Crossing the tipping point

Hydrogen Case Study

University of Exeter

EEIST

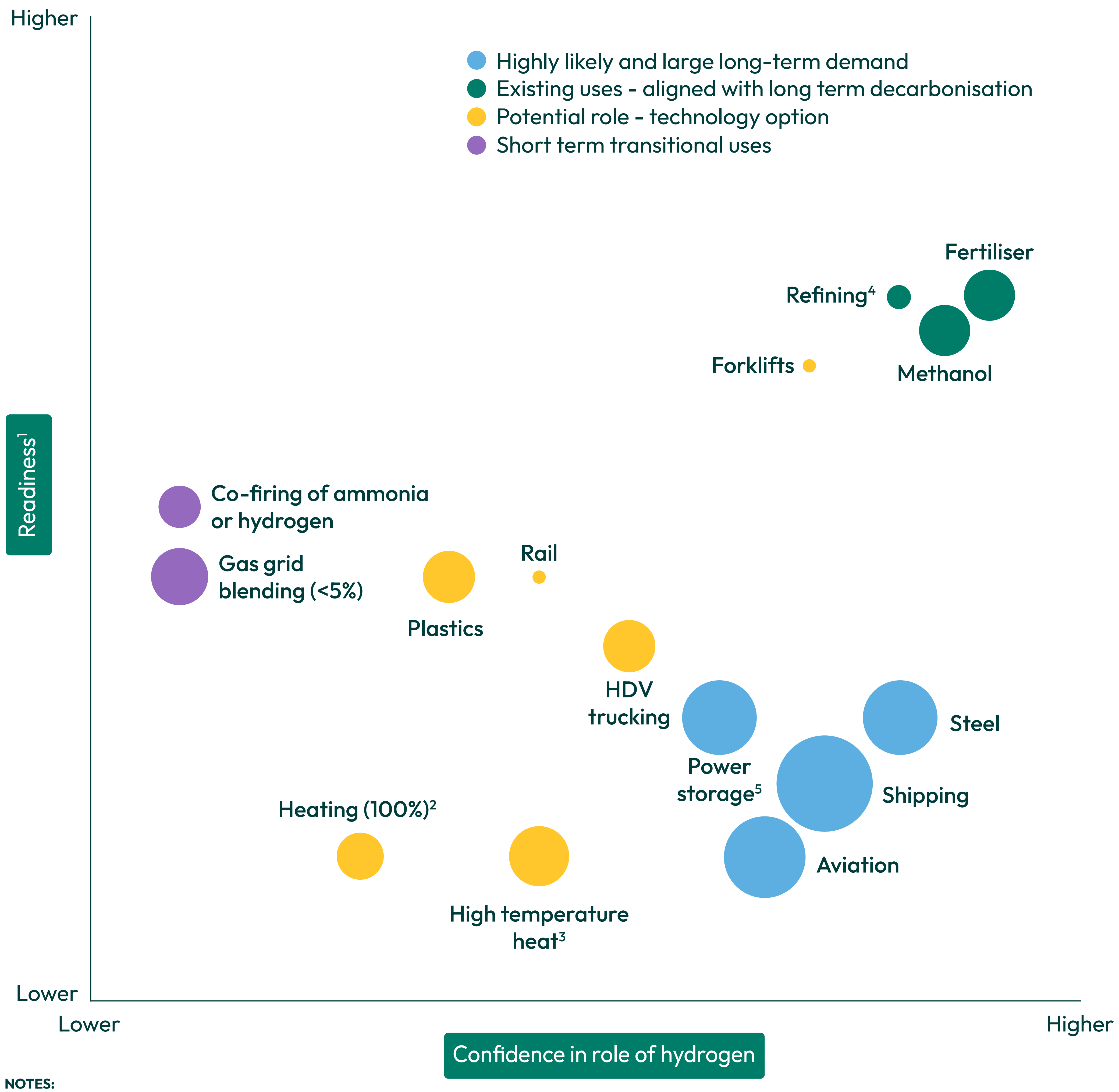
In partnership with:

BEZOS EARTH FUND

Hydrogen could be important to decarbonising some sectors of the economy

- **Electrifying as much as possible while fully decarbonising electricity supply is at the heart of global decarbonisation,** and electricity could supply over 70% of final energy demand [1].
- **In some sectors, direct electrification is likely to be impossible or prohibitively expensive, making hydrogen's properties useful as a second energy carrier.** Hydrogen could supply 13-24% of final energy demand by 2050, according to different scenarios from IEA, IRENA, ETC, Hydrogen Council, and BNEF [1].
- **Over 60% of the demand for green / low carbon hydrogen by 2030 is likely to be in sectors where 'grey' (fossil fuel derived) hydrogen is already used,** such as fertilisers, methanol and refining.
- Other sectors where hydrogen is most likely to be needed for decarbonisation include steel, shipping, long-term energy storage, and aviation.

Some applications of green hydrogen can provide early 'off-take'



NOTES:
1 Readiness refers to a combined metric of technical readiness for clean hydrogen use, economic competitiveness and ease of sector to use clean hydrogen.
2 'Heating (100%) refers to building heating with hydrogen boilers via hydrogen distribution grid,
3 'High temperature heat' refers to industrial heat processes above ca. 800°C
4 Current hydrogen use in refining industry is higher due to greater oil consumption.
5 Long-term energy storage for the power system.

Source: ETC (2021)

* Grey hydrogen is produced from natural gas without abatement, green hydrogen is produced from electrolysis using renewable energy, and blue hydrogen is produced from natural gas with carbon capture. Blue hydrogen is not the focus of this case study.

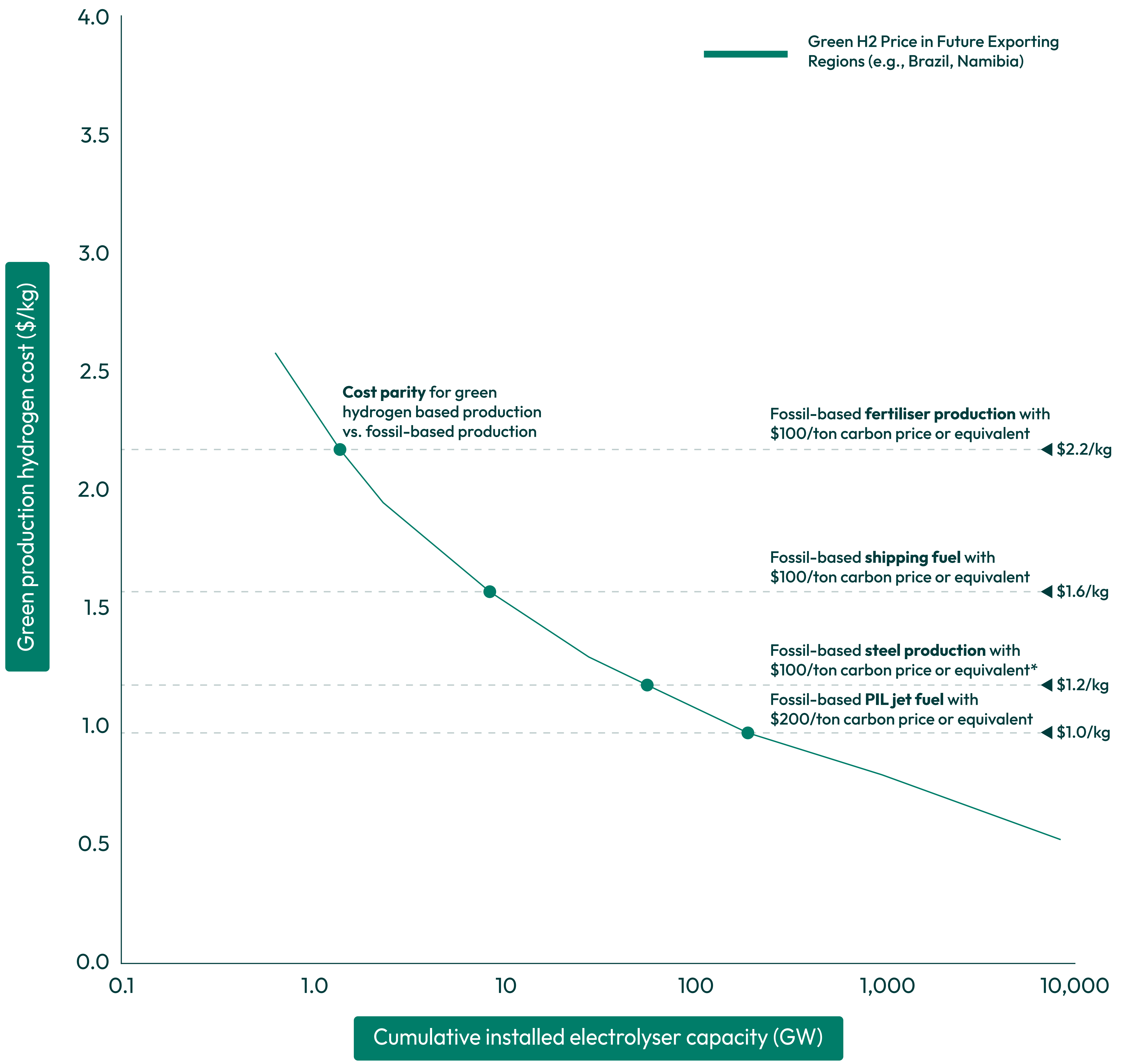
Source: [1] ETC (2021)

The biggest opportunity for rapid growth and cost-reduction is in sectors already using fossil fuel hydrogen

- **While green hydrogen is currently more expensive than grey and blue, it will in time become the cheapest source of hydrogen,** due to rapid cost declines based on economies of scale and learning-by-doing [1].
- **The greatest opportunity to scale up green hydrogen quickly - to build economies of scale and reduce costs - is in the sectors where grey hydrogen is already used.** These include ammonia production for fertilisers, crude oil refining, and methanol production [2]. Here, green hydrogen can deliver a like-for-like replacement, requiring no technological innovation. This graph shows how increasing cumulative production – by sector, starting with fertilisers – can rapidly reduce costs.
- **Using green ammonia in fertiliser production may be the best opportunity to quickly scale-up green hydrogen technologies,** given that (i) it has one of the lowest additional costs of using green hydrogen to decarbonise, among all sectors (ii) green ammonia can be shipped at relatively low-cost and (iii) it can be produced at low cost in areas with rich renewable resources, and then transported to fertiliser production sites competitively [3].
- **A 25% blending mandate globally for green ammonia use in fertilisers could create enough demand to reduce green hydrogen prices to $1.5/kg** in locations with cheap renewable electricity, in turn helping unlock price-parity tipping points in green ammonia use for shipping and green hydrogen use in steel production [3]. This would accelerate deployment and further cost reductions, enabling its spread across multiple applications.

Sources: [1] BNEF (2023) [2] ETC (2021) [3] Systemiq (2023)

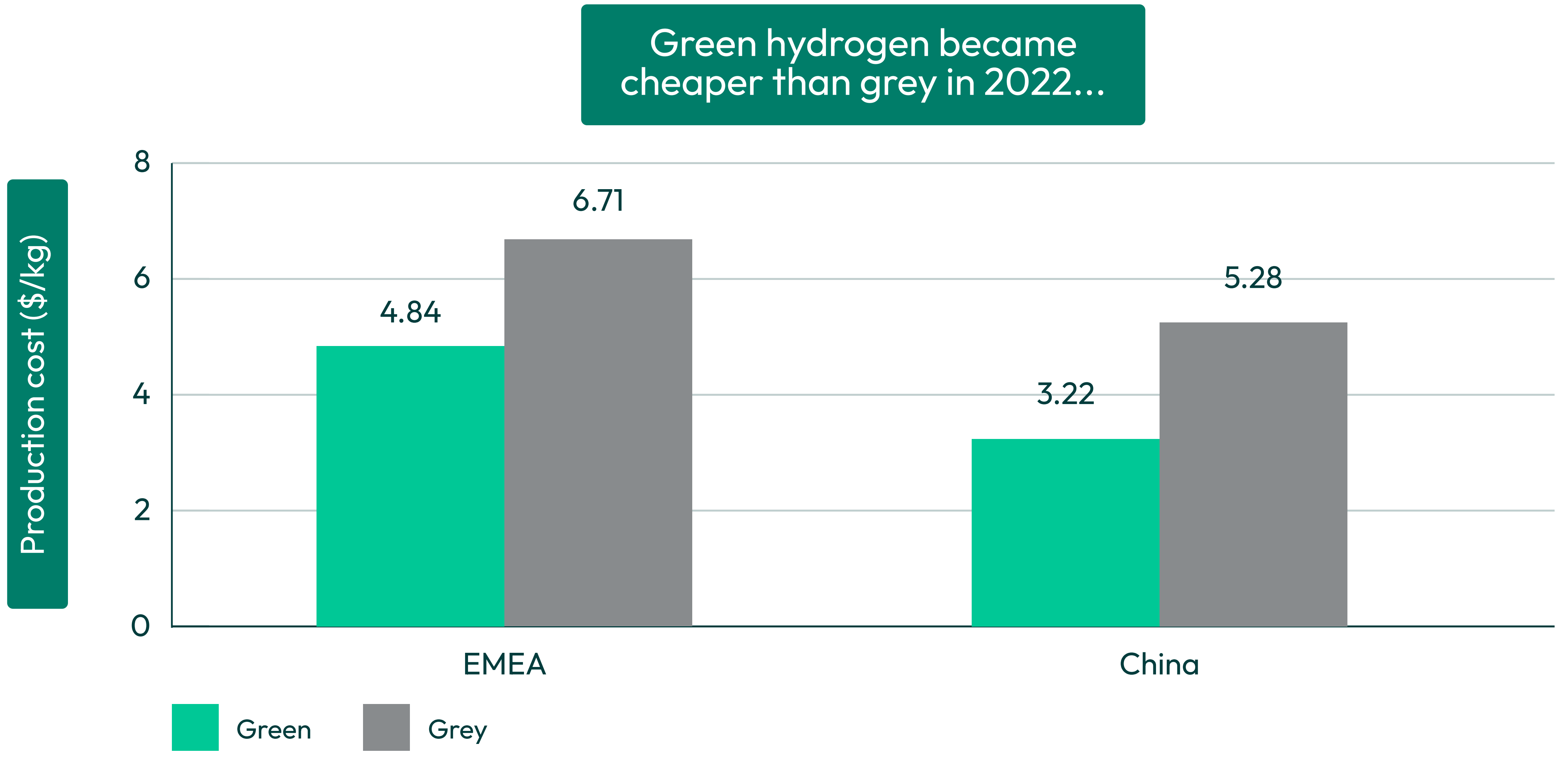
Impact of growing green hydrogen deployment by sector on production costs

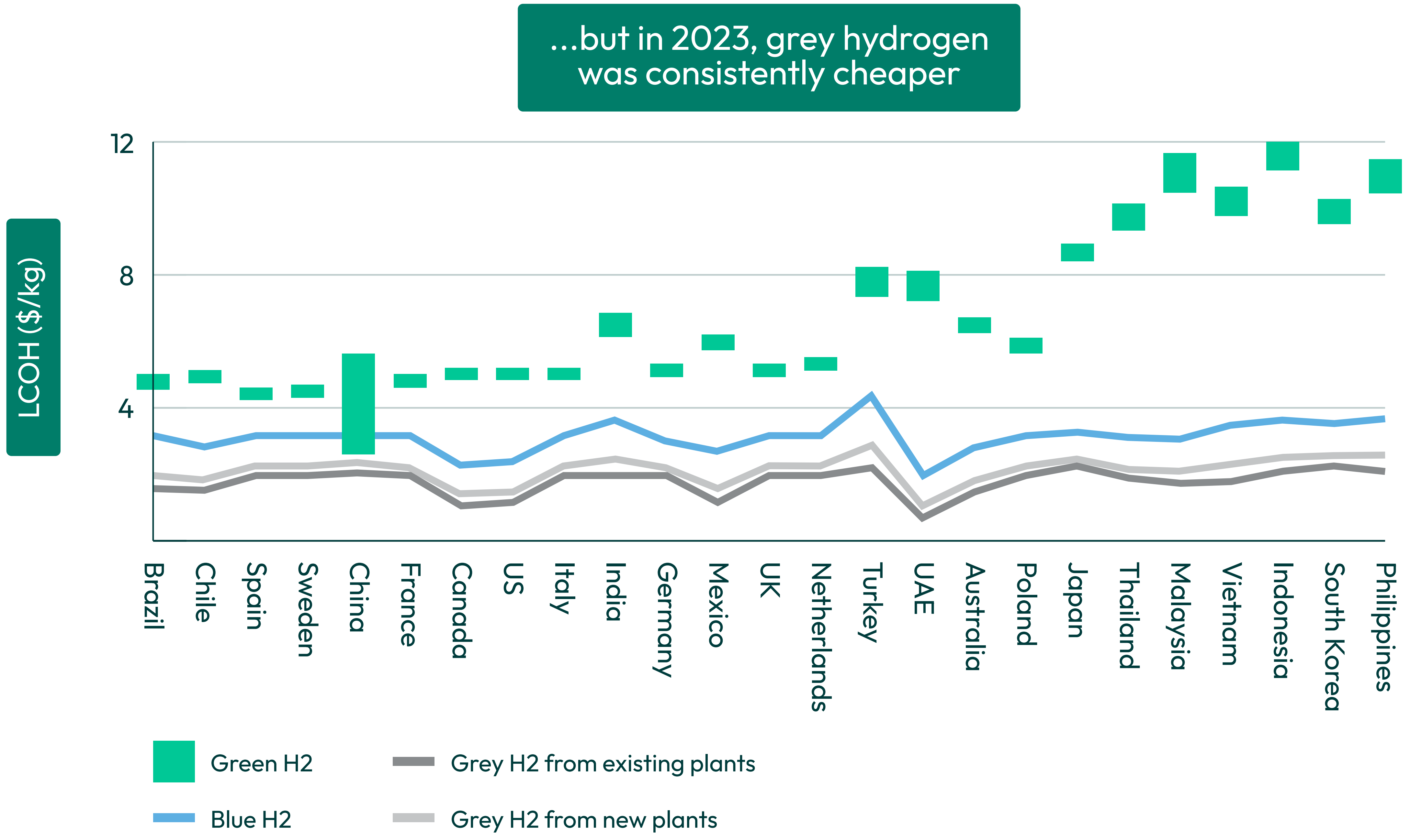


Source: Systemiq (2023)

Green hydrogen has already been cheaper than grey hydrogen at times of high gas prices

- **Green hydrogen is already cost-competitive with fossil-fuel based hydrogen in ideal locations with the lowest renewable electricity costs [1].**
- **When the Ukraine war pushed up natural gas prices by over 70%, the cost of green hydrogen became substantially less than the cost of new grey hydrogen in Europe, the Middle East, Africa and China** (before accounting for carbon prices) – something ‘unimaginable’ two years earlier [2].
- **By 2023, after gas prices fell, green hydrogen was consistently more expensive than grey again [3].**
- **The spike in gas prices rapidly accelerated investment commitments and pledges to build green hydrogen production capacity.** Global commitments made in the few months after the outbreak of the war totalled $73 billion, and will increase the speed at which green hydrogen’s production costs fall to under $2/kg [4].





Sources: [1] IRENA (2020) [2] RMI (2022); Recharge News (2022) [3] BNEF (2023) [4] Carbon Tracker (2022)

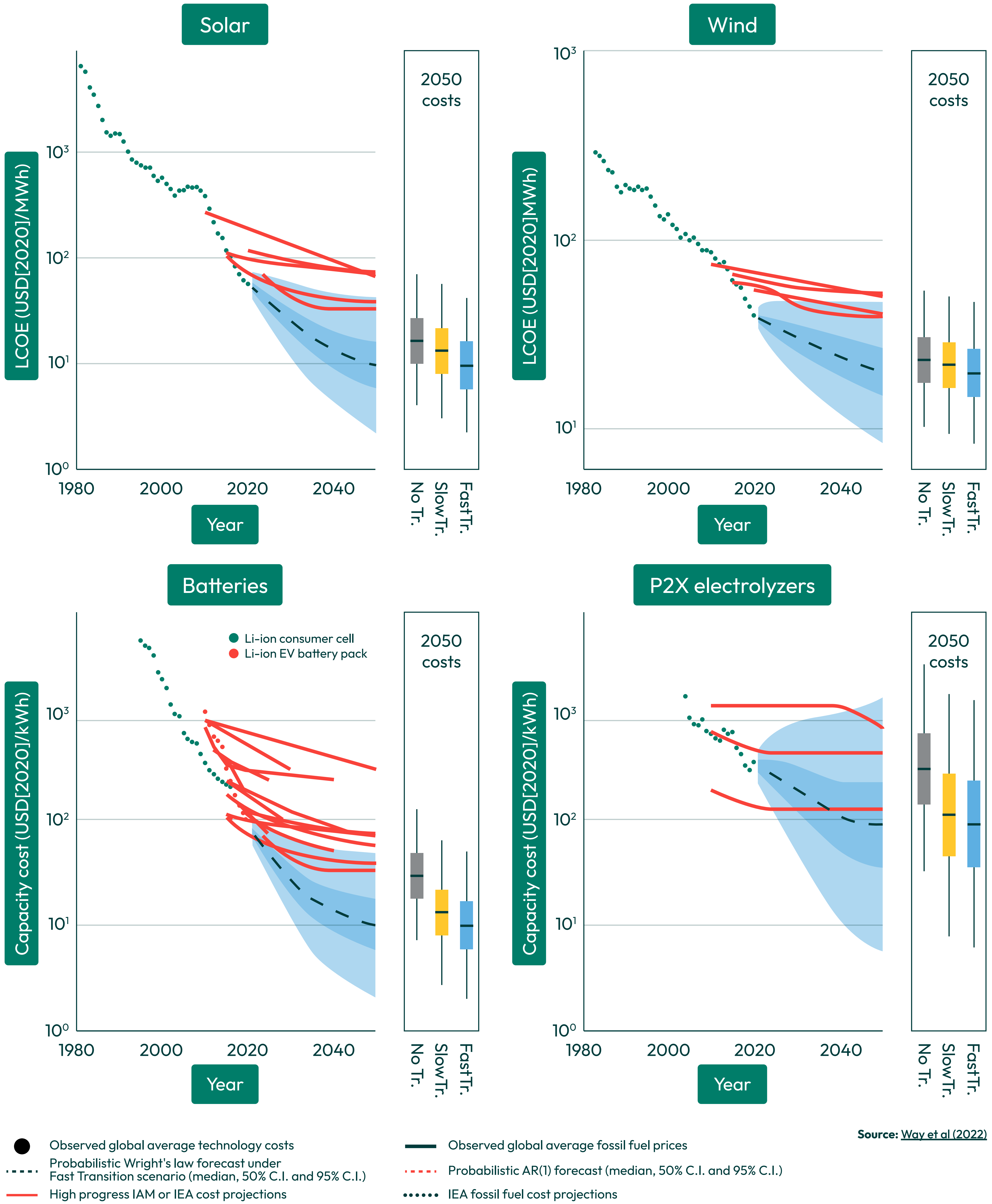
Source: Our World in Data (2022); BloombergNEF (2023)

Both key components of green hydrogen costs are rapidly getting cheaper

- **Both the main components of green hydrogen costs – renewable electricity, and electrolysers – are benefitting from rapid technology learning curves with exponential cost declines.** The cost of solar power has persistently fallen by 80-90%, and wind power by 70% each decade since 1960. The cost of electrolysers, similarly, has fallen 73% over the past 20 years [1].*
- Meanwhile, there is no obvious long term price decline in fossil fuels such as coal, oil, and gas: inflation-adjusted prices now are very similar to what they were 140 years ago [1].
- **This means that although green hydrogen is currently more expensive than grey hydrogen, it will in time undercut grey hydrogen and become the cheapest source of hydrogen in all markets.**
- **While electrolysers today are the main cost in green hydrogen production, electricity costs will become more important as electrolyser costs decline.** This more closely links the green vs grey hydrogen price-parity tipping point with renewable power deployment, which continues to outpace expectations [2].
- While recent increases in commodity prices may slow down cost declines in the near term, they are unlikely to stop cost declines over the longer term [3].

*Note there is some subjectivity and uncertainty in such a claim, as reported costs have significant variation. It also refers only to proton exchange membrane (PEM) electrolysers: other types have not improved this quickly.

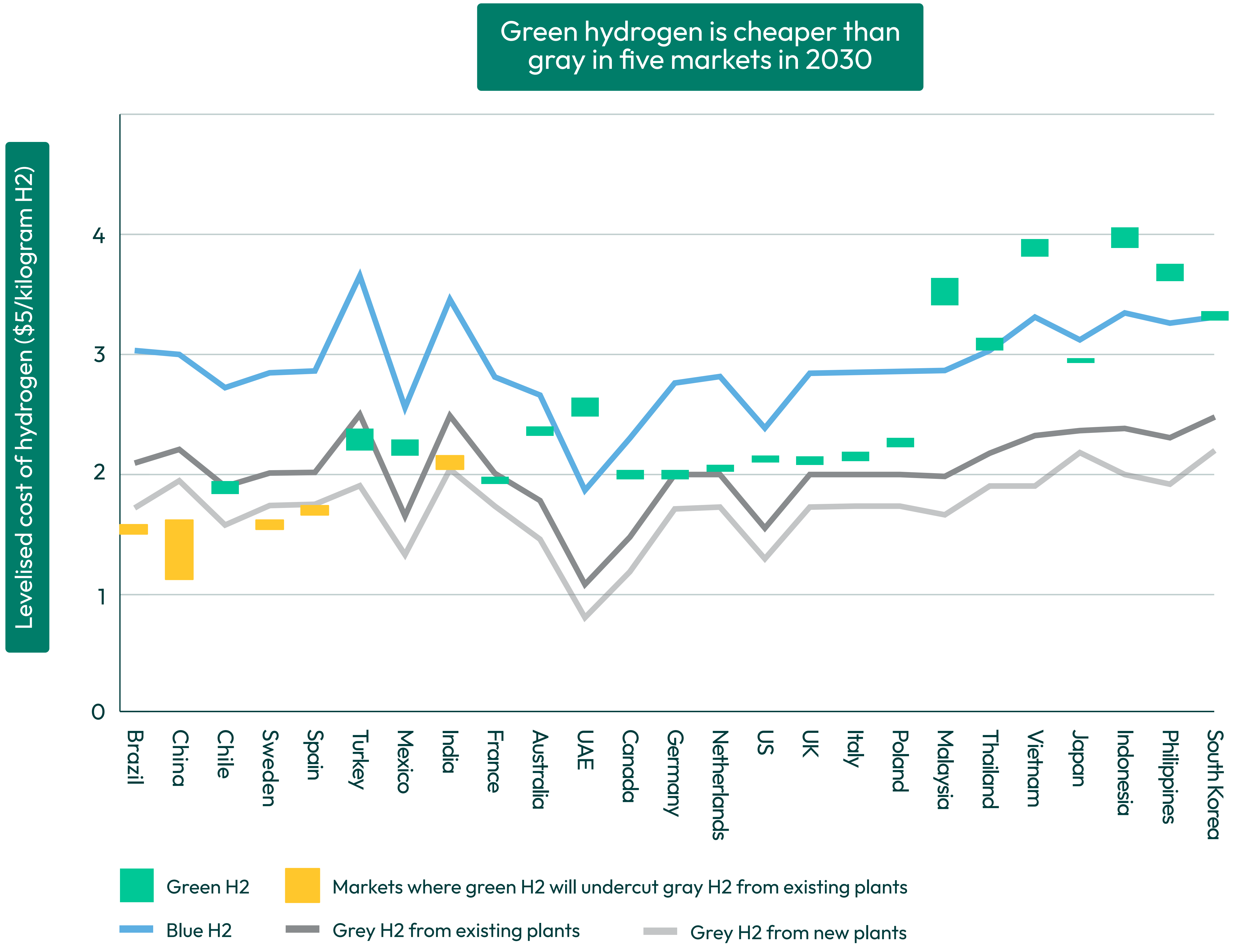
Sources: [1] Way et al (2022) [2] BNEF (2023) [3] IEA (2023)



Source: Way et al (2022)

Green hydrogen will be cheaper than grey hydrogen in leading markets by 2030 – and will eventually undercut grey hydrogen everywhere

- **By 2030, new green hydrogen will be cheaper than new grey hydrogen production in at least 8 countries, and 18% cheaper than continuing to run an existing grey hydrogen plant in Brazil, China, Sweden, Spain and India.** This is even without any subsidies for construction of the green hydrogen plants [1].
- If large-scale deployment of green hydrogen takes place, the costs of producing green hydrogen using electricity from solar PV could fall to $1.6/kg by 2030 in regions with the best sunlight, such as Africa, Australia, Chile, China and the Middle East [2].
- **Widely available and cheap renewables, combined with proactive policy,** are the key drivers underpinning cost-competitiveness across these leading markets. Where there is little sun or wind, the potential for clean hydrogen is much lower [3].
- **Green hydrogen is expected to undercut new grey hydrogen in over 90% of countries by 2035, and eventually in all of them [1].** The timing depends on uncertain factors including electricity prices, interest rates, land prices (affecting the cost of renewables), electrolyser efficiency and costs, and government policies [4].
- Many countries in sub-Saharan Africa, the Middle East and Latin America have plentiful renewable energy resources but there is huge uncertainty about the extent to which they will be able access capital at lower cost, enabling investment to take advantage of these resources [3].



Sources: [1] BNEF (2023) [2] IEA (2023) [3] IRENA (2022) [4] Way et al (2022); ETC (2021)

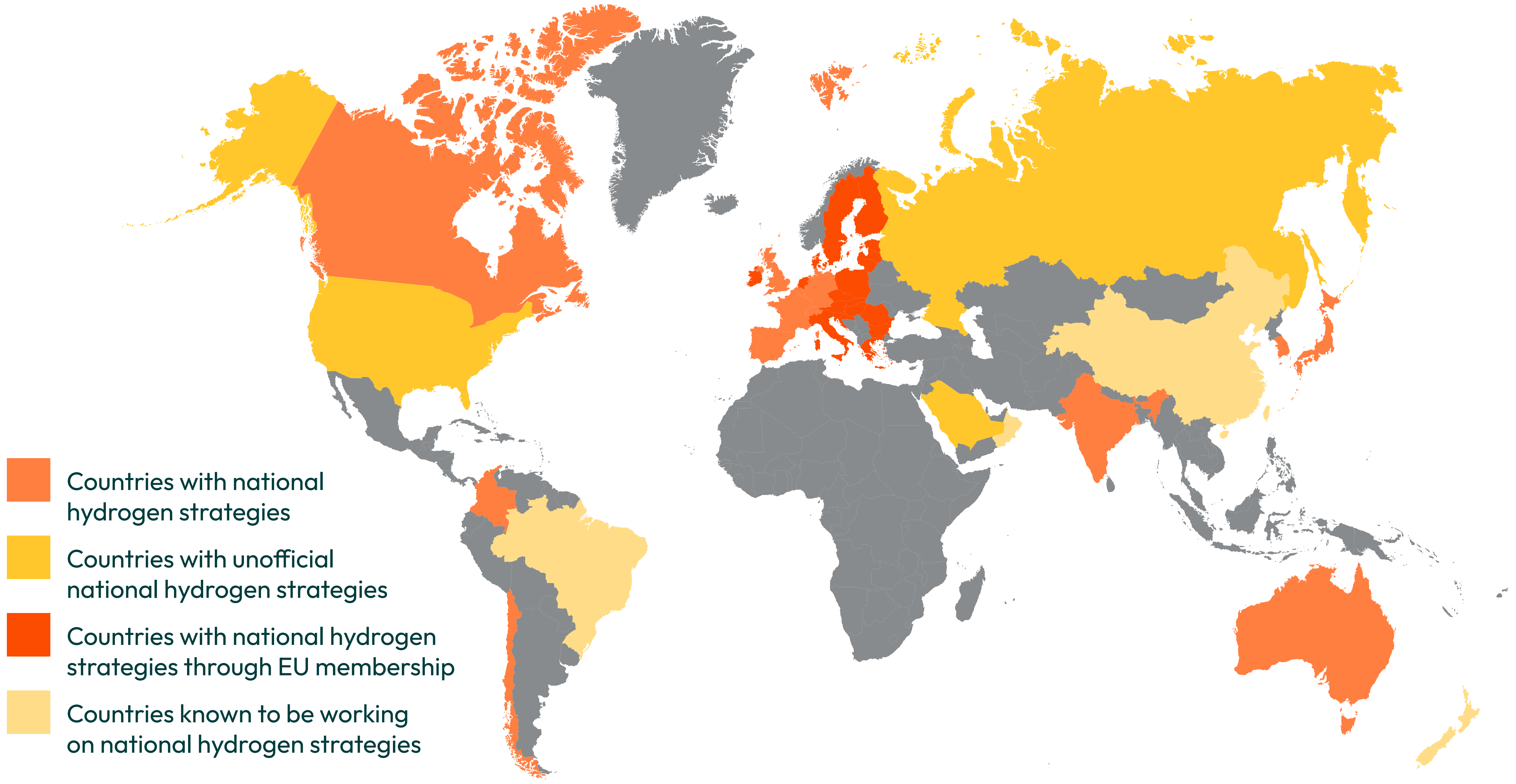
Source: BloombergNEF (2023)

National policies to bring forward the tipping point

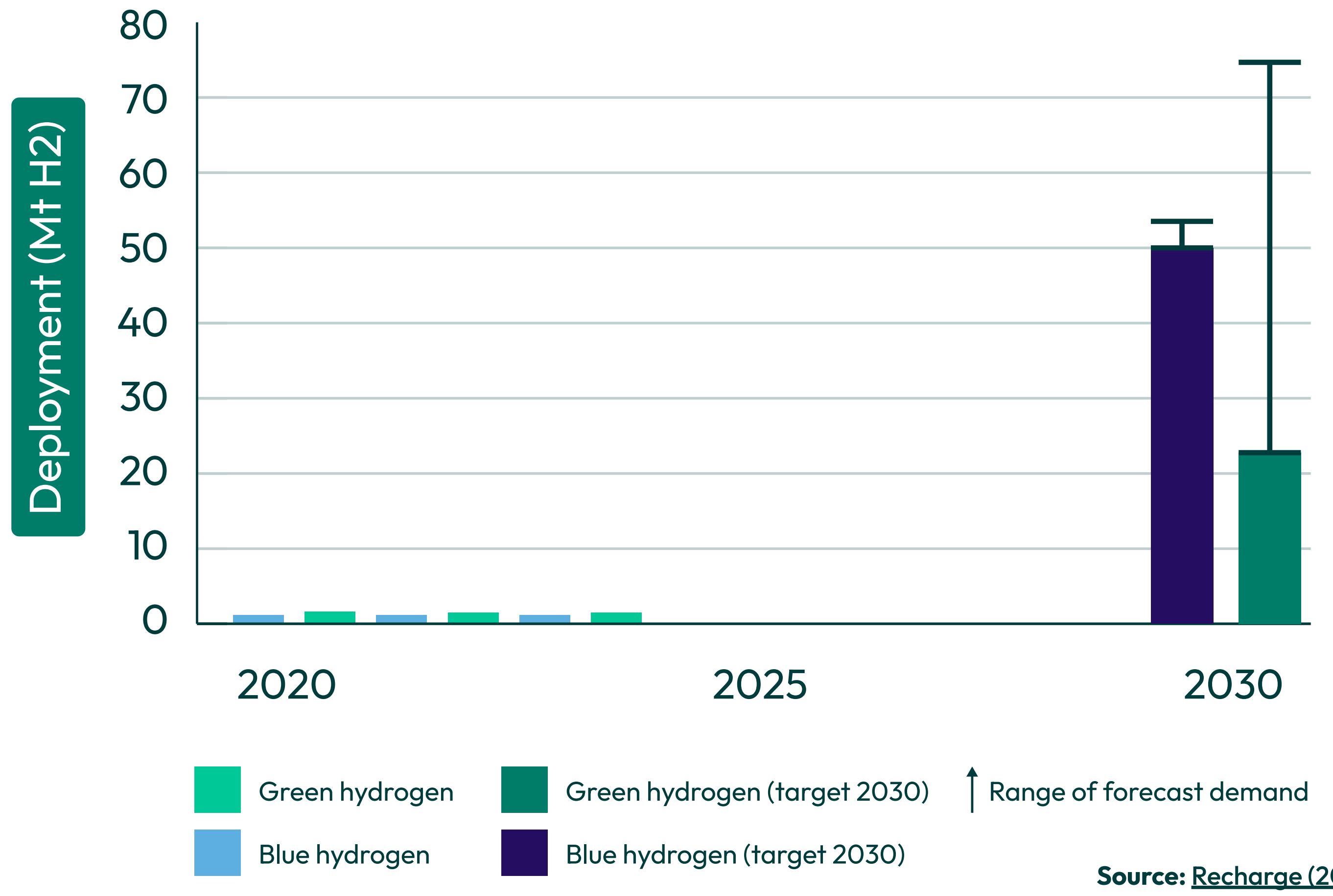
- **Strong policies can accelerate cost reduction and bring forward price-parity.** These include policies that: i) create demand and accelerate deployment of green hydrogen in sectors where grey hydrogen is already used; ii) improve financing and investment conditions; and iii) enable initial experimentation and learning in sectors where hydrogen has not been used before.
- **The most urgent priority is to create demand for green hydrogen in the sectors where it is needed.** Announcements to supply green hydrogen far exceed its current demand. Most of the demand-creation policies currently in place focus on road transport, where hydrogen may not be much needed. Far fewer focus on industry and refining.
- **Key policies to drive demand-creation include public procurement (e.g. requiring green steel in publicly funded construction); mandates or regulations such as those requiring blending of green ammonia in fertiliser production; and subsidies for green hydrogen use.** The EU quota for the use of 'renewable fuels of non-biological origin' in industry, transport and aviation by 2030 is a leading demand-side incentive for green hydrogen globally. India's hydrogen strategy envisages mandates for green ammonia use in fertiliser production (5% by 2023/24; 20% by 2027/28) [1].
- **Financial incentives can include contracts for difference (CfDs), tax breaks, subsidies and concessional loans, and carbon pricing.** The UK, Germany and Japan have or will introduce varying CfD schemes [2]. The United States' tax credits subsidise new green hydrogen assets by $3/kg, meaning new assets achieve LCOHs lower than $2/kg (compared to an average cost without subsidy of $4.5/kg) [3].
- **Demonstration projects are needed to test, prove and learn from the use of hydrogen in new sectors.** Creating hydrogen valleys (specific areas where the entire hydrogen value chain of supply and demand is clustered together) can help to de-risk investments and galvanise long-term funding [4]. The EU, Japan and US are all investing in hydrogen research, development and demonstration. The US Bipartisan Law provides USD$1 billion for R&D of clean electrolysis and $0.5 billion for manufacturing and recycling of clean hydrogen technologies over five years, and $8 billion will support hydrogen hub demonstration projects [5].

Sources: [1] BNEF (2023); IEA (2023) [2] IEA (2023) [3] Carbon Tracker (2022) [4] Breakthrough Agenda (2023); Mission Innovation (2023) [5] BNEF (2023)

Most countries have or are working on a hydrogen strategy...



...but deployment policies need to catch up



Source: Recharge (2023); Breakthrough Agenda (2023)

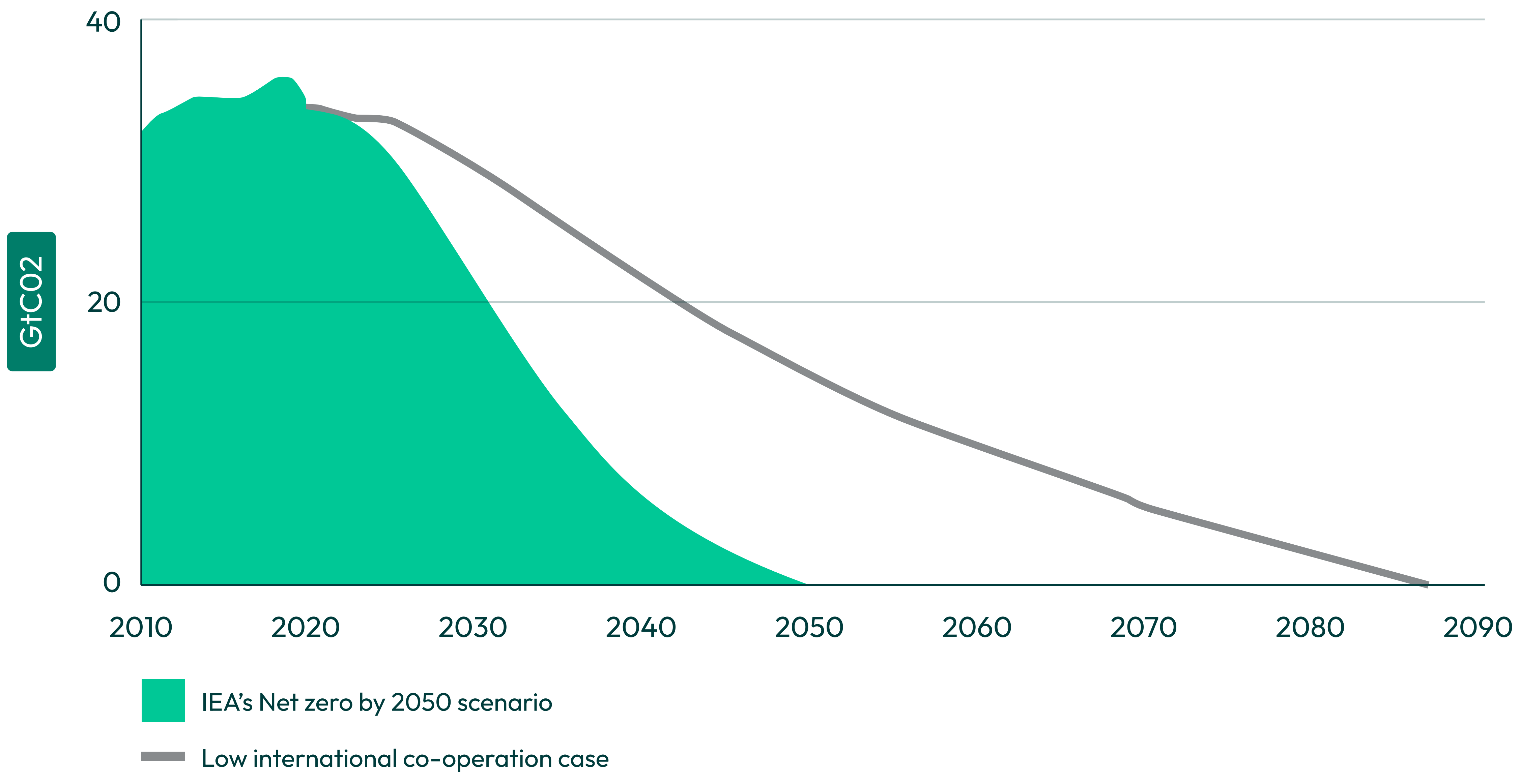
Hydrogen

Coordinated international action to bring forward the tipping point

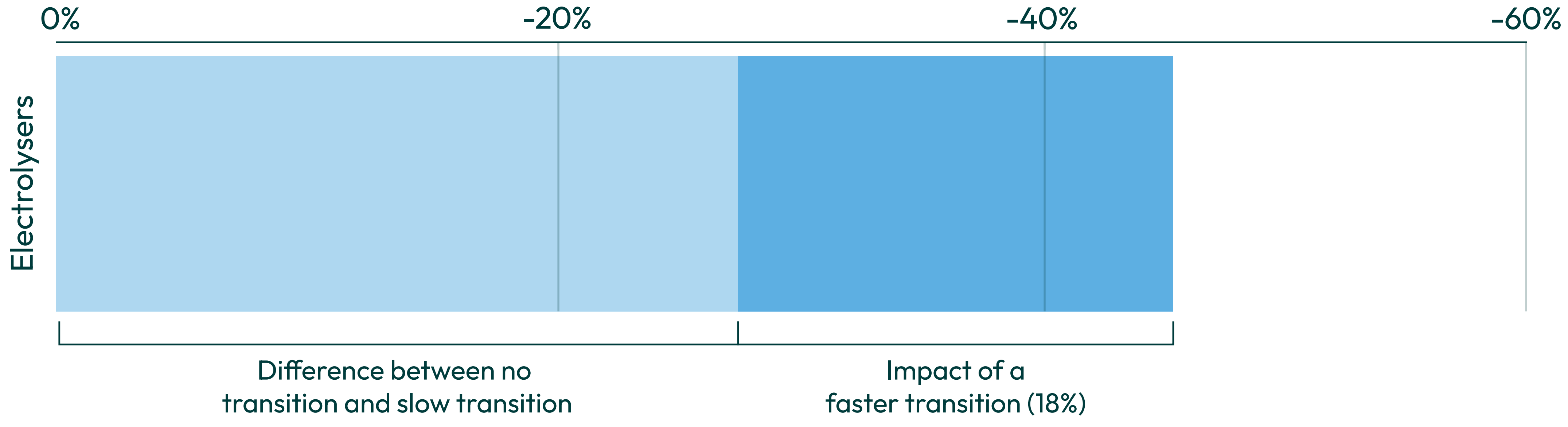
- **A fast global transition can only be achieved by countries taking coordinated action – no single country can make this happen on its own.** Indeed, net zero could be delayed by decades, and be more expensive, without international cooperation.
- **Standards and certifications, demand creation, technology demonstration, and finance,** are key priorities for international cooperation on green hydrogen [1].
- **Harmonised standards and certifications** are needed for governments to decide exactly which hydrogen can benefit from subsidies and trading, and to build investor and consumer confidence in the green hydrogen market [2].
- **Coordinated targets and policies** to deploy green hydrogen in sectors where grey hydrogen is already used would send a strong demand signal, mobilise investment in production, and enable larger economies of scale and faster cost reductions [1].
- **Sharing learning from demonstration projects in priority sectors can accelerate innovation and commercialisation.** Too many projects are focused on road transport; countries should share learning from demonstrations of hydrogen use in heavy industry, maritime shipping, aviation, and inter-seasonal electricity storage [1].
- **Governments need to work together with international financial institutions to identify ways to overcome project delays and reduce costs of capital [1].** Many projects are struggling to move from announcement to investment and construction. Doubling the cost of capital from 5% to 10% increases production costs by almost 40% [2], making this an important factor to address.

Sources: [1] Breakthrough Agenda (2023) [2] IEA (2022)

Net Zero by 2050 scenario (NZE) versus a Low International Co-operation Case



Electrolysers will be 18% cheaper to produce by 2030 in a fast transition compared with a slow transition



Source: IEA (2021); Breakthrough Agenda (2022)

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