4 | Implications: how to accelerate hydrogen's cost reduction and competitiveness

This is a pivotal moment for hydrogen.

As we demonstrate through the analysis contained in this report, hydrogen can become the most cost competitive, low-carbon solution for several specific use cases near-term, and it can quickly become so for many more. Urgent action is needed to achieve net-zero targets quickly, and hydrogen is a necessary part of the answer.

However, hydrogen's cost competitiveness can only be realised with sufficient policy support and investment to accelerate its scale-up. We recognise some progress has been made: governments are increasingly including hydrogen in their energy mix strategies and investment in numerous new projects have been announced. Yet, bringing hydrogen technologies to parity with other alternatives will require further action. We see three areas of needs: investment, policy alignment and market creation.

Need for investment

Achieving the scale-up and associated improvement in cost competitiveness discussed in this report requires additional investment. Reaching the scale required will call for funding an economic gap until a break-even point is reached – an investment to offset the initially higher costs of hydrogen as a fuel and of hydrogen equipment compared to alternatives. Instead of being perceived as costs, this should be seen as an investment to shift the energy system and industry to low-carbon technology.

Consumers, industry, and governments can all help fulfil this premium. One prominent example of where initial support to close the gap for a sub-scale industry involved the application of feed-in tariffs and other compensation schemes used for solar PV and wind power, which led to cost competitiveness with fossil fuel alternatives. Similar compensation schemes could be envisaged for hydrogen.

The smart development and deployment of hydrogen can keep this cost premium manageable. We have identified six key areas where investments between now and 2030 would make the biggest difference (Exhibit 35).

In production, achieving competitive renewable hydrogen from electrolysis production requires about 70 GW of cumulative electrolyser capacity to be deployed over the next decade, with an implied economic gap to cover of roughly USD 20 billion. To get low-carbon hydrogen from fossil fuel reforming plus CCS off the ground, we estimate a gap of approximately USD 6 billion through 2030. In transport, the refuelling and distribution networks and the difference in costs for fuel cells and hydrogen tanks would mean a premium of an estimated USD 30 billion. In heating for buildings and industry, the cost difference between hydrogen and natural gas and investments to build the first hydrogen networks to heat about 6 million households amounts to approximately USD 10 billion through 2030.

Granted, these are big numbers, but they pale in comparison to the amount the world currently spends on energy. In fact, they represent less than 5 per cent of the planet's total energy spend of USD 1.8 trillion in 2017 alone. By way of comparison, the annual support for renewables in Germany was USD 28 billion in 2019, of which about USD 10 billion were subsidies for solar energy. Even more drastically, fossil fuel subsidies are estimated to be over USD 60 billion in the EU in 2016. Stakeholders should find an equitable distribution of this investment across investors, businesses, and energy consumers – as all stand to benefit: meeting this break-even premium will open the door to global CO_2 emissions reductions of up to 6 Gt CO_2e per year.

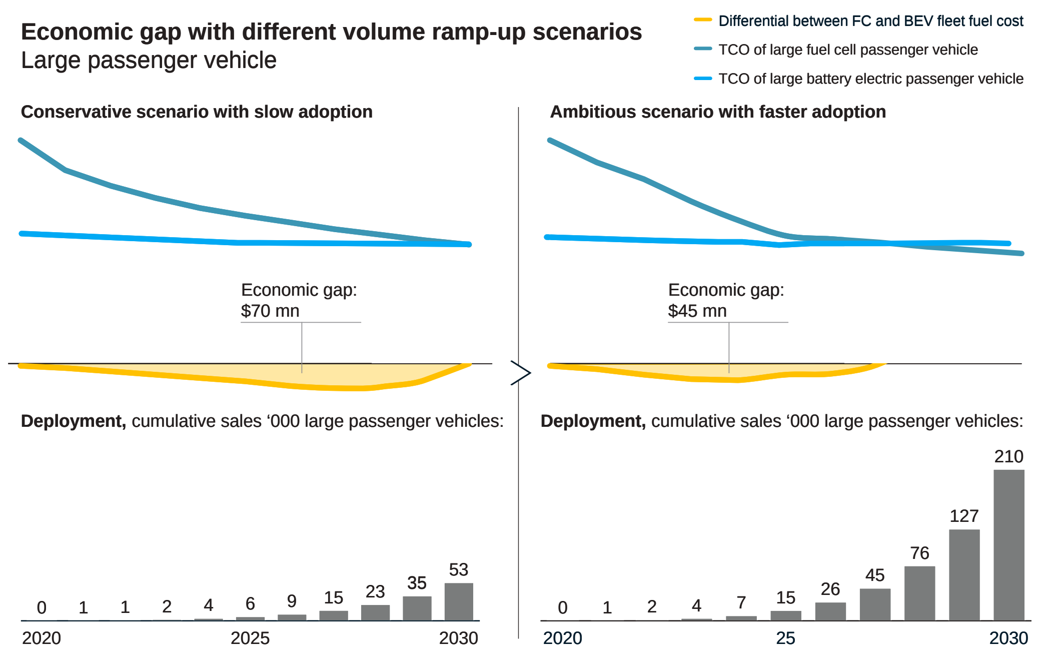
Exhibit 35 | Cumulative economic support needed for hydrogen to reach break-even with low-carbon alternatives by 2030, USD billion

	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

The economic gap is not a static number. In fact, the economic cost of scaling up hydrogen technology and applications to cost competitiveness is influenced by the speed at which cost-parity with competing low-carbon technologies is reached. Exhibit 36 shows a case in point for the supply of hydrogen to large passenger vehicles for private usage. The additional support required to supply large passenger fuel cell vehicles with hydrogen before parity with BEV is reached can be reduced by 35 per cent to USD 45 million with a faster volume ramp-up, as distribution network and station utilisation is optimized more quickly. This is true if the ramp-up of fuel cell vehicles is approximately 2.5 times faster until 2030. In this ambitious scenario the large passenger vehicle breaks even in 2027 instead of in 2030. The clear implication is that investing in hydrogen sooner rather than later will ultimately reduce the cost of transition and accelerate decarbonization of these respective segments.

Exhibit 36 | Economic gap with different volume ramp-up scenarios for large passenger vehicles



Need for policy alignment

Governments need to support the above-mentioned investment and deployment across the board with policies that begin to level the playing field for low-carbon and conventional technologies. These may include all or some of the following:

— **National strategies.** Governments have to play a role in setting national targets, as they have done already through 18 hydrogen roadmaps developed across the globe. These roadmaps provide strong objectives for critical stakeholders to converge around.

— **Coordination.** Governments are well positioned as neutral conveners of industry stakeholders around potential local investment opportunities. This cost perspective provides some early indications of potentially important supply chain investments. Governments can play a role to convene investors around such opportunities.

— **Regulation.** Governments can help remove barriers that may exist to invest in the hydrogen economy today – for instance, by facilitating the process to obtain permits for new refuelling stations.

— **Standardisation.** Governments can also support industry to coordinate national and international standards; for example, around pressure levels and safety.

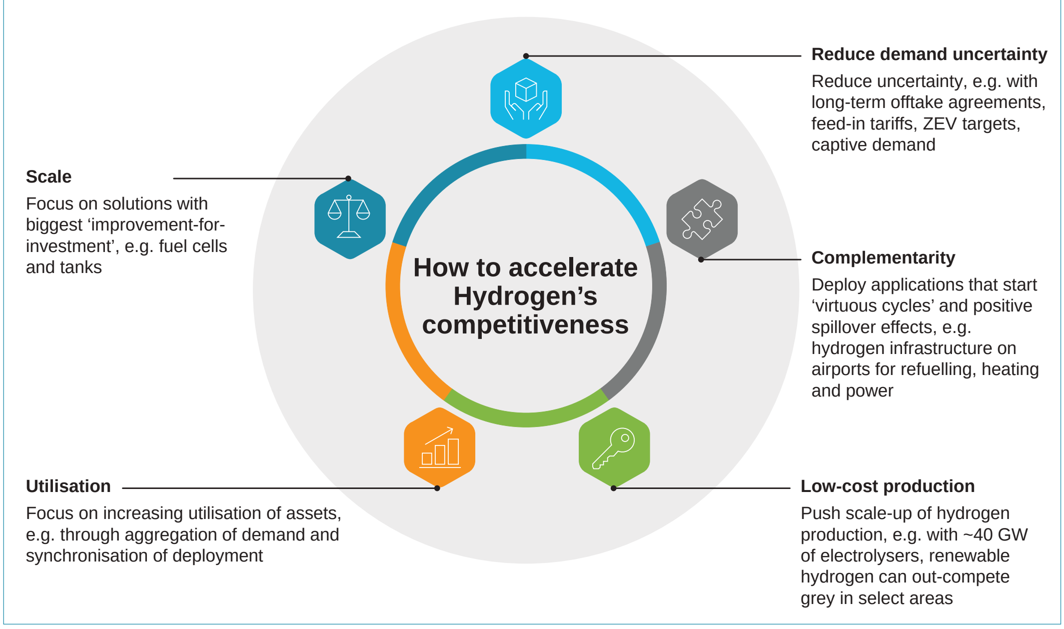
— **Infrastructure.** Governments can decide to support investments in deployment of new infrastructure, such as refuelling networks and re-use, where relevant, of existing natural gas grids. Such signals (along with corresponding moves on demand and supply) would be a strong motivation for industries to roll out technologies.

— **Incentives.** Finally, governments could decide to apply incentives such as tax breaks, subsidies or penalties on conventional alternatives to encourage (or even mandate) the initial acceleration of hydrogen. To represent these various incentives in our modelling, we include an implicit carbon cost – achievable by enacting a variety of policies – of USD 50 per ton of CO_2e by 2030, slowly increasing from today. More may be required if we want to reach a net-zero carbon economy by 2050.

Need for market creation

Even with the right enabling investments and policy support, the choices made at critical inflection points along the hydrogen industry's development will serve to either nurture or suppress its growth. We have identified five levers for stakeholders that can lead to major step changes in creating a market: reducing demand uncertainty, scaling applications with the biggest cost improvement per dollar invested, deploying complementary solutions to spark virtuous cycles, designing distribution networks to maximise utilisation and scaling up production to drive down supply costs. Exhibit 37 illustrates these levers.

Exhibit 37 | Five levers for stakeholders to create a market



Reduce demand uncertainty to attract investment

Investors typically seek some degree of certainty that demand exists to make them willing to fund new hydrogen projects. Industry and regulators have a number of options available, based on lessons learned from renewables, to minimise or mitigate market, regulatory, and technology risks. These fall into one of two categories: private-private and private-public arrangements. On the former, long-term offtake agreements have long been an investment vehicle of choice for renewables players. In addition to securing demand for renewables, offtake agreements have provided a hedge on energy prices for the offtaker while advancing energy transition and carbon abatement goals. Of the private-public variety, feed-in tariffs provide guaranteed payments from governments to private operators (e.g. industry or residential) in exchange for renewable energy supplied to the grid. They remove risks for producers to develop energy from renewable sources, reducing external costs and increasing security of energy supply. Similar arrangements could be imagined in hydrogen production and distribution, with pre-arranged offtake agreements and/or feed-in tariffs.

Another example to reduce demand uncertainty is facilitating the shift to hydrogen for end-to-end fleet logistics solutions that serve captive, recurring demand. For example, an end-to-end hydrogen fleet solution – as we see demonstrated in Switzerland, where it is underpinned by specific road fuel regulation – reduces demand uncertainty because it ensures players carry only the risks they can manage (as is also the case with feed-in tariffs).

Scale applications with the biggest cost improvement for investment

Critical tipping points – after which, costs fall sharply – appear throughout our analyses. Certain hydrogen applications have tipping points whereby a small volume increase can drastically reduce costs due to initially steep manufacturing learning rates. This is particularly true for fuel cells and tanks for vehicles. For example, scaling fuel cell vehicle production from 10,000 to 200,000 units can reduce unit costs by as much as 45 per cent, irrespective of any major technological breakthroughs, and can impact multiple end-use cases. Triggering these tipping points requires investment; for instance, in the first fuel cell car manufacturing plants as discussed above.

Deploy complementary solutions to spark virtuous cycles

Certain solutions create positive spill-over effects. The development of certain hydrogen solutions can create a virtuous cycle that makes other hydrogen applications viable. For example, leveraging hydrogen infrastructure around airports for on-site refuelling of buses, airport heating, local industry feedstock and, potentially in the future, aircraft refuelling will reduce the costs of each individual application.

Design distribution networks to maximise utilisation

For many hydrogen applications, network presence drives competitiveness. Stakeholders can make decisive moves to invest in solutions that are designed to reach high levels of utilisation quickly. For example, hydrogen boilers make the most sense as a heating solution where gas pipeline infrastructure already exists. Realising the potential first requires the grid operator – with support from regulators – to choose to decarbonise the gas grid versus continuing as is or shutting it down entirely. But once the choice is made, even factoring in the investment needed to retrofit the network and upgrade consumer appliances, hydrogen can still emerge as the most competitive solution.

Similar binary distribution choices exist for other applications, including hydrogen refuelling stations. If players build networks of larger stations to serve captive fleets, e.g. trucks, buses, and taxis, they can more quickly reach sufficient utilisation than if they focused on smaller stations serving the broader public. Networks serving the broader public should reach a minimum threshold scale to adequately serve customer needs, and therefore improve utilisation through volume. In the early ramp-up phase, specific demand guarantees can enable the development.

Scale up production to drive down supply cost

The cost of hydrogen production is instrumental for overall competitiveness of all hydrogen solutions. Unless we bring down the supply costs, all other business cases fail. Stakeholders can accelerate the hydrogen's cost reduction in a variety of way:

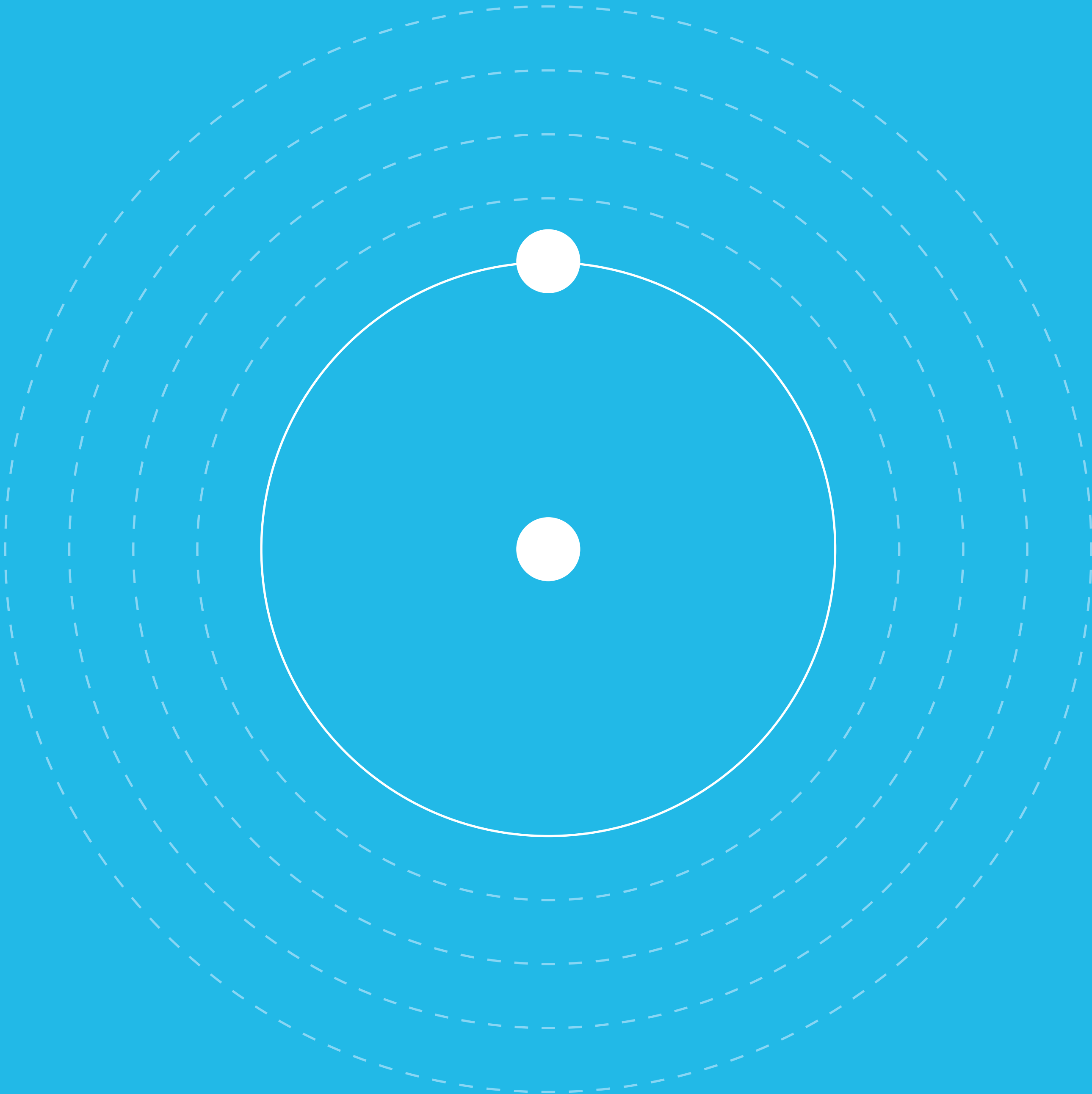
- **Renewable hydrogen.** The cost of renewable hydrogen from electrolysis consists of two components: the cost of renewables, specifically solar and wind, and the cost of electrolysis. Renewables are likely to continue to get progressively cheaper and more widely available given the current policy landscape. However, electrolysis cost reduction requires a concerted push to increase in electrolyser capacity deployed, with options for each of three types of hydrogen: we estimate that scaling up to 70 GW deployed would tip renewable hydrogen production to break even with grey. In fact, installing only roughly 40 GW of electrolysers could make renewable hydrogen competitive with grey in some regions. An initial regulatory push to incentivise production in countries with favourable renewables conditions could have a significant impact on lowering costs.
- **Reforming plus CCS.** Low-carbon hydrogen from reforming plus CCS can be relatively cheap in specific regional contexts – the abatement cost of switching from grey to low-carbon hydrogen from reforming plus CCS is relatively small – and would have a big impact on the viability of other applications further down the supply chain. However, producing low-carbon hydrogen from reforming plus CCS will require decision-makers to commit to large-scale projects, which will need regulatory support.
- **Grey hydrogen.** Most applications break even sooner when supplied by grey hydrogen. Although it is not a low-carbon solution, it can still be cleaner than the conventional alternative. Allowing it in cases where it is most cheaply and easily available, e.g. as a by-product, may make hydrogen applications financially viable much sooner. If no carbon reduction is achieved initially, this can be a first step to reduce the scale-up cost, and subsequently switch to low-carbon or renewable hydrogen along a clear and defined roadmap.

Conclusion

Hydrogen is a viable solution to the global decarbonisation challenge. As we have demonstrated through our analyses, the path to increasing cost competitiveness for hydrogen is clear for many applications. In some use cases, hydrogen can already outcompete other low-carbon and conventional alternatives.

The benefits of scaling up the hydrogen economy extend beyond its head-to-head cost competitiveness. Hydrogen can support governments' energy security goals, and its relative abundance creates opportunities for new players to emerge in energy supply and for new job creation to stimulate the global economy. Hydrogen remains the only viable, scalable option to decarbonise industry and other segments that have struggled to minimize their environmental impact. In addition, it can significantly advance goals around building a circular economy given the strong recyclability of the materials consumed along the entire value chain.

The time to act is now. There are many paths to realising hydrogen's full potential in the global energy transition, and nearly all of these options are worth pursuing immediately.



Glossary

ATAG	Air transportation action group
ATR	Autothermal reforming
BECCS	Bioenergy with carbon capture and storage
BEV	Battery electric vehicle
BOF	Blast oxygen furnace
BTX	Benzene, toluene, xylene
CHP	Combined heating and power
CCGT	Combined cycle gas turbine
CCP	Combined cooling and power
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture storage or utilisation
DoE	Department of Energy
DRI	Direct reduced iron
EAF	Electric arc furnace
EIA	Energy Information Administration (US)
EU	European Union
FC	Fuel cell (hydrogen)
FCEV	Fuel cell electric vehicle, including light- and heavy-duty vehicles, and material-handling vehicles
GHG	Greenhouse gas
HDV	Heavy-duty vehicle
HVO	Hydrotreated vegetable oil (type of biofuel)
ICE	Internal combustion engine
LDV	Light-duty vehicle

LPG	Liquified petroleum gas
MHE	Material-handling equipment
MMBTu	Million British thermal units (unit of energy, 1 MMBTU = 1.06 GJ)
NO_x	Nitrogen oxides (type of tailpipe emission from ICE vehicles)
NG	Natural gas
PEM	Polymer electrolyte membrane
R&D	Research and development
RE	Renewable energy
RNG	Renewable natural gas
SMR	Steam methane reforming
SOx	Sulfur oxides (type of tailpipe emission from ICE vehicles)
SUV	Sport utility vehicle
TCO	Total cost of ownership
T&D	Transmission and distribution
TW/GW/MW/kW	Terawatt, gigawatt, megawatt, kilowatt (unit of power, 1 Watt = 1 J per s)
TWh/MWh/kWh	Terawatt hour, megawatt hour, kilowatt hour (unit of energy, 1 Watt-hour = 3600 J)
ZEV	Zero-emissions vehicle