World Hydrogen Outlook

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International Energy Agency

What do energy & climate ambitions mean for energy technology?

- A growing number of governments & companies are making ambitious pledges to reach net-zero emissions in coming decades. But achieving those goals & ensuring energy security is a big challenge.

- Major progress has been made: the rise of solar PV, wind and batteries has significantly reduced the costs of renewable electricity and electric cars.

- But transitioning the energy system to net-zero emissions requires broader technology efforts – hydrogen can play an important role in this endeavour.

Hydrogen – A common *element* of our energy future?

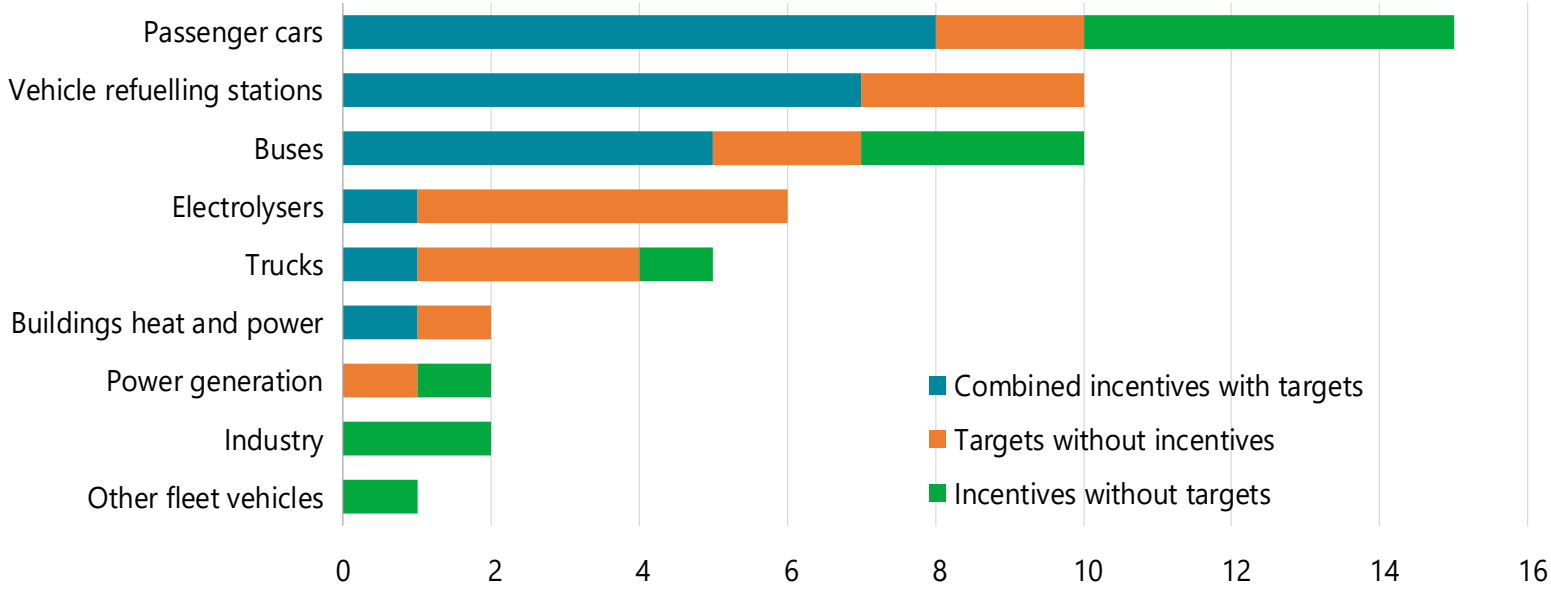
- Momentum currently behind hydrogen is unprecedented, with more and more policies, projects and plans by governments & companies in all parts of the world

- Hydrogen can help overcome many difficult energy challenges
  - ***Integrate more renewables,*** including by enhancing storage options & tapping their full potential
  - ***Decarbonize hard-to-abate sectors*** – steel, chemicals, trucks, ships & planes
  - ***Enhance energy security*** by diversifying the fuel mix & providing flexibility to balance grids

- But there are challenges: ***costs*** need to fall; ***infrastructure*** needs to be developed; ***cleaner hydrogen*** is needed; and ***regulatory barriers*** persist

Current Status

Renewed interest in hydrogen reflected in policy action



(source: Future of Hydrogen, 2019; updates at TCEP, Hydrogen)

A growing number of countries have policies to encourage hydrogen deployment, mainly focusing on transport.

Hydrogen has not lost its momentum in 2020

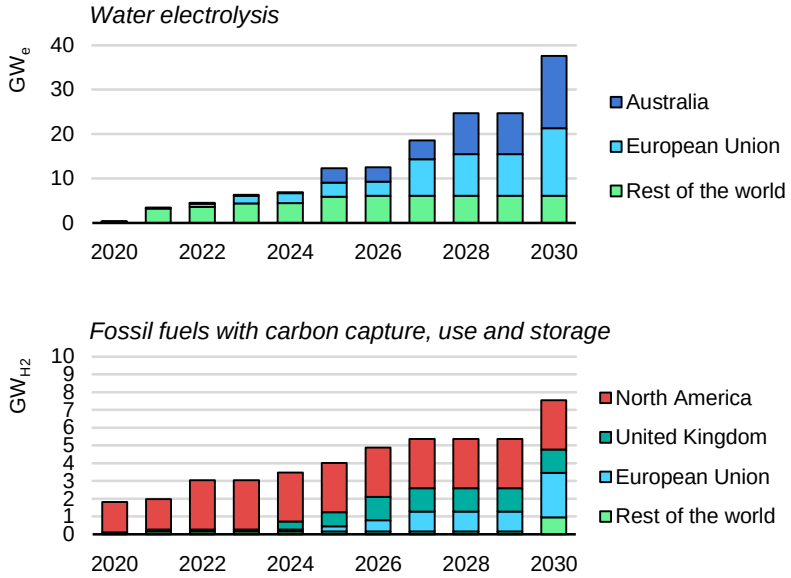
Announced hydrogen strategies and roadmaps

2018

2019

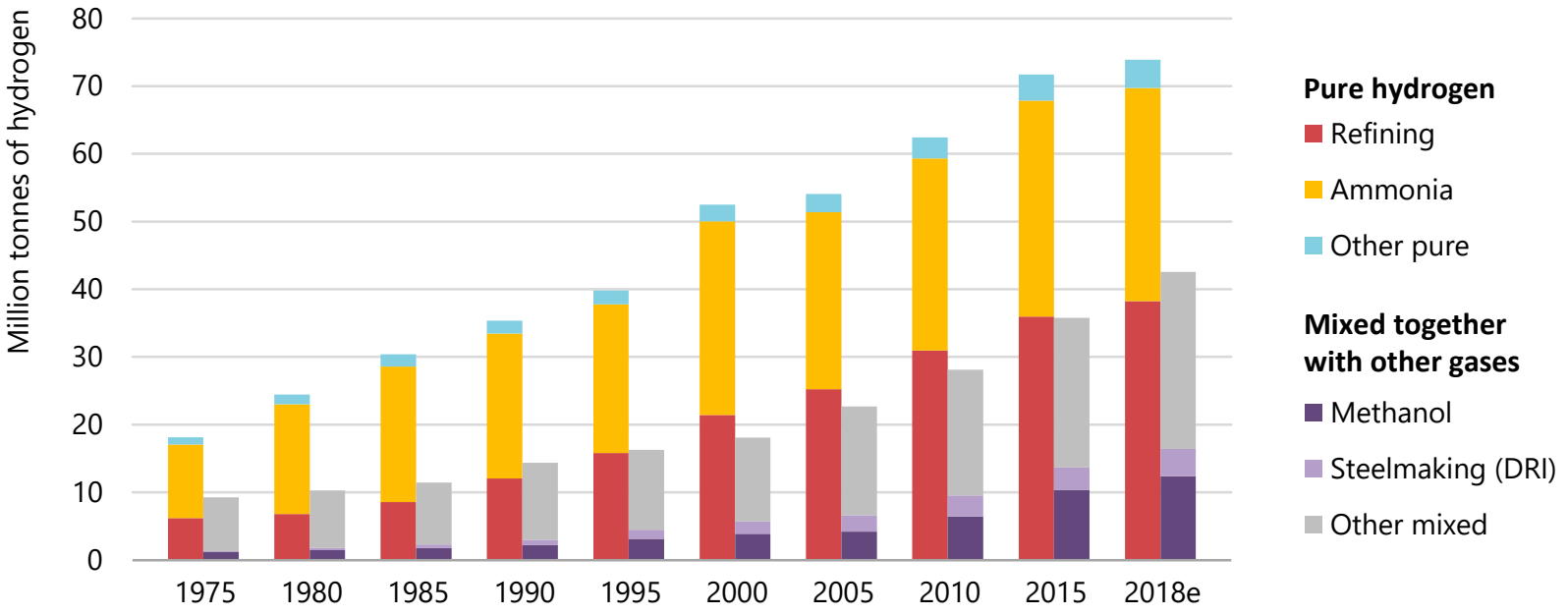
2020

Pipeline of low-carbon hydrogen production projects



In 2020, 9 countries and the EU announced national hydrogen strategies and roadmaps.
Many low-carbon hydrogen production projects were announced, some of them in the GW scale.

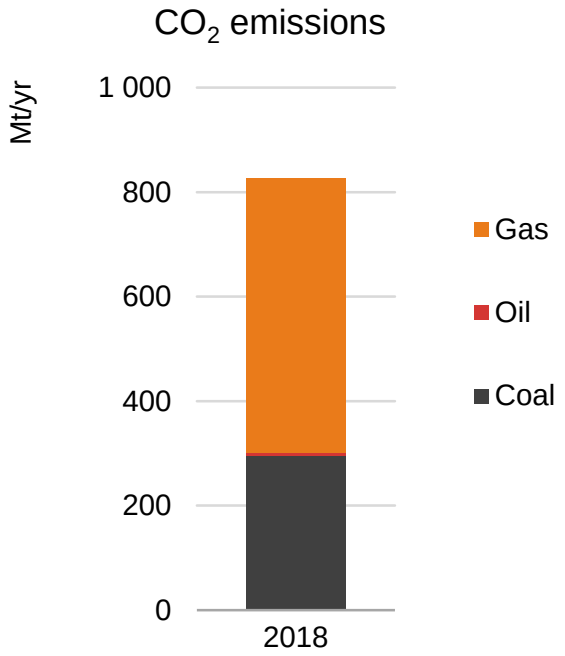
Hydrogen is already part of the energy mix

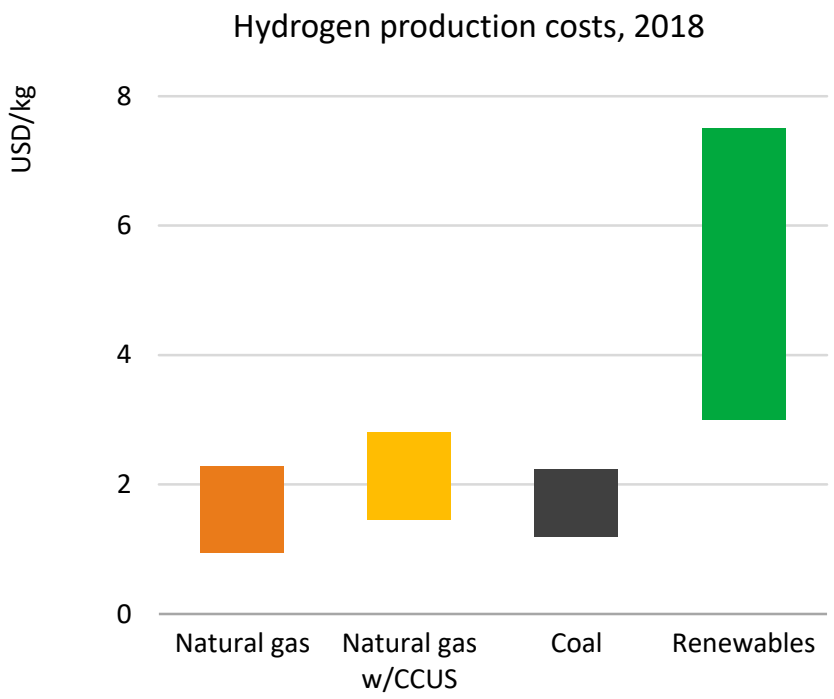


(source: Future of Hydrogen, 2019)

Global demand for hydrogen in pure forms has grown steadily over the past 50 years to around 70 Mt today. More than 40 Mt is also produced in a mixture of other gases.

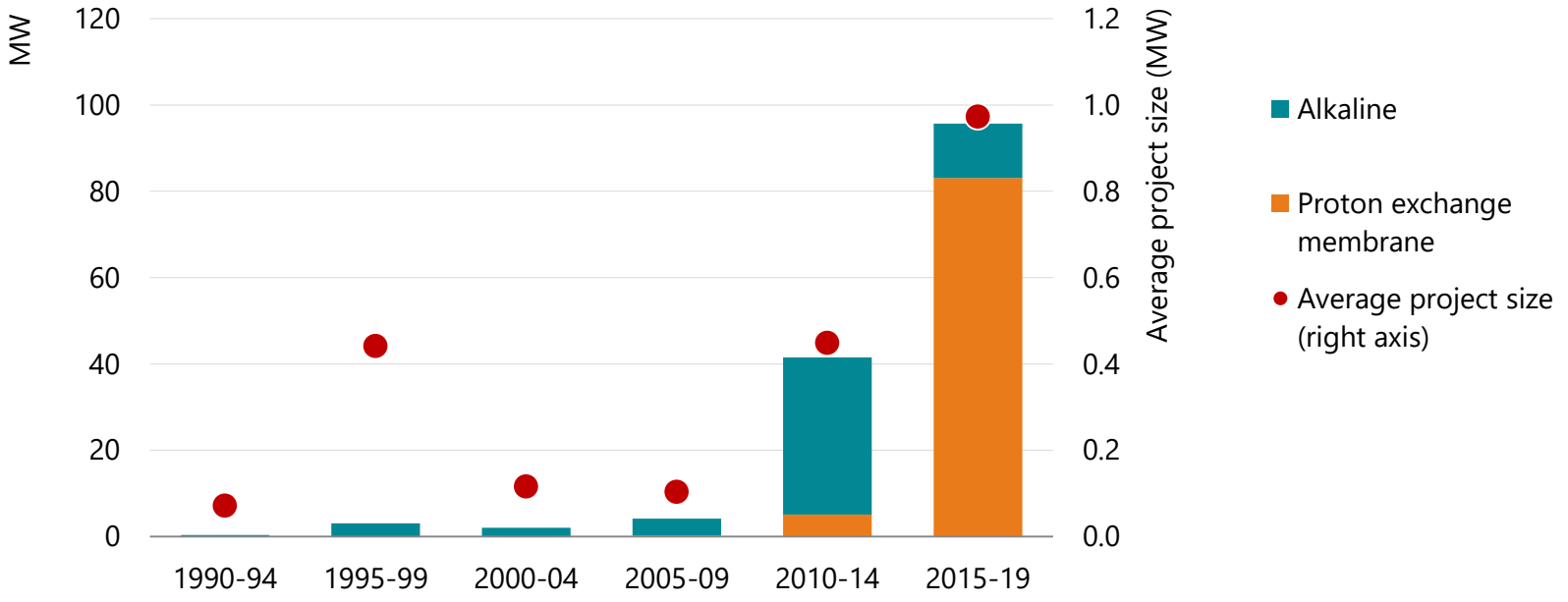
The current state of hydrogen production





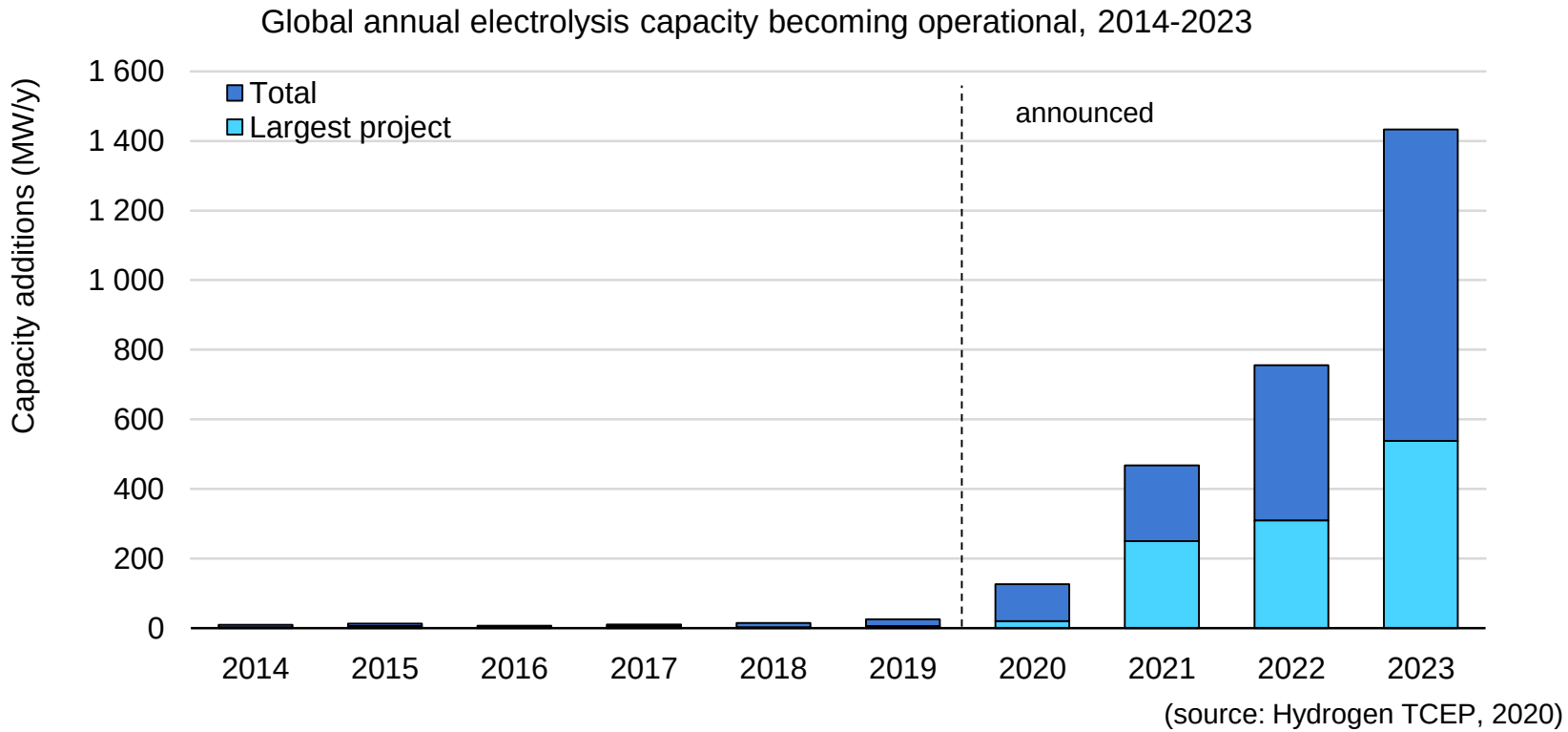
Virtually all hydrogen today is produced using fossil fuels, as a result of favourable economics.

Global electrolyser capacity additions and average unit size



Electrolyser capacity additions and their average sizes have been growing rapidly in recent years, providing cost reductions from economies of scale and learning effects.

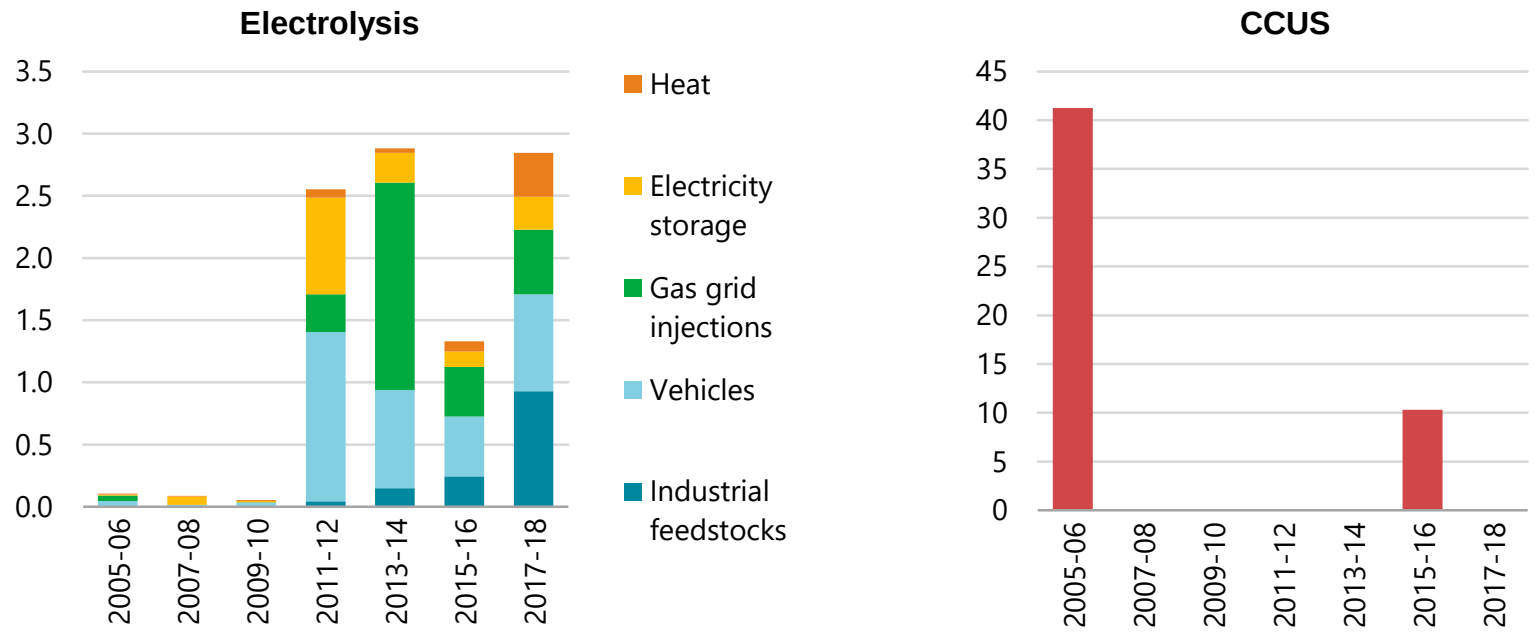
Electrolytic hydrogen is on the rise



The pipeline of projects could bring installed capacity to 3 GW by 2023.

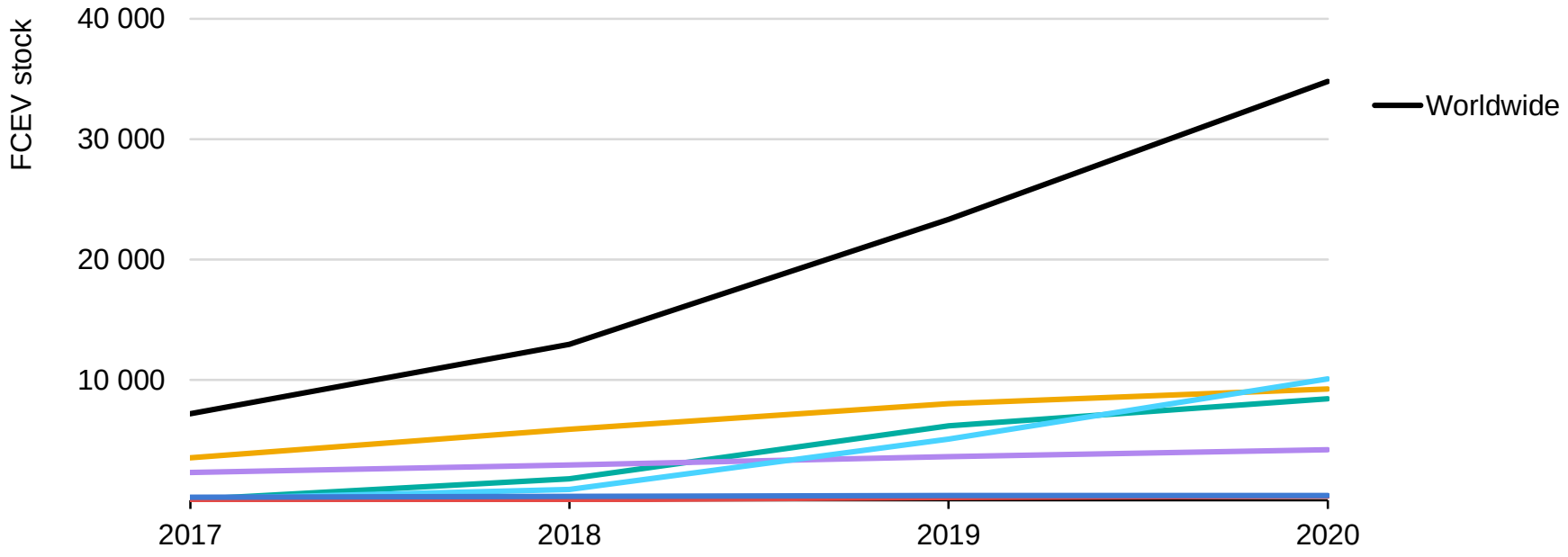
Europe is a global pioneer for clean hydrogen projects

Clean hydrogen production capacity additions in Europe (thousand tonnes/year)



Electrolysis projects have expanded in Europe, but have much less potential to produce clean hydrogen than two CCUS projects.

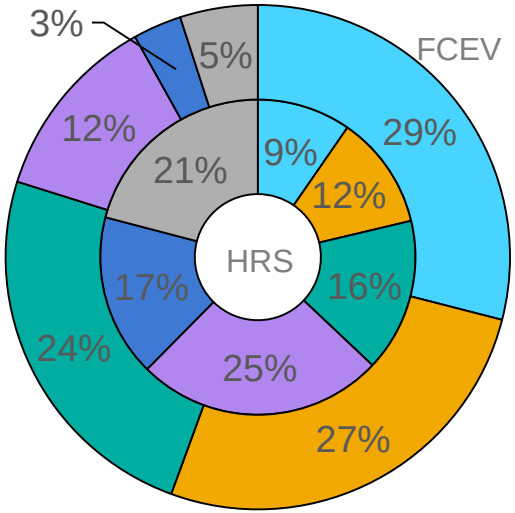
Fuel cell electric vehicle deployment



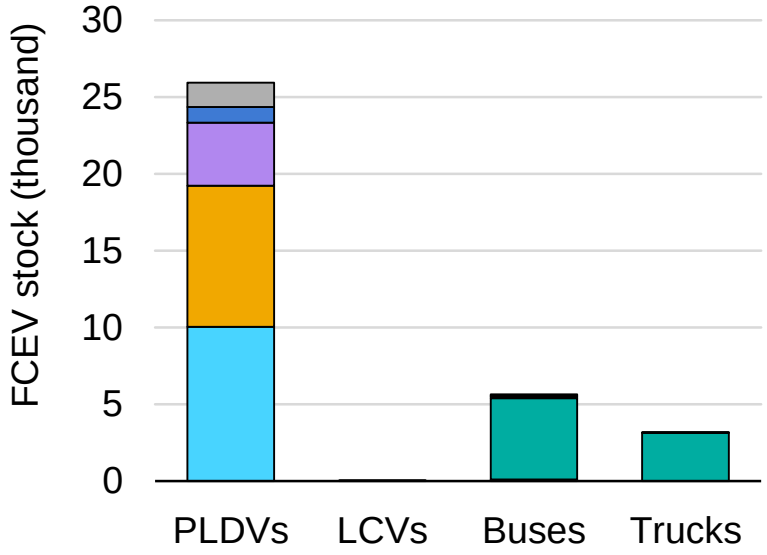
In 2020, the global FCEV stock increased 40%

FCEV strategy differs by country

Fuel cell vehicles and hydrogen refuelling station stock by region, 2020



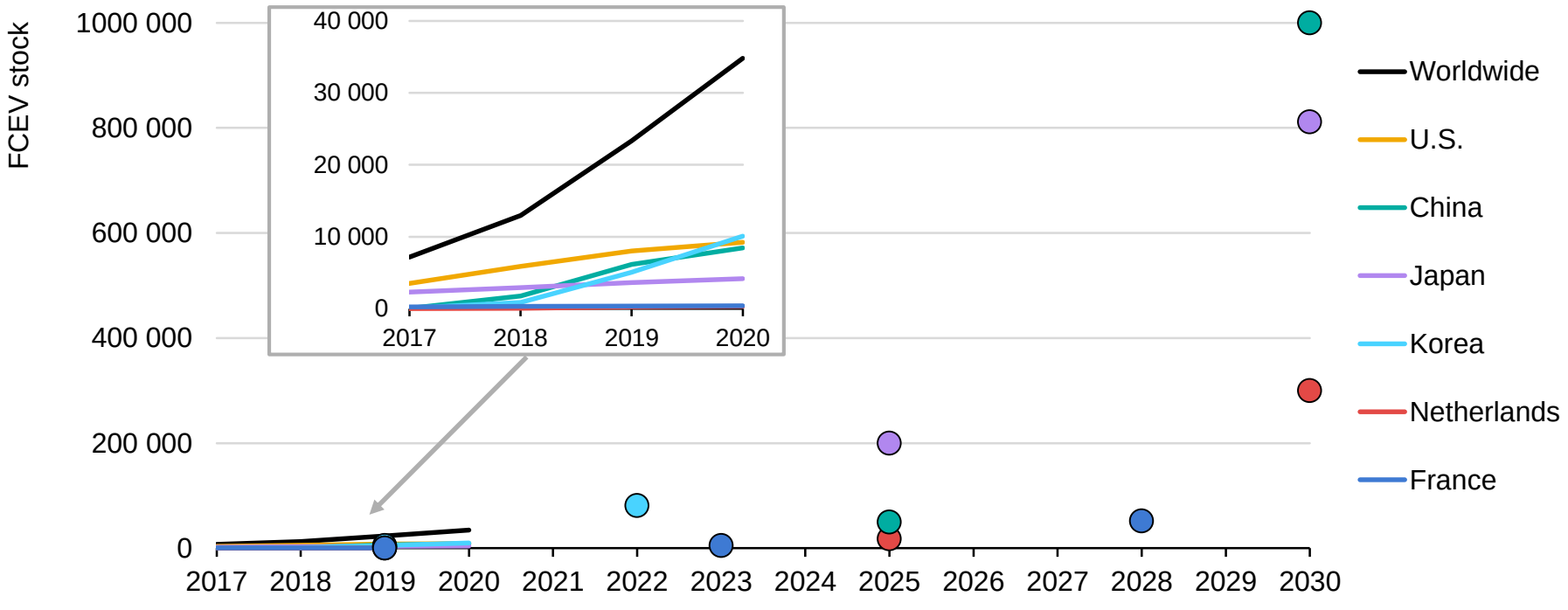
Fuel cell vehicles by mode and region, 2020



(source: GEVO 2021)

China dominates the market for fuel cell buses and trucks, while other countries have focused on cars.

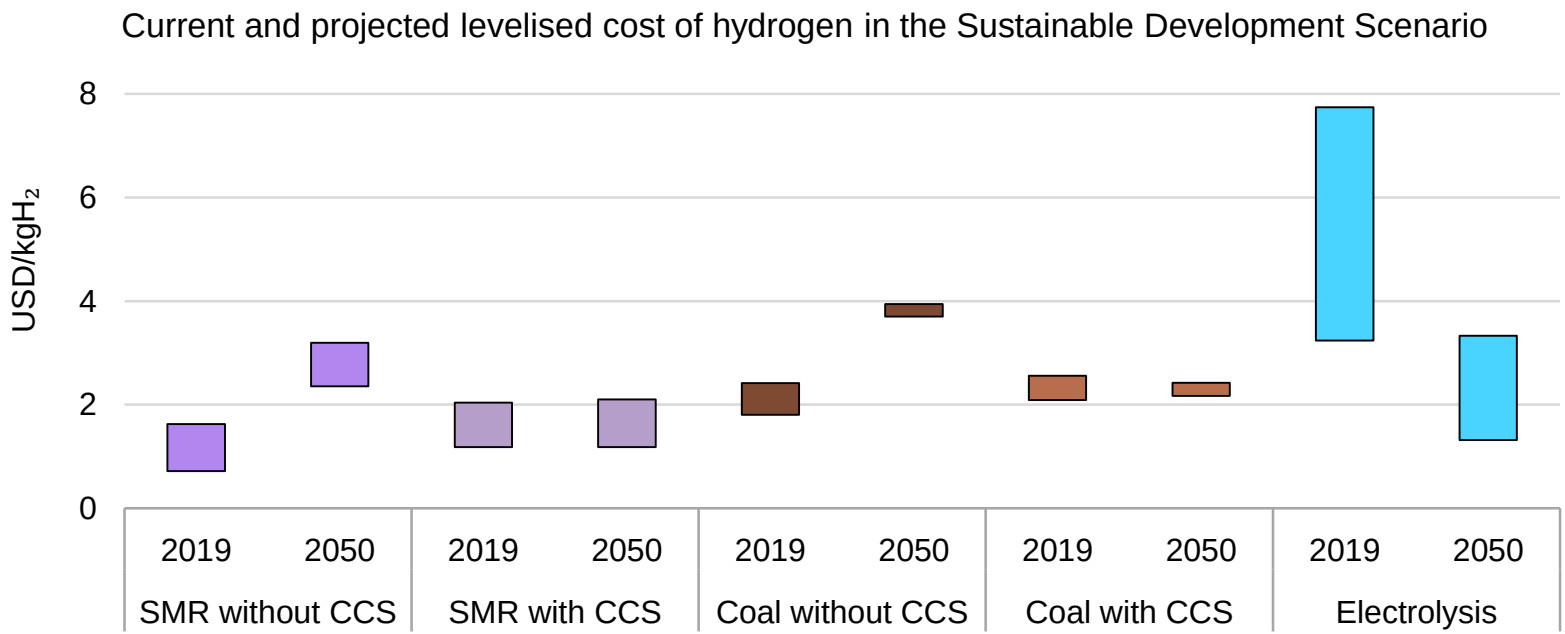
Countries have announced ambitious targets over the next decade



Combined FCEVs deployment targets across countries exceed 10 million vehicles in 2030 (285 times the current stock).

Global Outlook

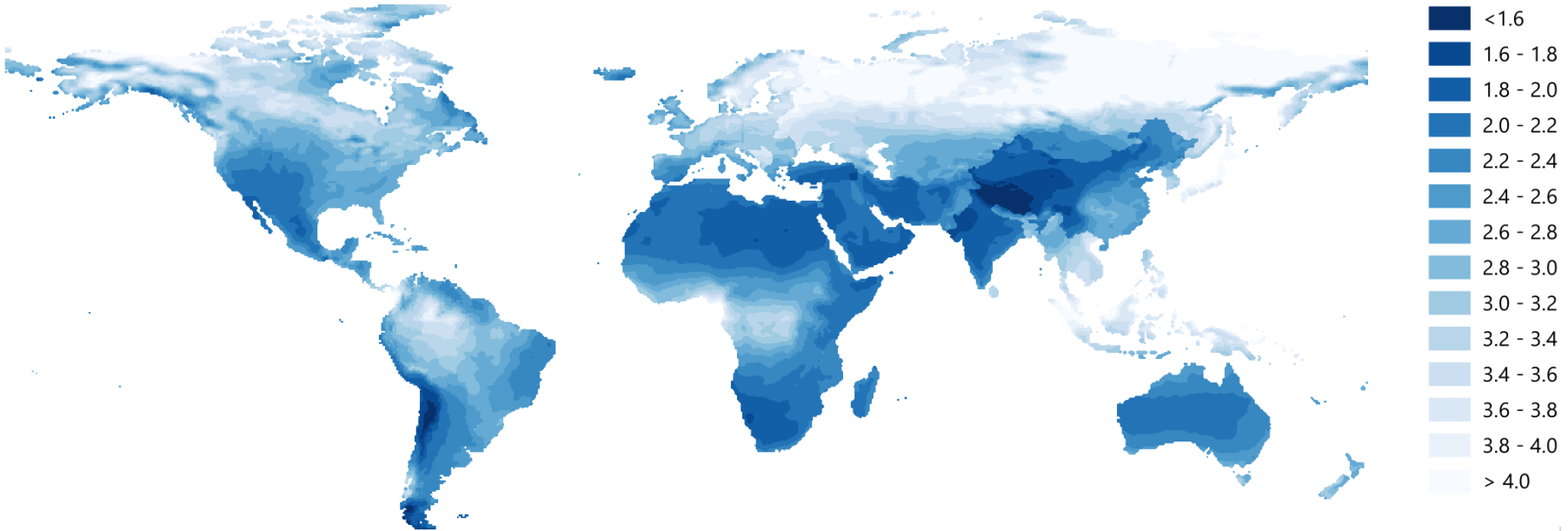
Scale up can make low-carbon hydrogen competitive



Hydrogen produced from electrolysis powered by renewables can become competitive with conventional fossil generation in several parts of the world.

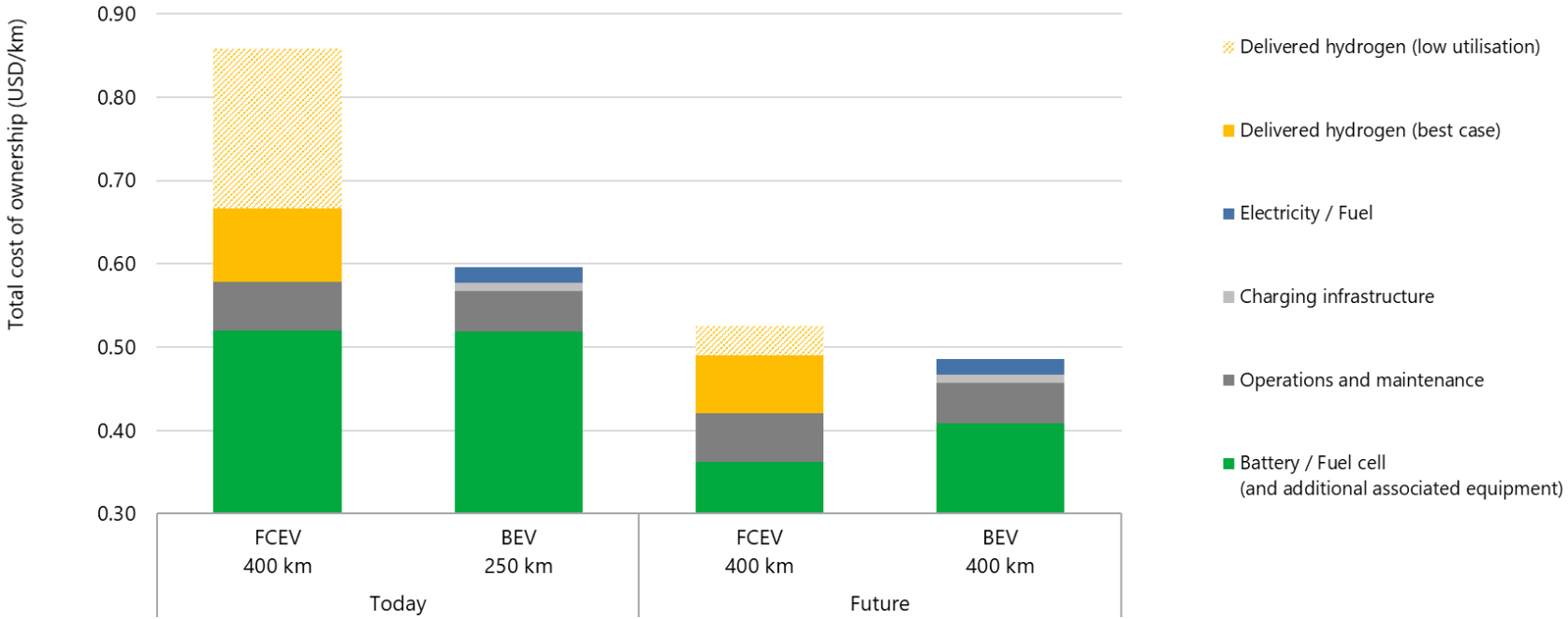
Renewables hydrogen costs are set to decline

Long-term hydrogen production costs from solar & wind systems



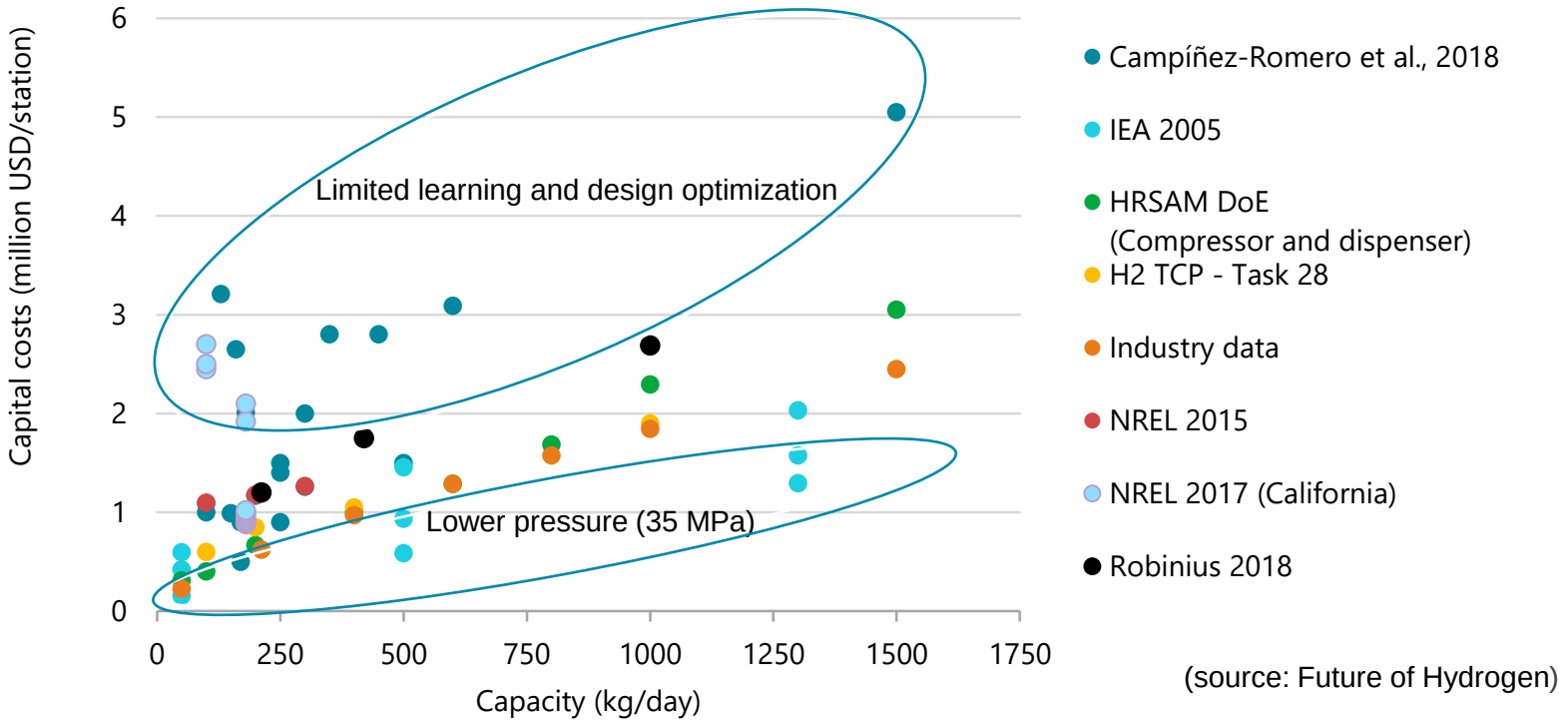
The declining costs of solar PV and wind could make them a low-cost source for hydrogen production in regions with favourable resource conditions.

The competitiveness of fuel cell vehicles depends on many factors



Costs of fuel cells and hydrogen storage tanks need to fall, but costs of hydrogen supply & delivery is the critical factor to make hydrogen fuel cell vehicles competitive in future car markets.

Hydrogen refuelling station capital costs as a function of capacity

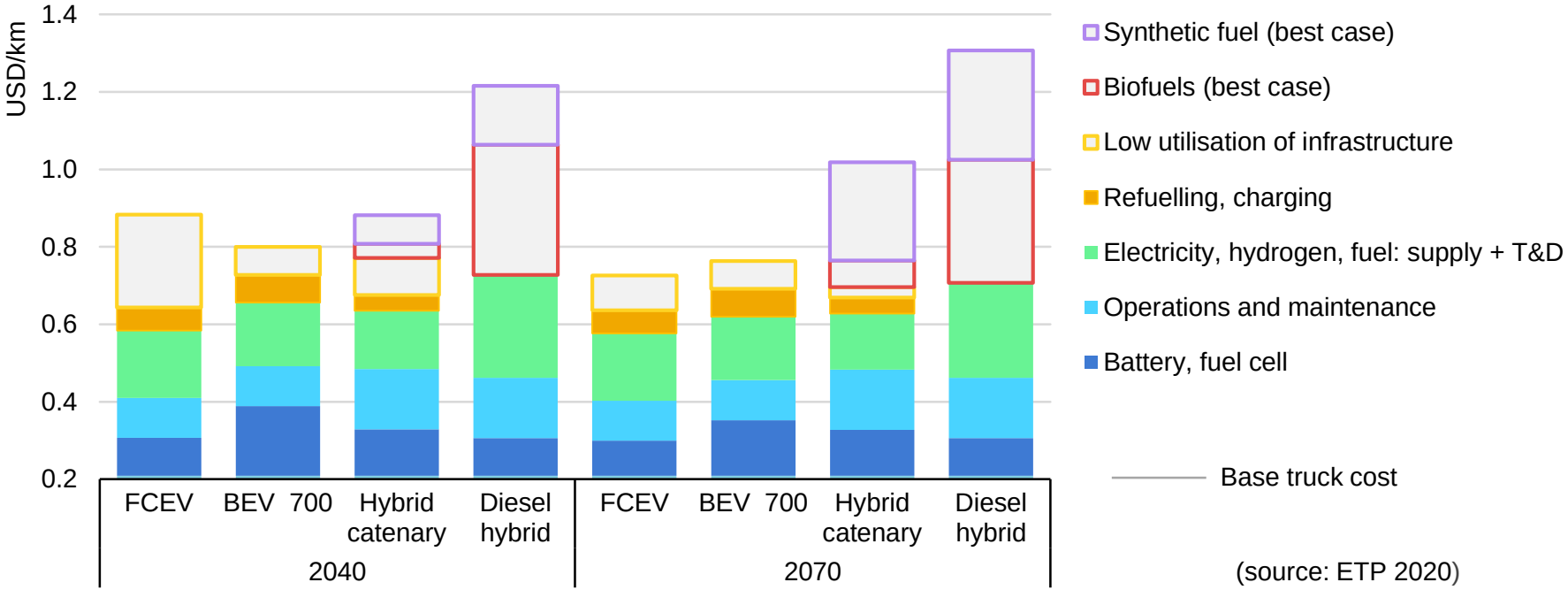


(source: Future of Hydrogen)

The costs of providing hydrogen to FCEVs can be brought down by building larger refuelling stations as long as expected hydrogen demand allows.

Batteries and fuel cells fulfill different niches in road freight

Total cost of ownership of heavy-duty trucks by low-carbon fuel in the Sustainable Development Scenario, 2040 and 2070

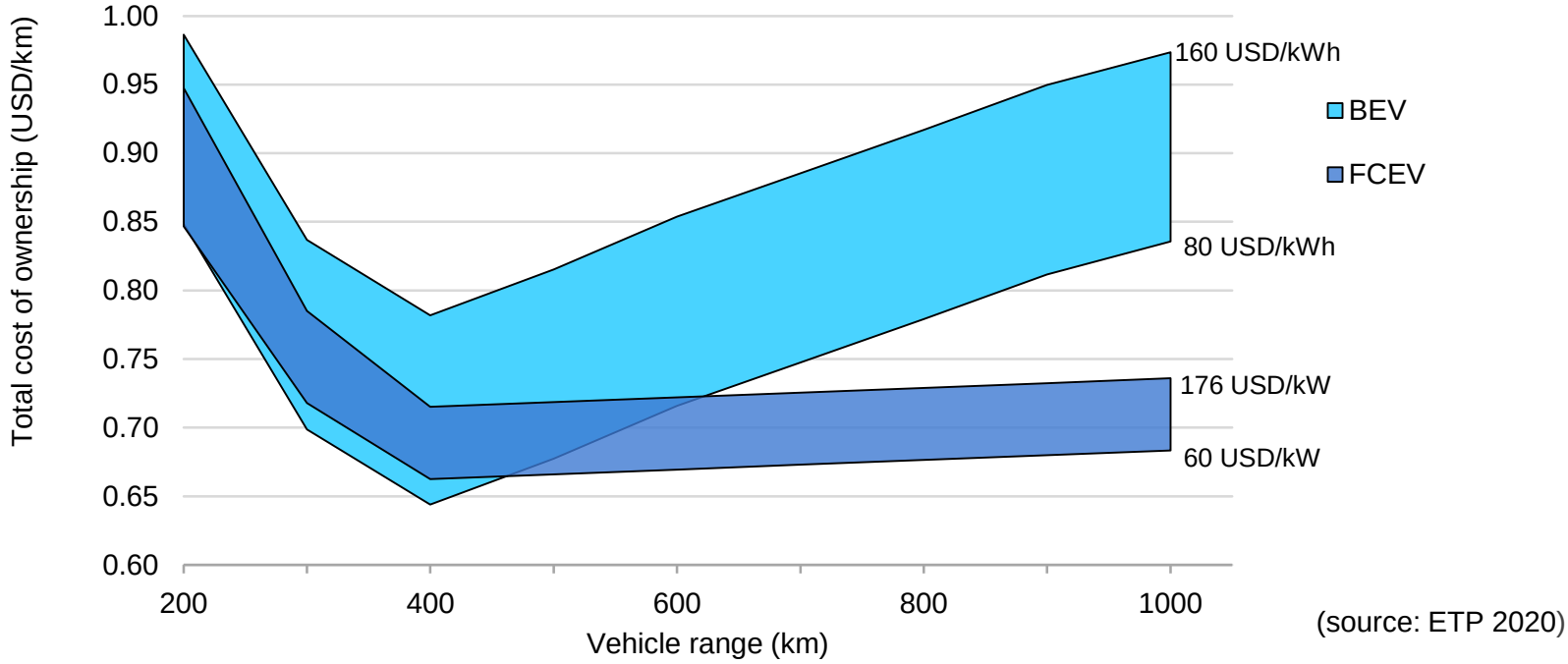


(source: ETP 2020)

Rolling out the dedicated infrastructures – ultra-fast charging, hydrogen refuelling stations, and electric road systems – will be a critical step in transitioning to zero-emissions truck technologies.

Fuel cell electric trucks may deliver lower costs in certain operations

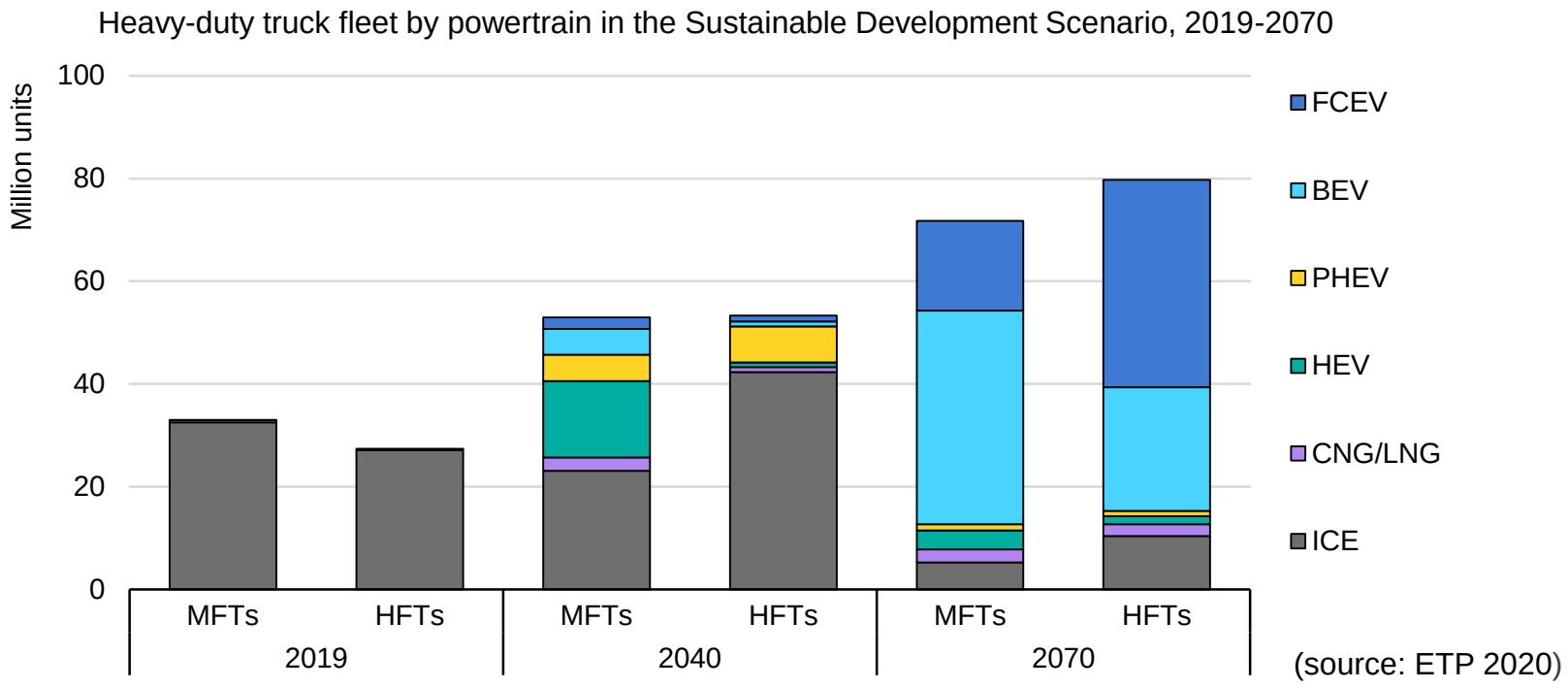
The effect of battery and fuel cell prices on total cost of ownership of heavy-duty trucks in long-haul operations



(source: ETP 2020)

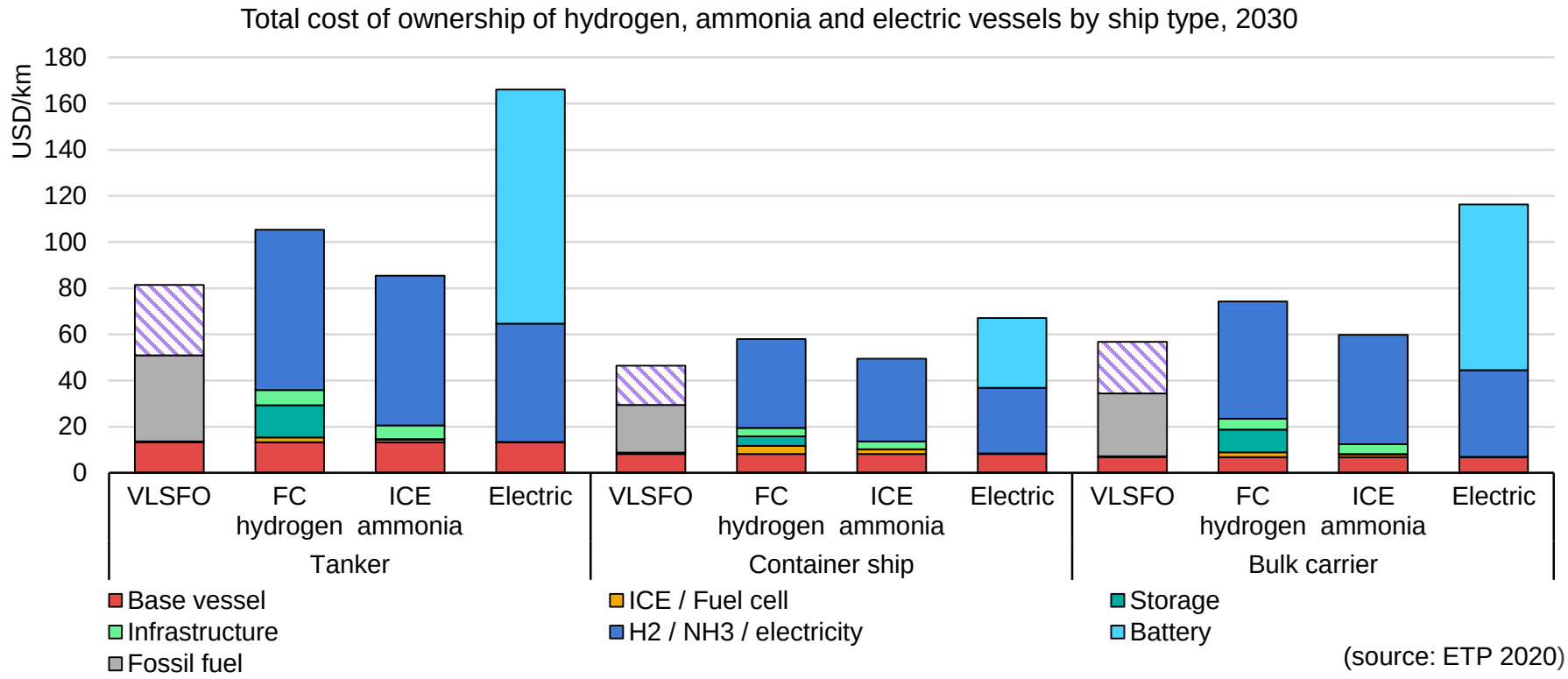
The prospects for competing powertrain options hinge on the future trajectories of the cost and performance of batteries and fuel cells. Fuel cell electric trucks may offer lower cost operations than battery electric trucks at daily ranges greater than 400 kilometres.

The low-carbon fuel mix depends on the truck segment



Nearly half of medium-freight trucks have hybrid or full electric powertrains by 2040, while most medium- and heavy-freight trucks operate with batteries or hydrogen fuel cells in 2070 in the Sustainable Development Scenario.

Alternative low-carbon fuels and powertrains are expensive

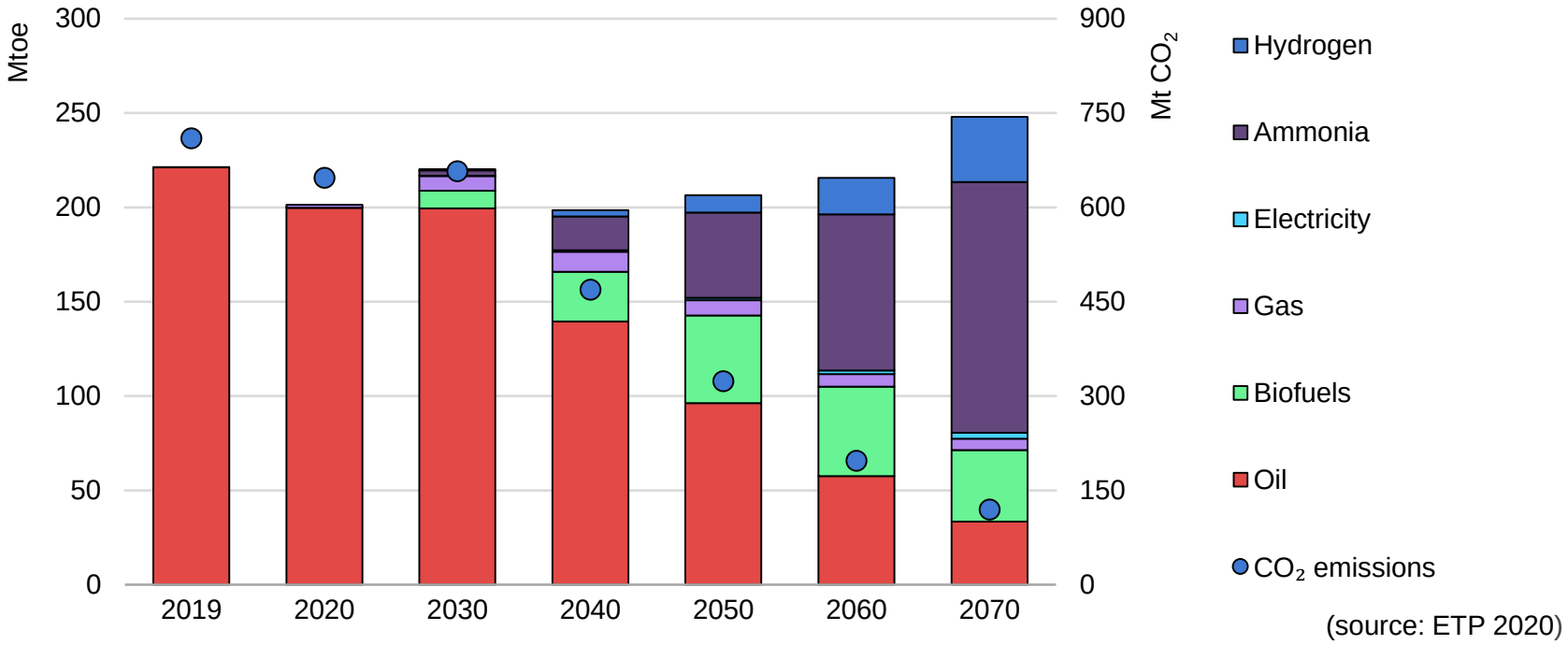


(source: ETP 2020)

The high cost of storing hydrogen makes it less economical than ammonia.

Ammonia, biofuels, and hydrogen replace oil in maritime shipping

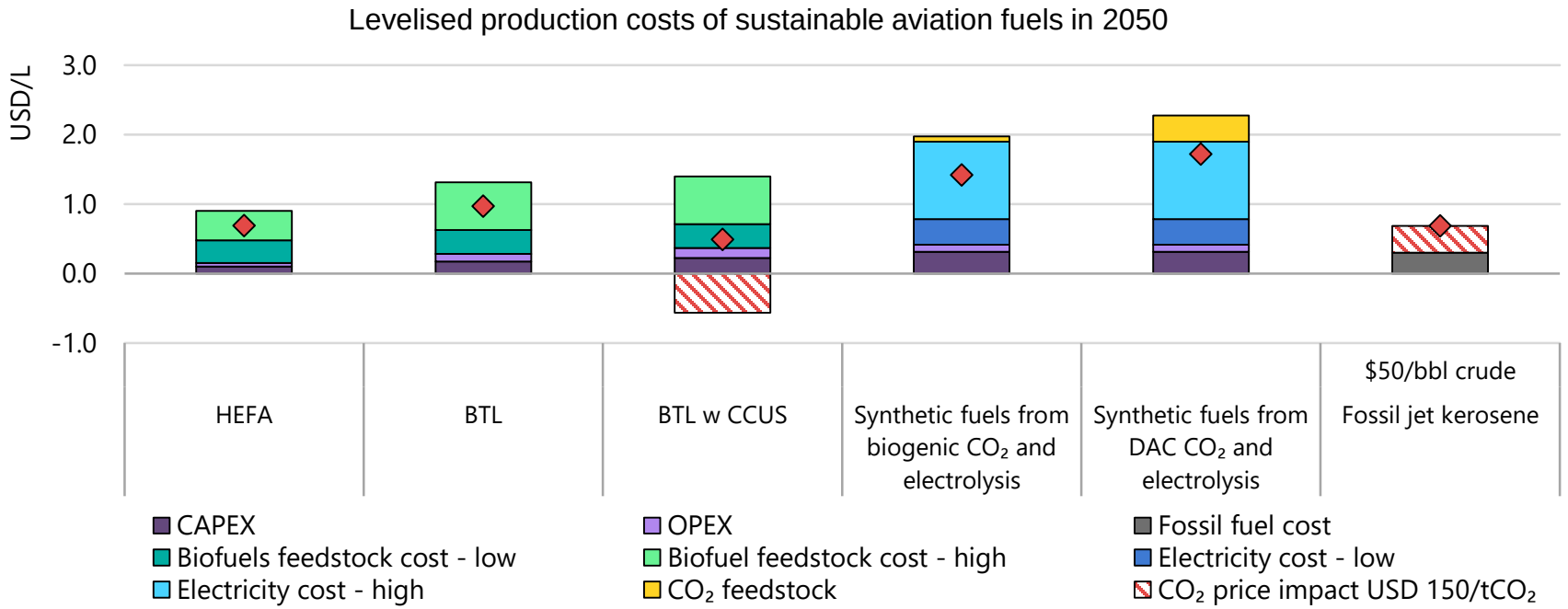
Global energy consumption and CO_2 emissions in international shipping in the Sustainable Development Scenario, 2019-70



(source: ETP 2020)

Emissions from international shipping fall by more than four-fifths between 2019 and 2070 in the Sustainable Development Scenario, mainly due to switching to biofuels and hydrogen-based fuels.

Long term projections of levelised costs of sustainable aviation fuels

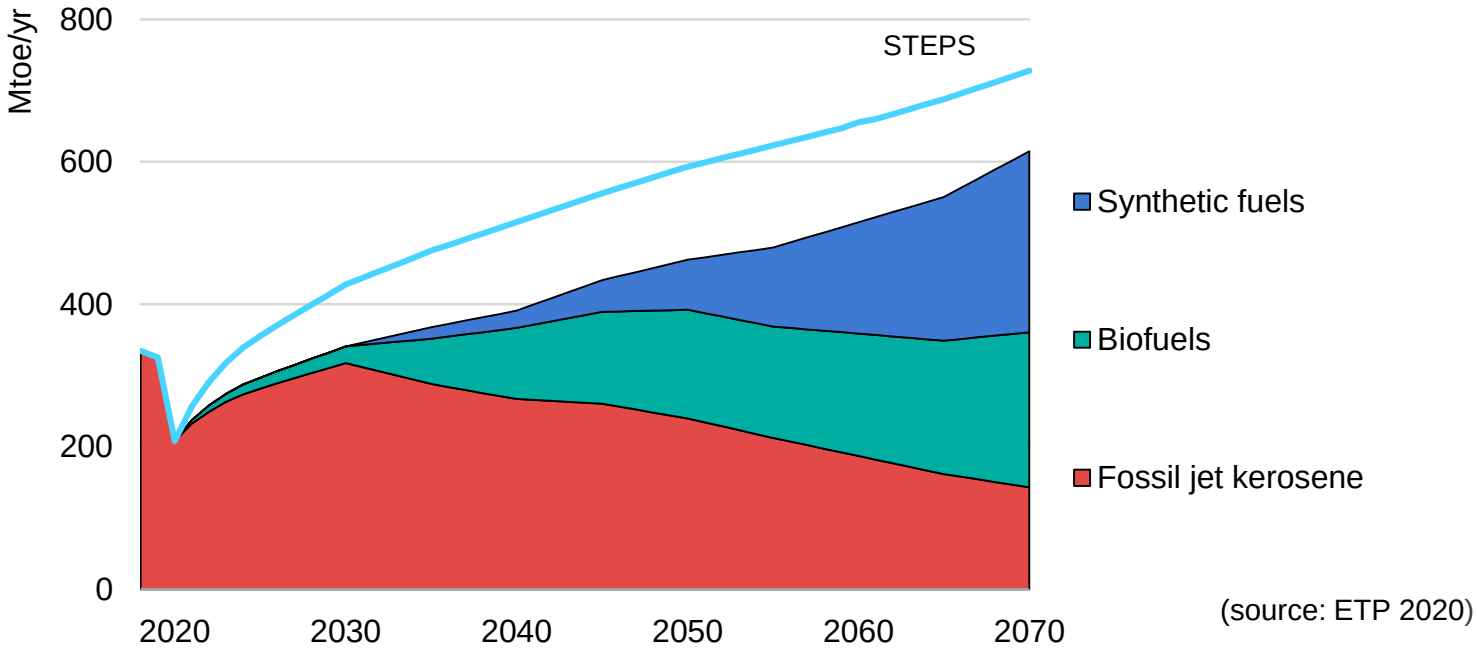


(source: ETP 2020)

With a carbon price of USD 150/tonne, sustainable aviation fuels begin to compete with oil-based jet kerosene, though policy support will need to account for the volatility and uncertainty of future feedstock costs and oil prices.

Sustainable Aviation Fuels are critical to reducing aviation emissions

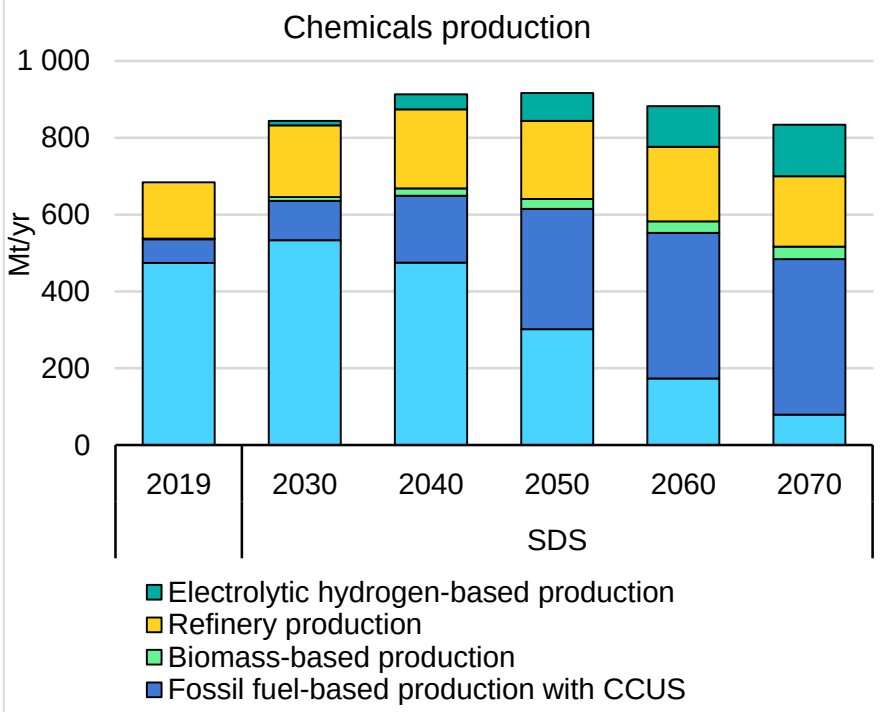
Global aviation fuel consumption in the Sustainable Development Scenario and total fuel use in the Stated Policies Scenario, 2019-70

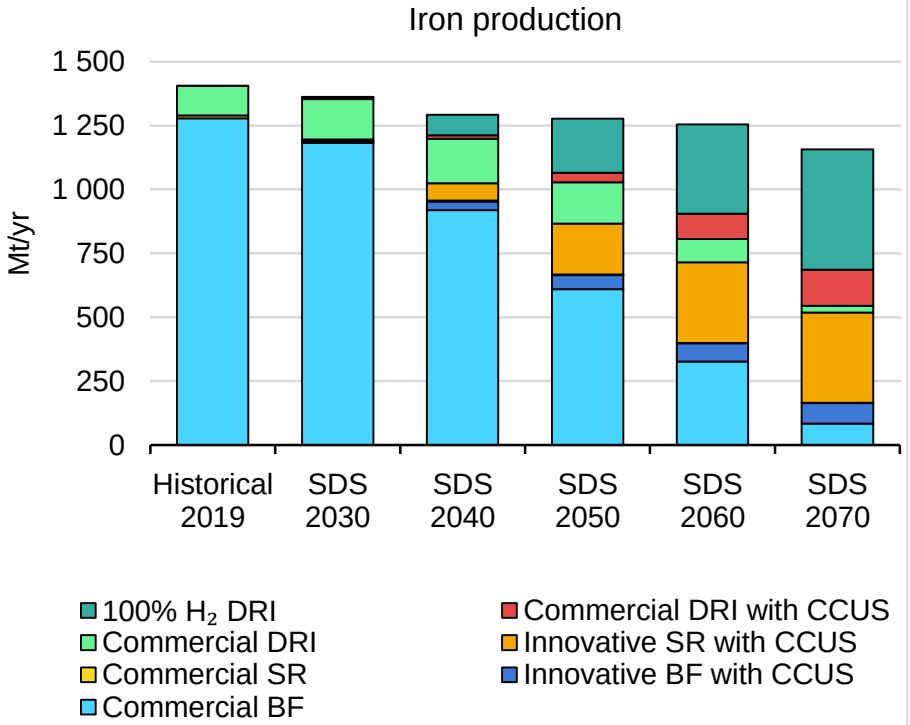


(source: ETP 2020)

Rigorous policies to promote the development and adoption of sustainable aviation fuels play the leading role in reducing the climate impacts of aviation in the Sustainable Development Scenario.

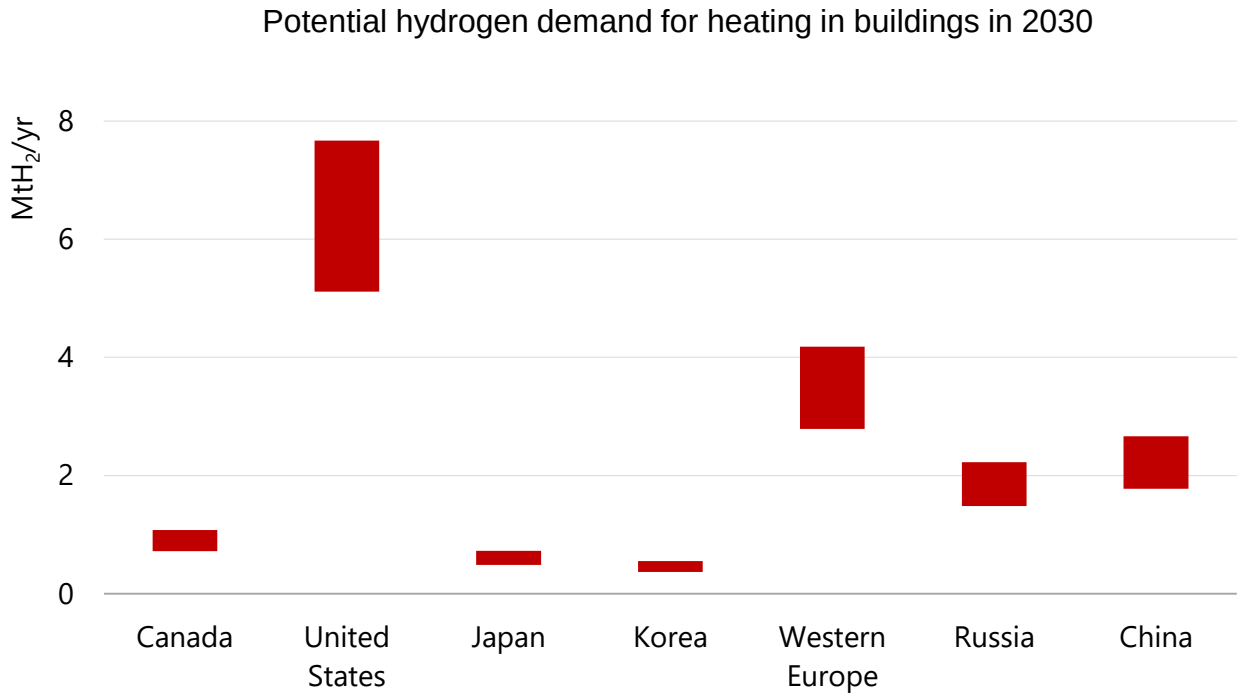
The role of hydrogen in the industrial sector





Electrolytic hydrogen can play a significant role as a "drop-in" replacement of fossil-derived hydrogen in chemicals. DRI using electrolytic hydrogen can take a significant share of iron and steel production.

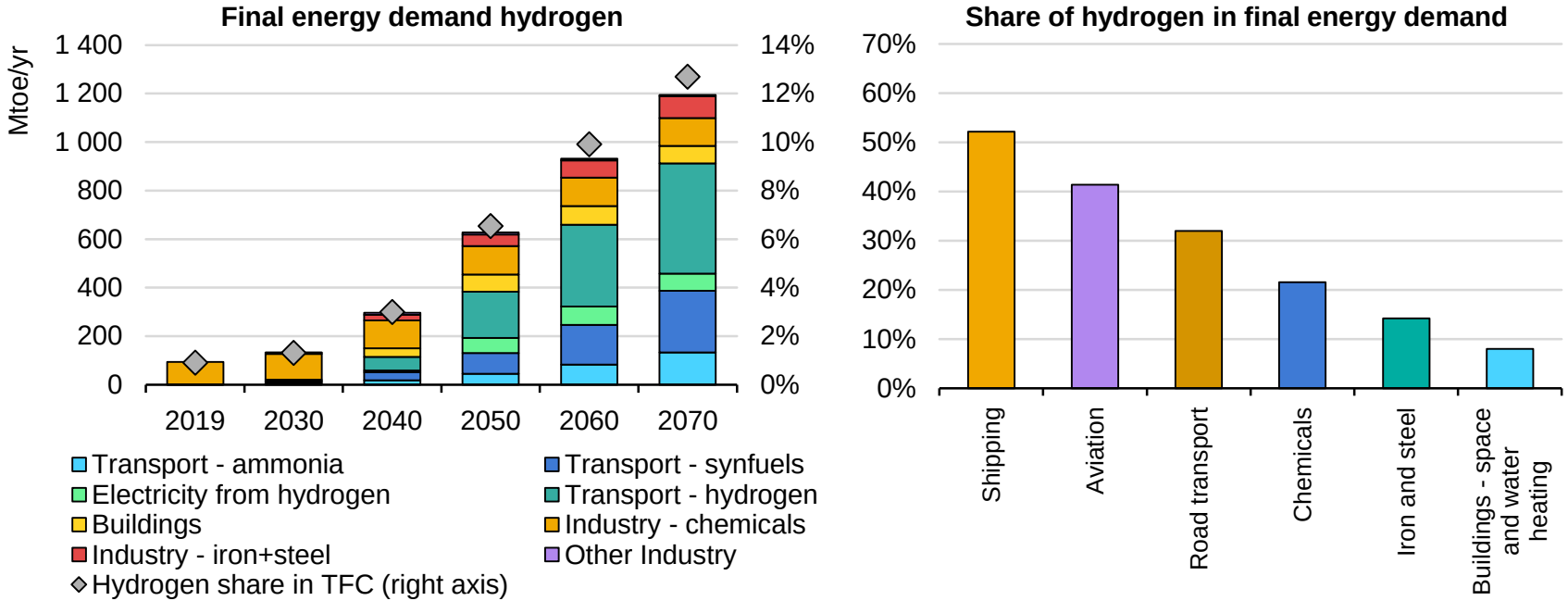
Buildings represent a big – but challenging – opportunity



Potential hydrogen demand might be on the order of 12–20 MtH_2/yr in key markets, but would require hydrogen prices of USD 1.5–3.0/kgH_2 in order to be competitive.

Hydrogen use in sectors with hard to abate emissions

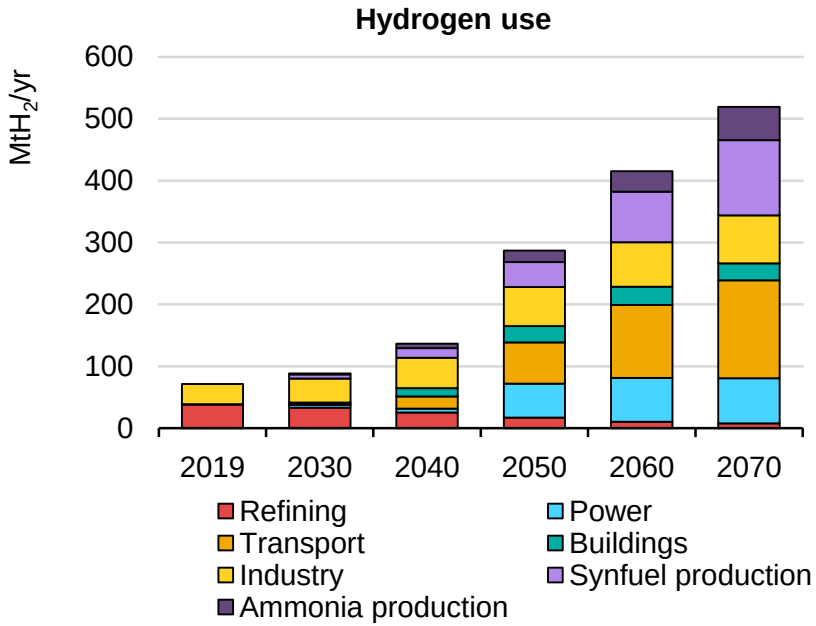
Global hydrogen energy demand by sector in the Sustainable Development Scenario, 2019-2070

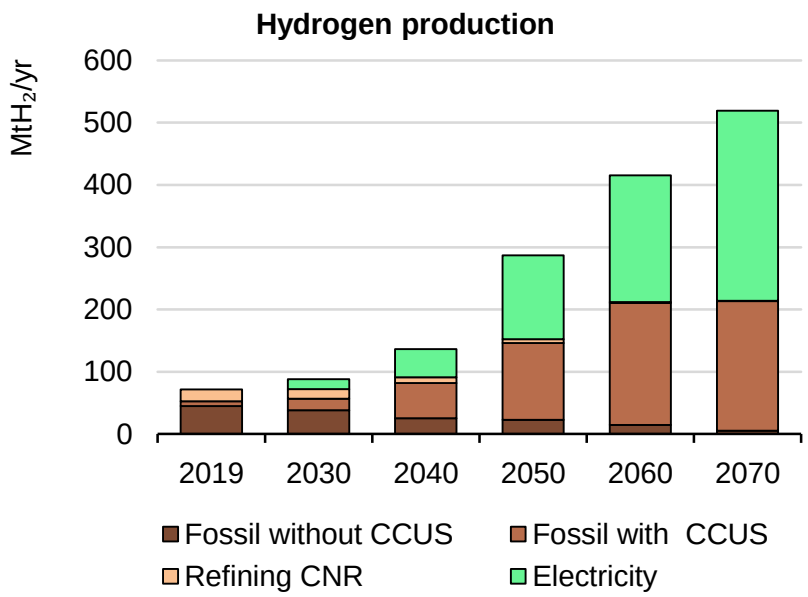


Hydrogen and hydrogen-based fuels account for 13% of global final energy demand by 2070 in the Sustainable Development Scenario, and are mostly used in transport and industry.

Hydrogen – an important pillar for net-zero emissions

Global hydrogen production and use by sector in the Sustainable Development Scenario, 2019-2070



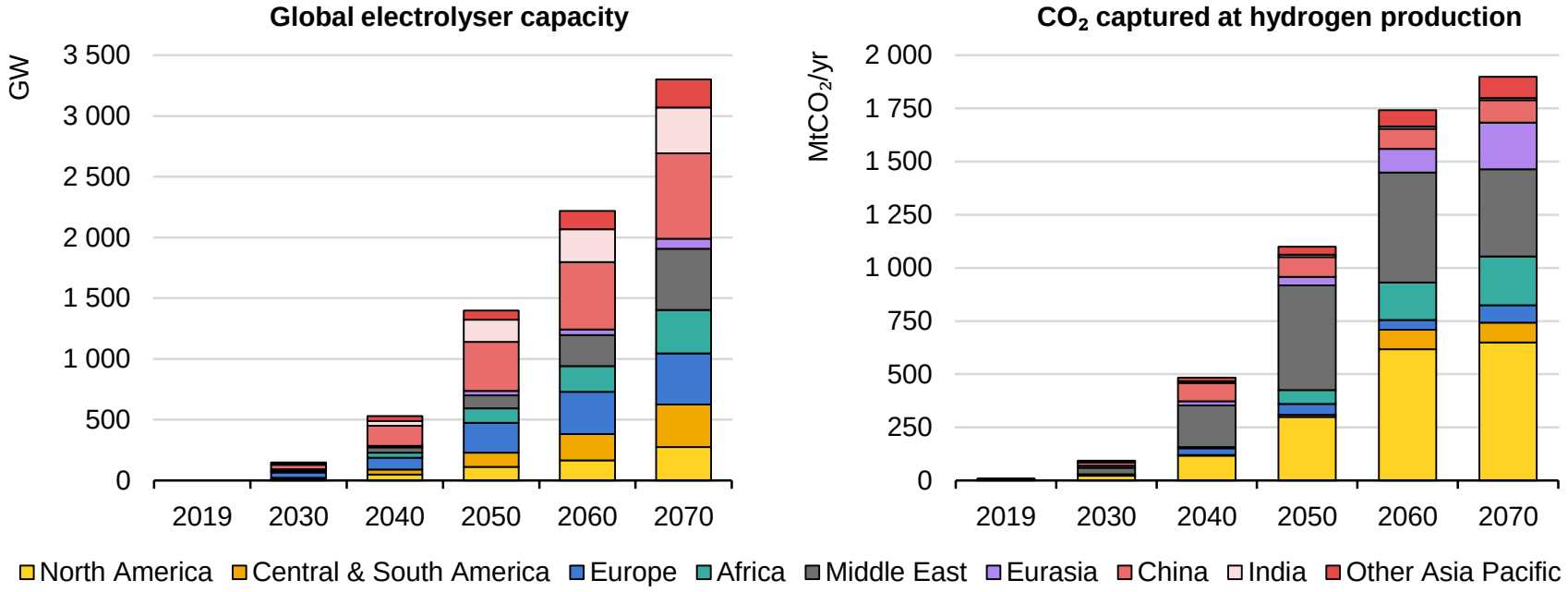


(source: ETP 2020)

Global hydrogen production and use grows sevenfold by 2070 compared to today in the Sustainable Development Scenario, with demand growth almost completely met by low-carbon hydrogen.

Hydrogen production opportunities differ by region

Hydrogen production by technology and region in the Sustainable Development Scenario, 2019-2070

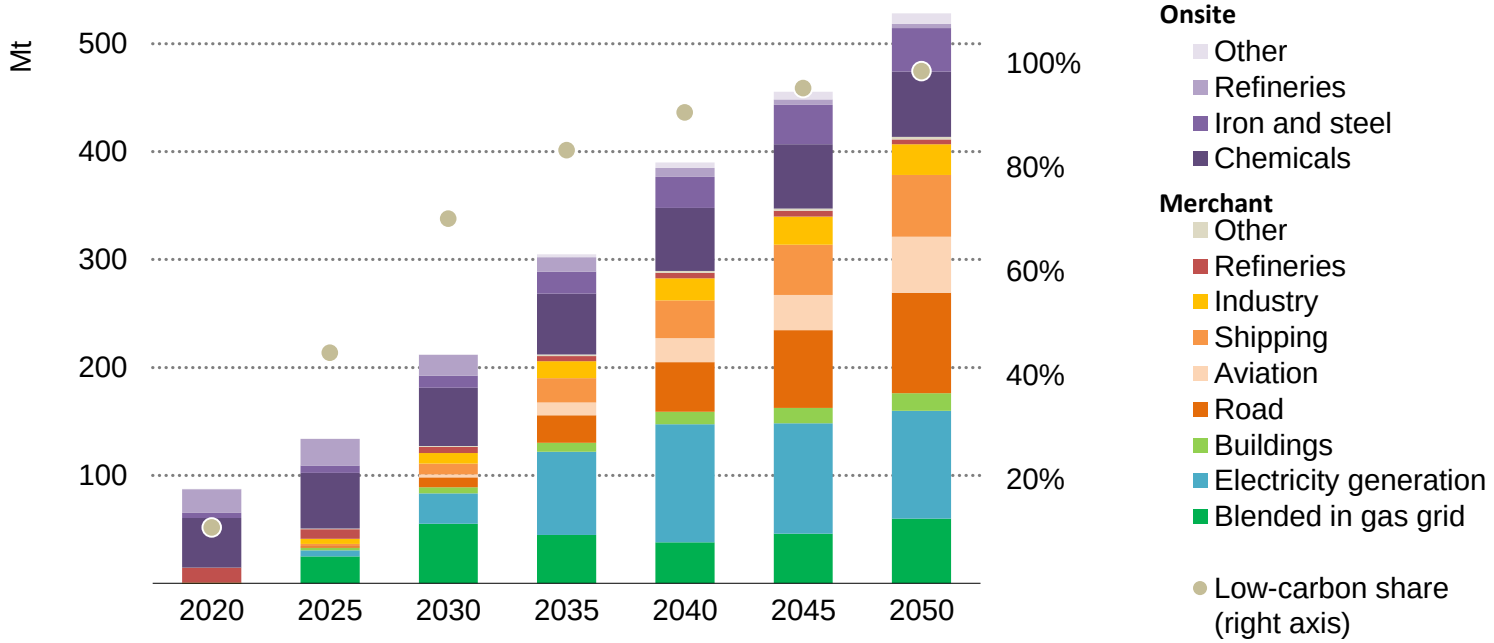


(source: ETP 2020)

Production and technology choice profiles for low-carbon hydrogen differ across regions reflecting factors such as the availability of renewable energy resources, CO_2 storage and access to low cost natural gas.

In the IEA Net-zero by 2050 pathway, hydrogen use expands rapidly

Global hydrogen and hydrogen-based fuel use in the IEA Net-Zero by 2050 scenario



In the Net-Zero scenario, hydrogen demand reaches over 500 Mt in 2050, twenty years earlier than in the Sustainable Development Scenario.

Four key opportunities for scaling up hydrogen to 2030

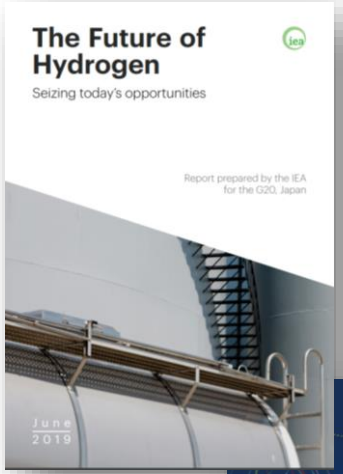
Conclusions

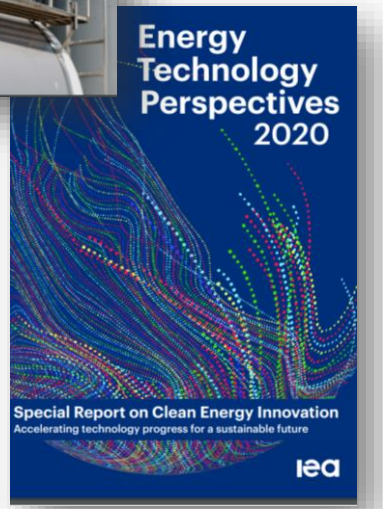
The IEA's 7 key recommendations to scale up hydrogen

1. Establish a role for hydrogen in long-term energy strategies
2. Stimulate commercial demand for clean hydrogen
3. Address investment risks for first-movers
4. Support R&D to bring down costs
5. Eliminate unnecessary regulatory barriers and harmonise standards
6. Engage internationally and track progress
7. Focus on four key opportunities to further increase momentum over the next decade

Further resources

- The Future of Hydrogen (2019)
- Article: Batteries and hydrogen technology: keys for a clean energy future
- Hydrogen Projects Database (June 2020)
- Tracking Clean Energy Progress 2020; Transport; Hydrogen
- Energy Technology Perspectives 2020
- Hydrogen in North-Western Europe (April 2021)
- Global EV Outlook 2021: Accelerating ambitions despite the pandemic (April 2021)
- Net Zero by 2050: A Roadmap for the Global Energy Sector (May 2021)
- Upcoming: Global Hydrogen Review (September 2021)





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