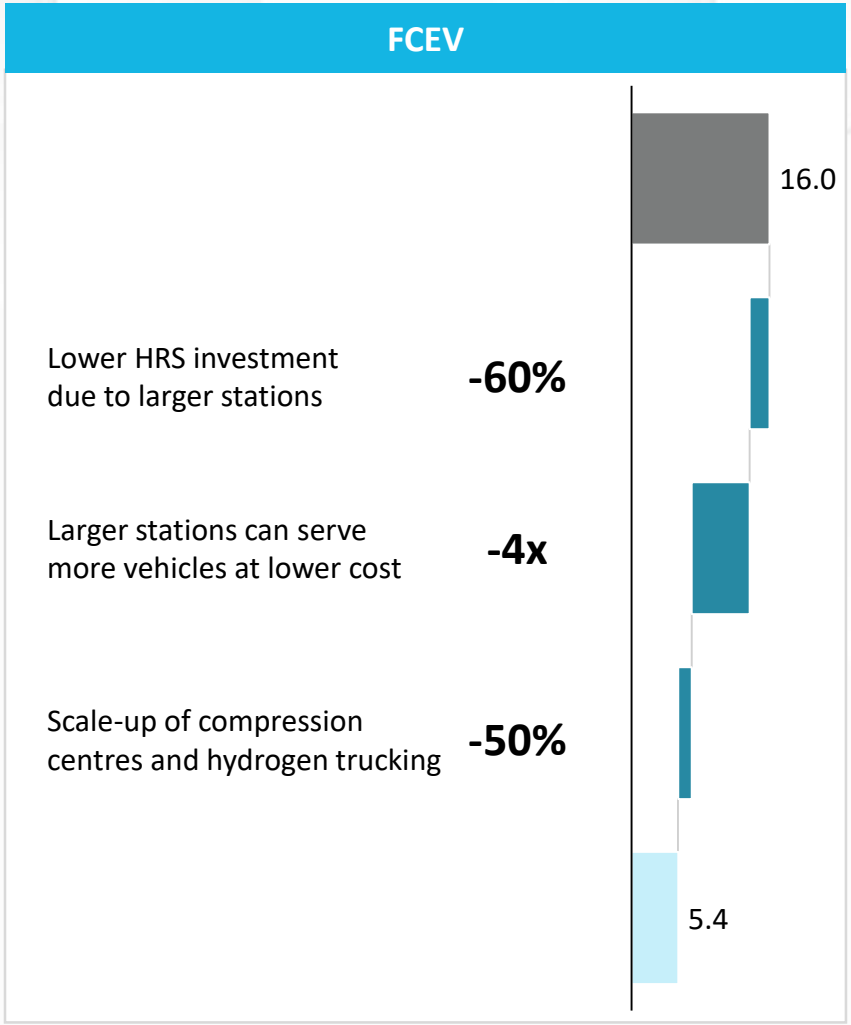
SOURCE: McKinsey Center for Future Mobility

Cost of refuelling/recharging infrastructure investment and operations over lifetime (Germany use case) (USD/vehicle, thousands)

Vehicle cost for first adopters (<0.01% penetration)



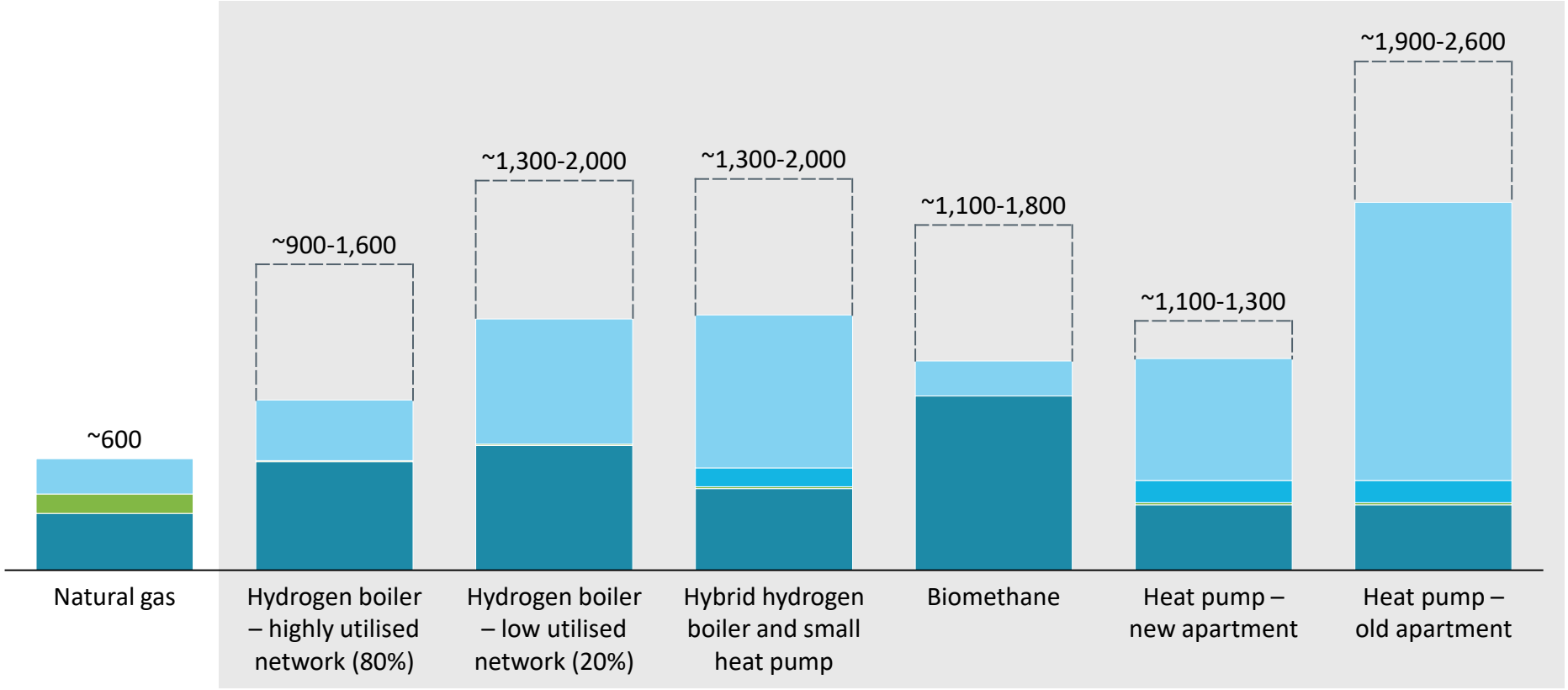
Vehicle cost at higher penetration (up to 20%)



SOURCE: McKinsey Center for Future Mobility

Household heating (USD/year per household in 2030[1] (consumption 10 MWh/year))

NORTHERN EUROPE USE CASE



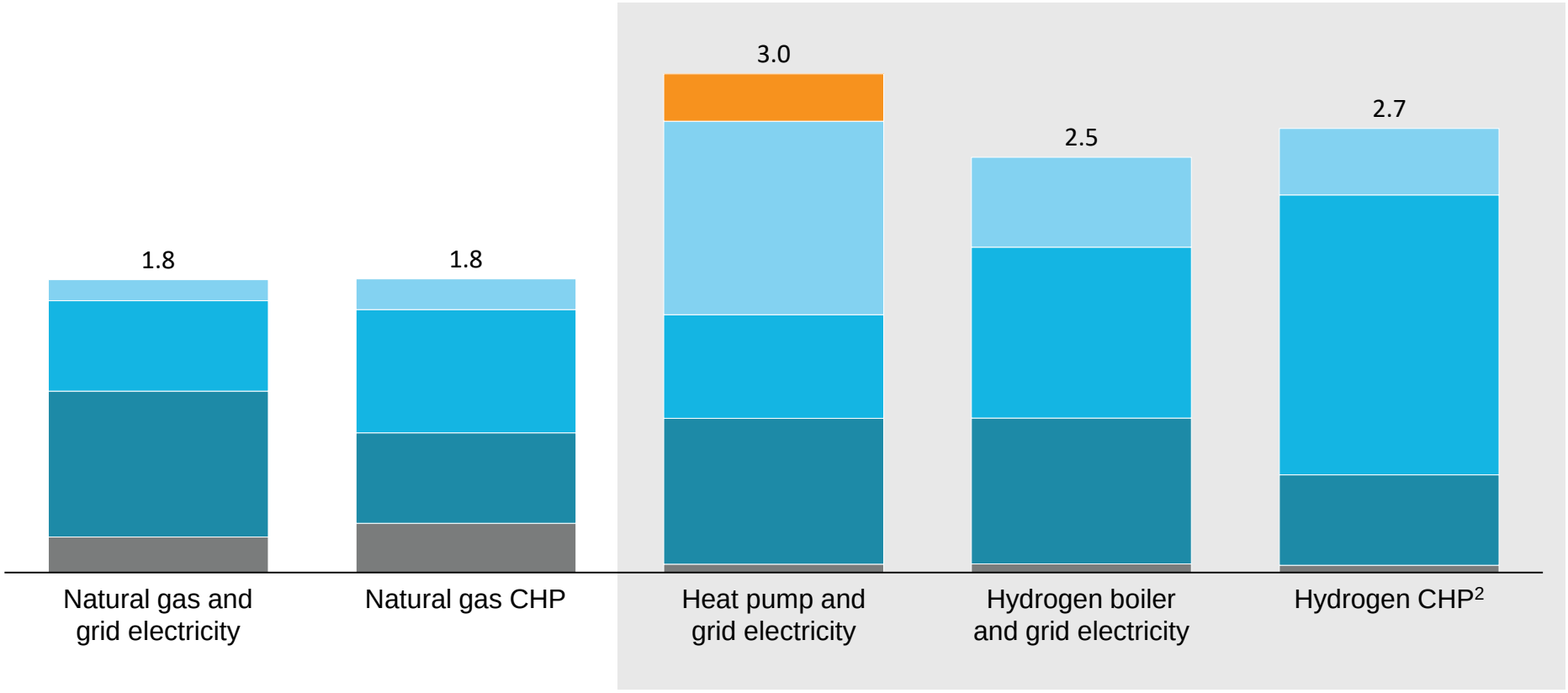
Range of investment[2] | Grid upgrade | Fuel[3] | Investment | CO_2 cost | Low-carbon heating alternatives

Hydrogen heating cost depends heavily on the utilisation of existing natural gas pipelines, at a rate of 90%

In contrast, the cost of heat pumps is strongly impacted by the refurbishment cost: low- to no-cost for new builds but substantial for old apartments

1. One household is assumed to consume 10 MWh of heat per year
2. Range due to different state of insulation in building (new vs. old)/grid infrastructure requirements from high heat pump penetration/cost and utilisation of hydrogen network
3. Fuel cost varies by resources available; can be lower or higher than shown here

Competitiveness H_2 CHP[1] vs. conventional and green alternative (all newbuild)
North of England (USD/year per household[2], thousands)

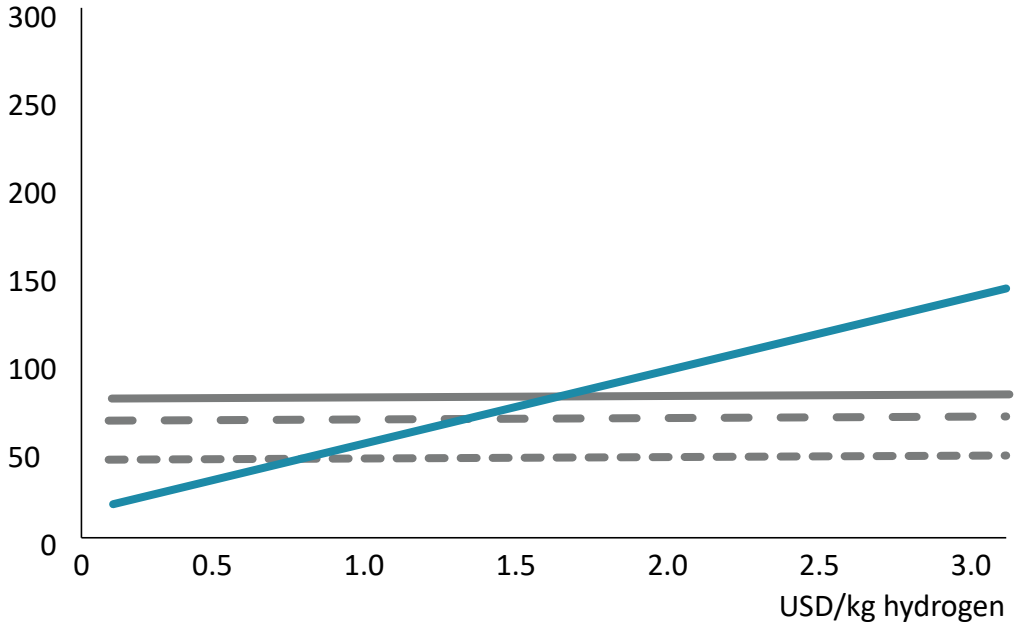


Grid upgrade
Infrastructure cost and charging time
Electricity costs
CO_2 cost
Fuel cost
Low carbon heating alternatives

1. We system (30% electrical efficiency; 80% overall efficiency)
2. Assumes new build house with 18 MWh heat and 7.5 MWh electricity consumption – Note that fuel and electricity costs will vary due to specific local conditions

SOURCE: H21; DoE; Element Energy; SGC Rapport 2014; Eurostat; IEA; Battelle Memorial Institute

Combined cycle turbine 2030 hydrogen vs. natural gas (USD/MWh)

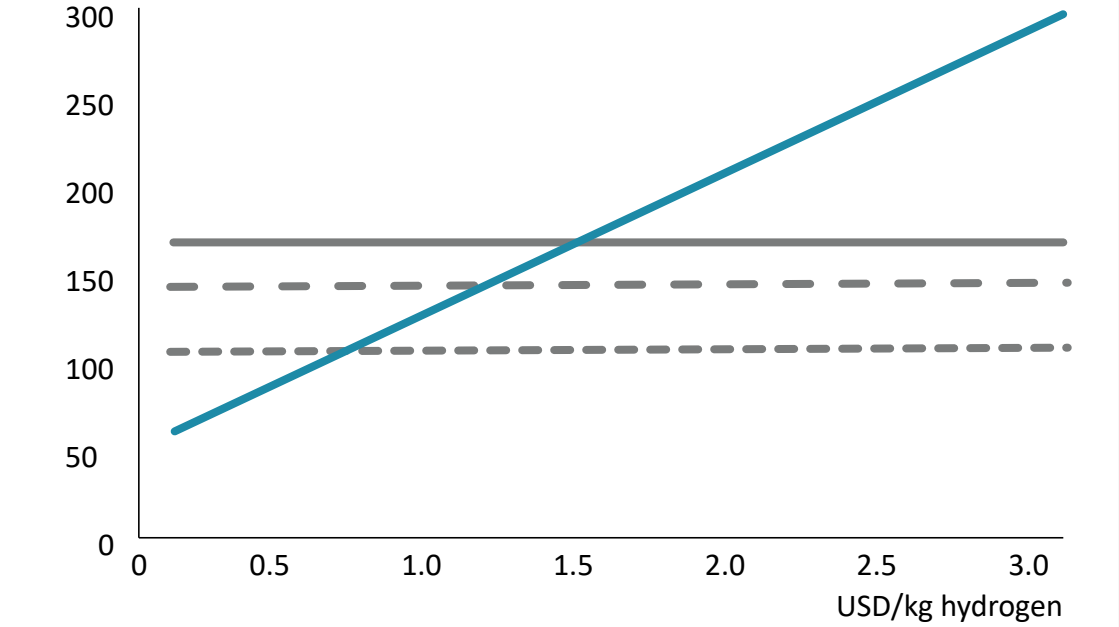


800 MW combined cycle turbine

Efficiency of **~60%**

Utilisation of **~75%** or **6,500** full load hours annually

Flexible capacity (simple-cycle) 2030 hydrogen vs. natural gas (USD/MWh)



50 MW single cycle turbine

Efficiency of **~40%**

Utilisation of **~25%** or **2,100** full load hours annually

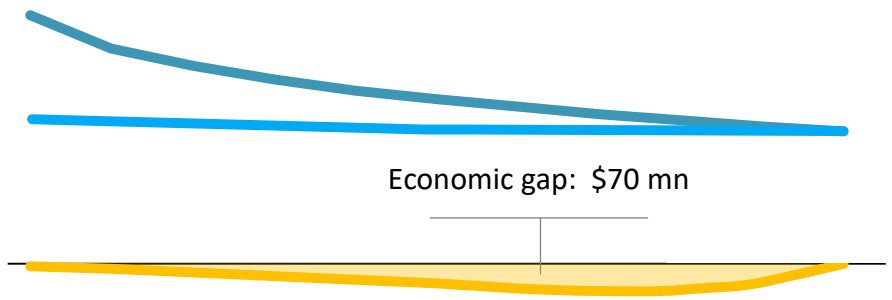
1. Assumed hydrogen cost from ATR with CCS in 2030 in the US at USD 1.1/kg, EU/Germany USD 1.7kg, Japan/Korea USD 1.8/kg
2. NG cost of USD 0.12/kg
3. NG cost of USD 0.31/kg

	Segment	What needs to be achieved		Required premium to 2030, USD bn
HYDROGEN SUPPLY	**Renewable hydrogen**	**Renewable production scale up** to cost parity with grey in countries with favourable renewables	**70 GW**	20
	Low-carbon hydrogen	**Low-carbon production at scale** until cost parity with grey	**~10 Mtpa** in 2030	6
	Transportation	**Distribution and refuelling station** network scale up	**20,000** HRS	10
		Manufacturing scale-up	**3 m** FCEVs	20
HYDROGEN APPLICATIONS	**Heat and power for buildings**	**Network and gas boilers** upgrades, fuel cost gap bridged	**6m** households	10
	Heat and power for industry	**Fuel cost gap** bridged	**115 Twh** in 2030	7

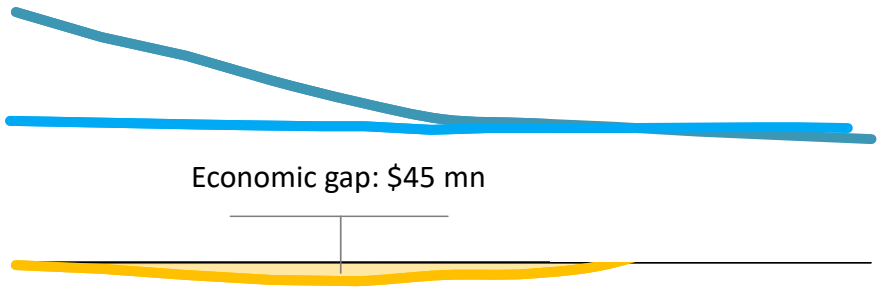
Supporting regulation to embed USD 50/t CO_2 by 2030

Economic gap with different volume ramp-up scenarios (Large passenger vehicle)

Conservative scenario with slow adoption



Ambitious scenario with faster adoption

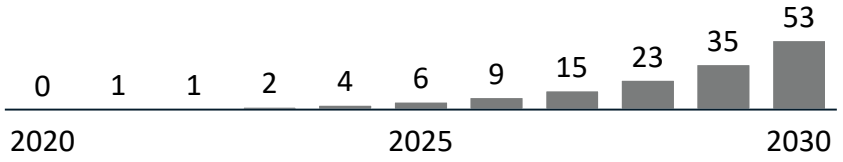


Differential between FC and BEV fleet fuel cost

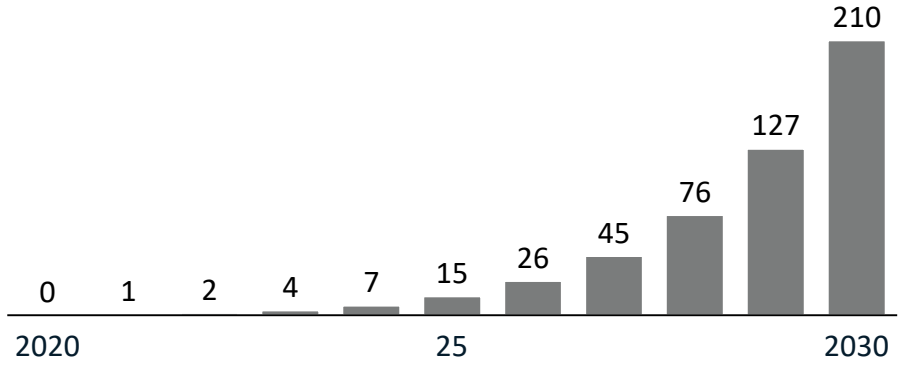
TCO of large fuel cell passenger vehicle

TCO of large battery electric passenger vehicle

Deployment, cumulative sales ‘000 large passenger vehicles:



Deployment, cumulative sales ‘000 large passenger vehicles:



How to accelerate Hydrogen's competitiveness

Reduce demand uncertainty

Reduce uncertainty, e.g. with long-term offtake agreements, feed-in tariffs, ZEV targets, captive demand

Complementarity

Deploy applications that start 'virtuous cycles' and positive spillover effects, e.g. hydrogen infrastructure on airports for refuelling, heating and power

Low-cost production

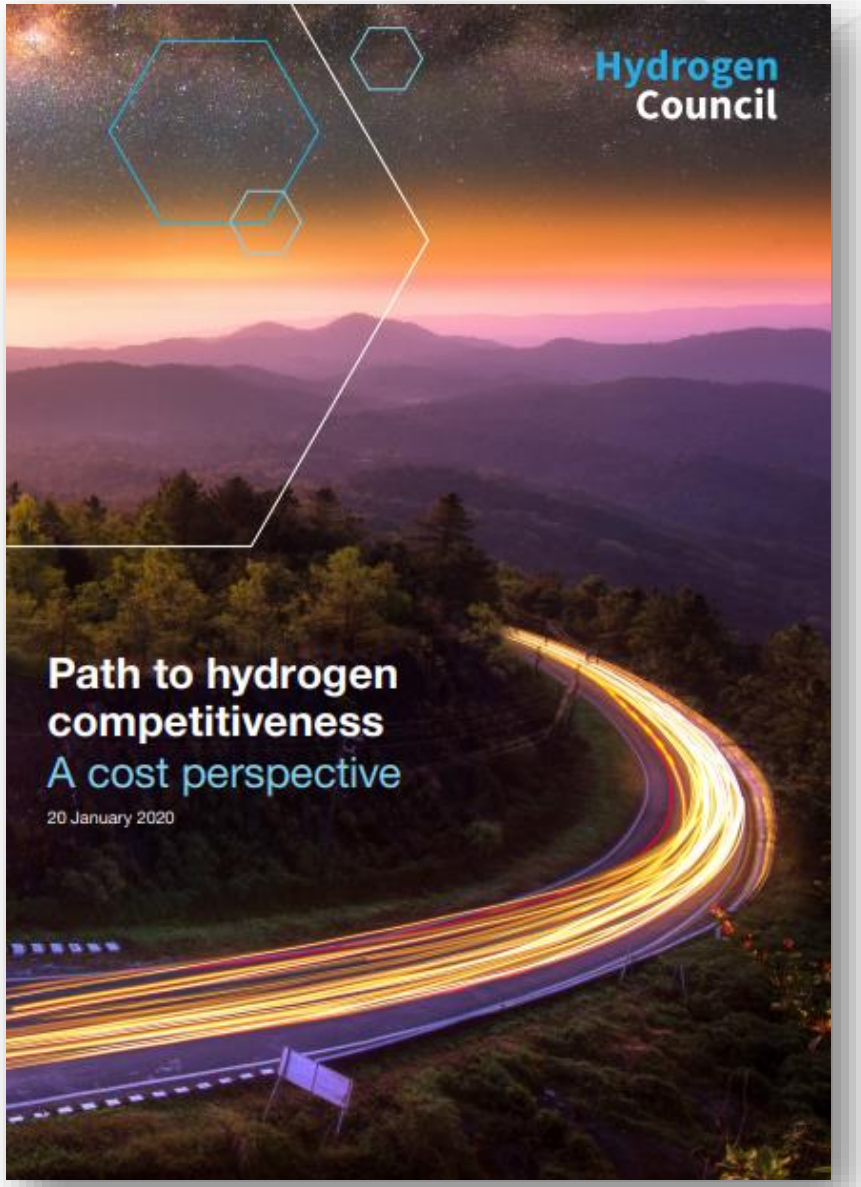
Push scale-up of hydrogen production, e.g. with ~40 GW of electrolysers, renewable hydrogen can out-compete grey in select areas

Utilisation

Focus on increasing utilisation of assets, e.g. through aggregation of demand and synchronisation of deployment

Scale

Focus on solutions with biggest 'improvement-for-investment', e.g. fuel cells and tanks



www.hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective

Hydrogen Council

Thank you

secretariat@hydrogencouncil.com

+32 (0)2 289 04 99

@HydrogenCouncil

Hydrogen Council