

Green Hydrogen: Time to Scale Up

European Hydrogen Forum

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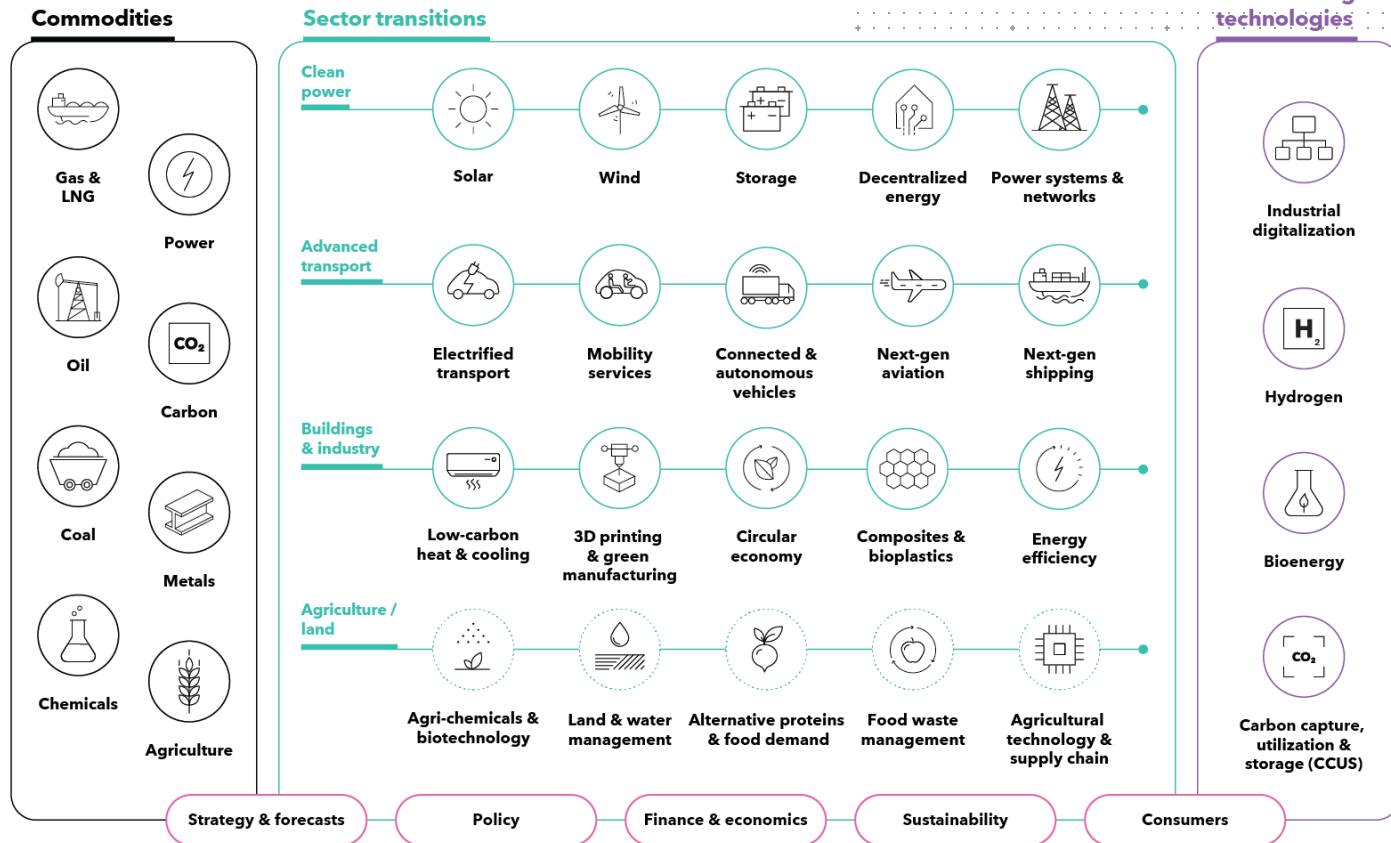
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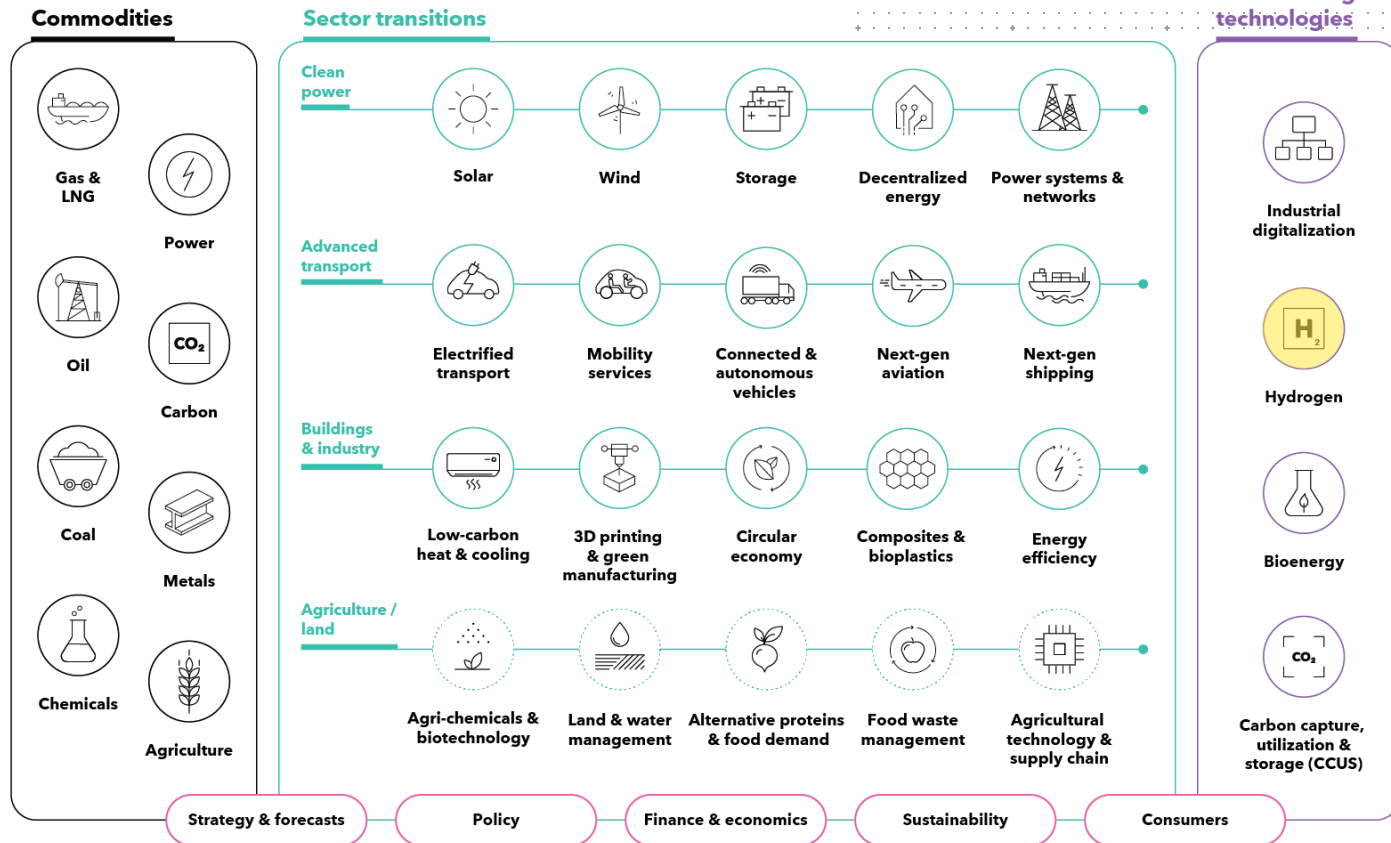
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Strategies for a cleaner, more competitive future



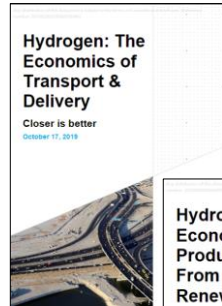
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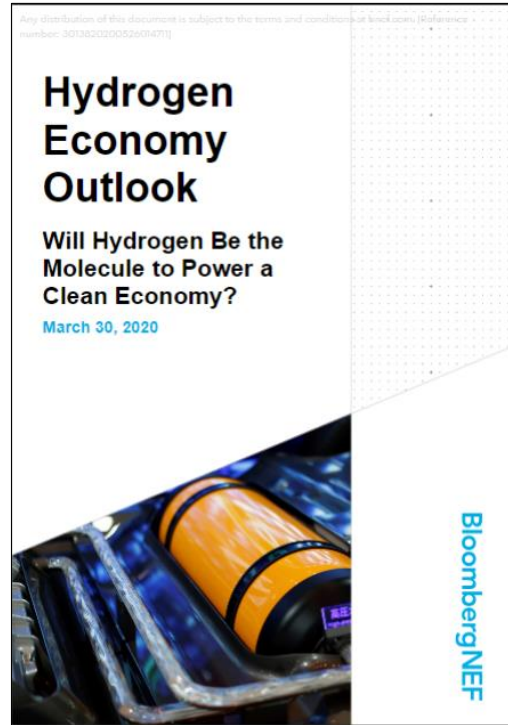
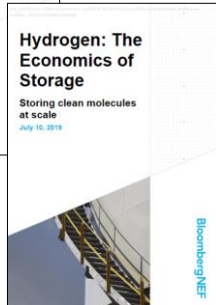
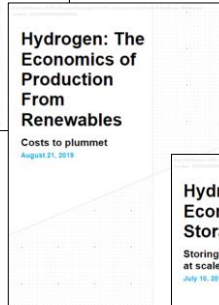


The Hydrogen Economy Outlook

A free summary of the key messages is available at about.bnef.com/blog.



13 reports

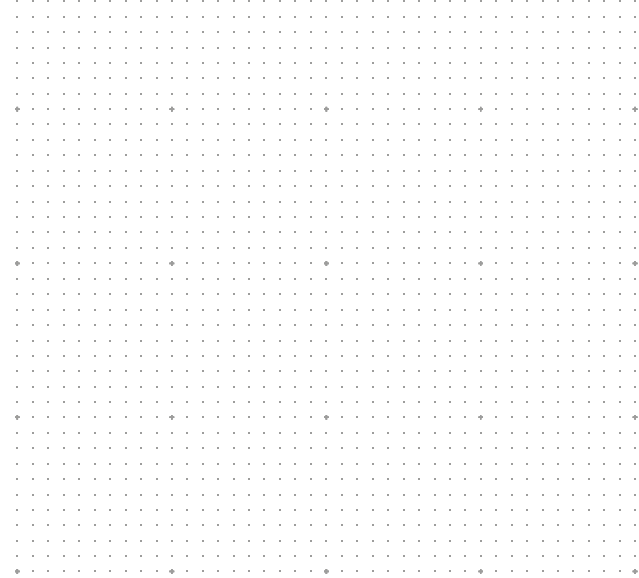


Hydrogen: Fuel Cell Vehicle Outlook
In the 1980s and 1990s, fuel cell vehicles (FCVs) were considered the most promising alternative to internal combustion engines. However, they were largely abandoned in favor of electric vehicles (EVs). Now, with the resurgence of interest in hydrogen, FCVs are being revisited as a potential solution for long-haul trucking and heavy-duty transport. This report analyzes the market potential for FCVs and compares them to EVs and internal combustion engines.

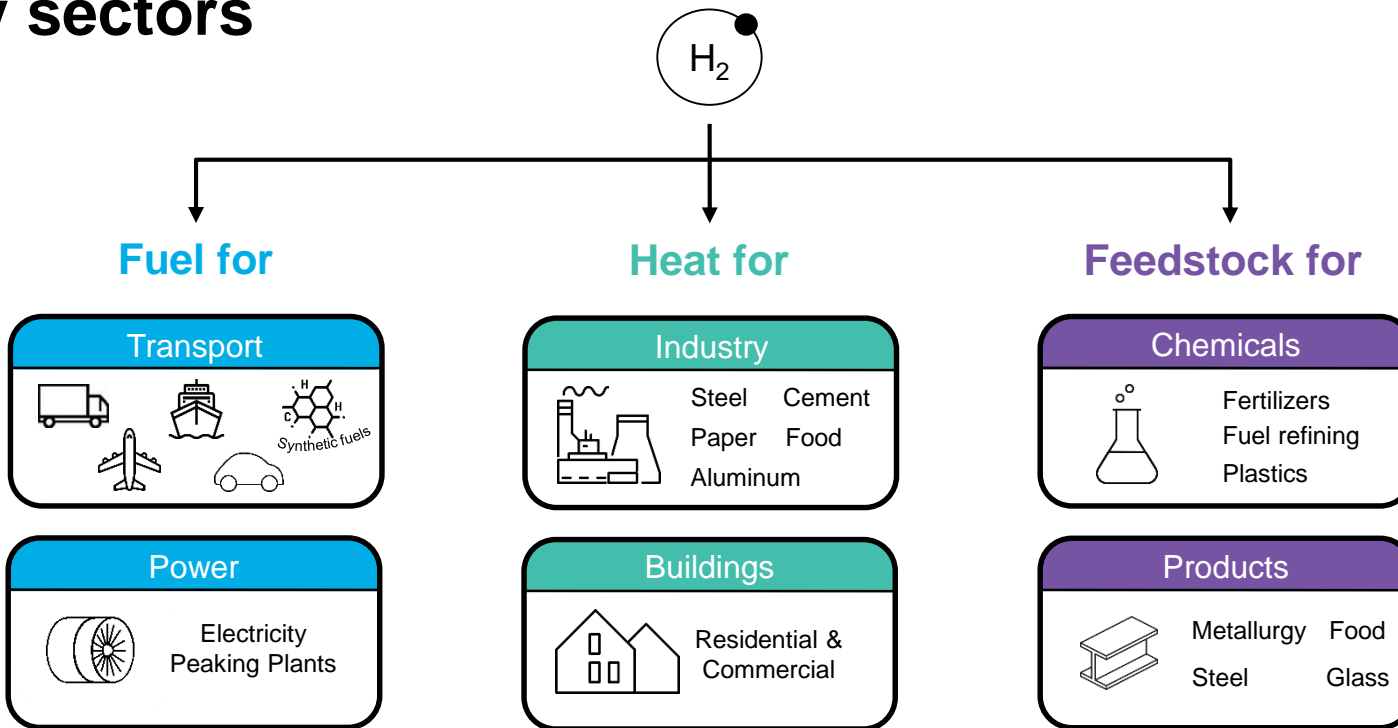
Hydrogen: The Economics of Powering Ships
The shipping industry is under increasing pressure to decarbonize. While electric and hybrid propulsion are viable for smaller vessels, larger ships require alternative fuels. Hydrogen offers a promising solution, but its high production and storage costs are currently prohibitive. This report explores the economic challenges and opportunities for hydrogen-powered shipping.

Hydrogen: Making Fossil-Free Steel
The steel industry is a major source of CO2 emissions. Replacing fossil fuels with hydrogen in the blast furnace process could significantly reduce emissions. However, the high cost of hydrogen and the need for infrastructure changes are significant barriers. This report examines the feasibility and economic impact of hydrogen-based steel production.

Why hydrogen?

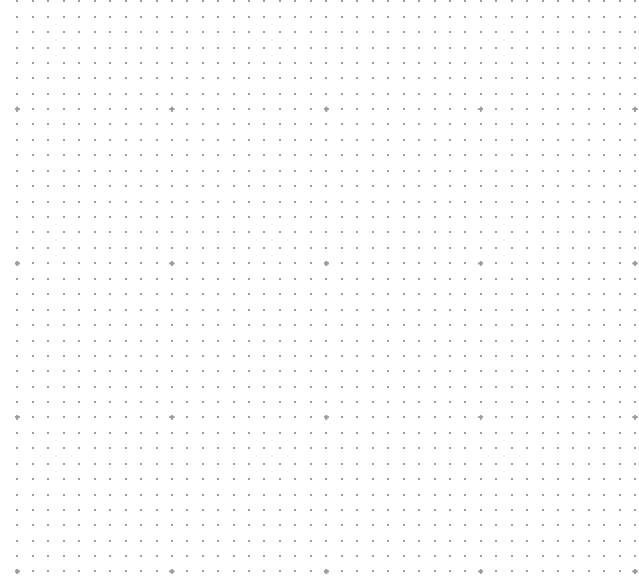


Hydrogen is well placed to decarbonize many sectors



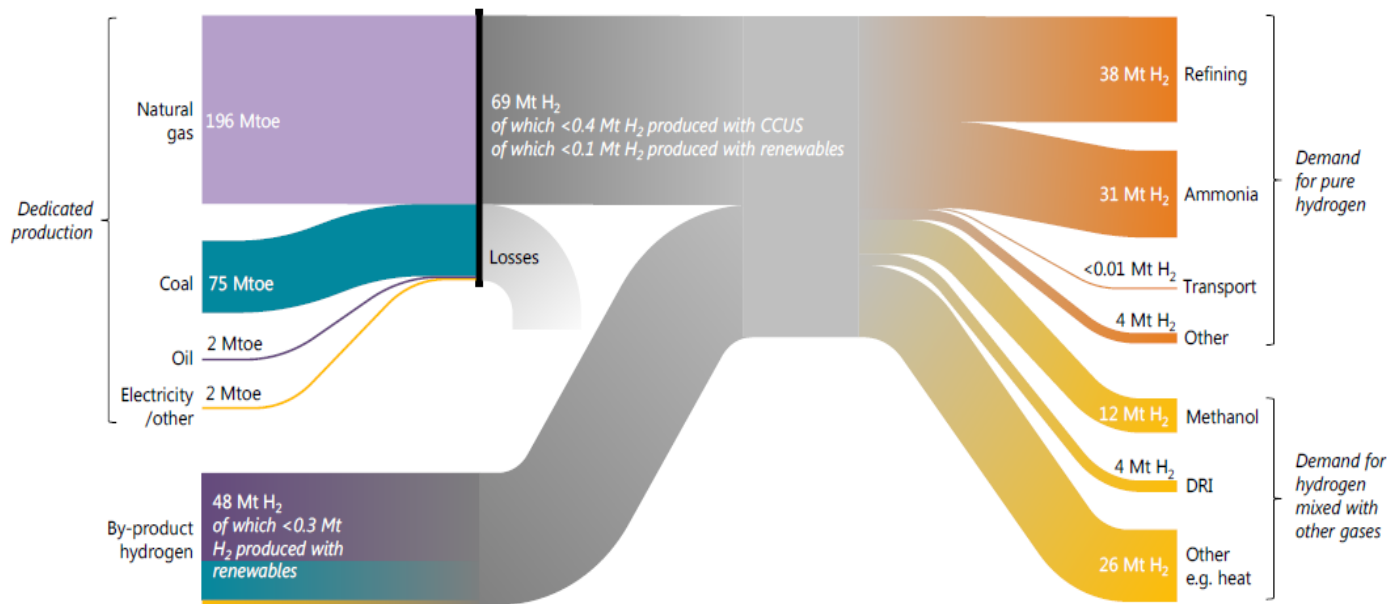
Source: BloombergNEF

Production costs



Production of hydrogen today is already a big, and polluting, business

Supply and demand for hydrogen globally, 2018



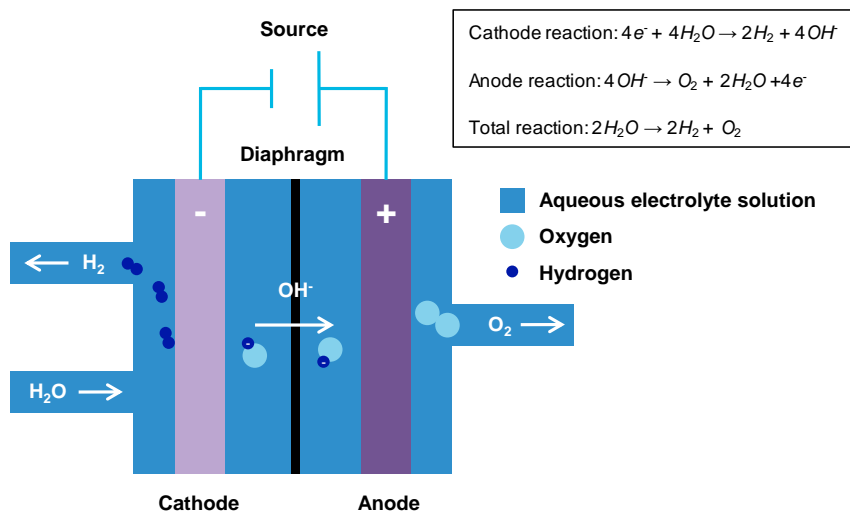
Key statistics, 2018

- 117MMT produced
- \$130 billion in sales
- Over 99% derived from fossil fuels
- Releases 830MtCO₂ (2.2% of global energy related CO₂)
- Consumes around 6% of natural gas and 2% of coal

Source: International Energy Agency, Morgan Stanley. See notes pane for notes.

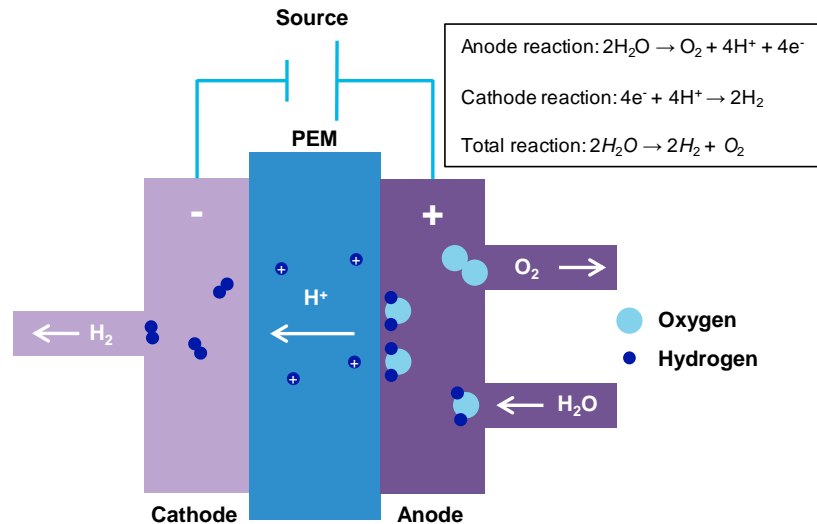
Renewable hydrogen can be made using renewable electricity

Alkaline electrolysis



Source: BloombergNEF

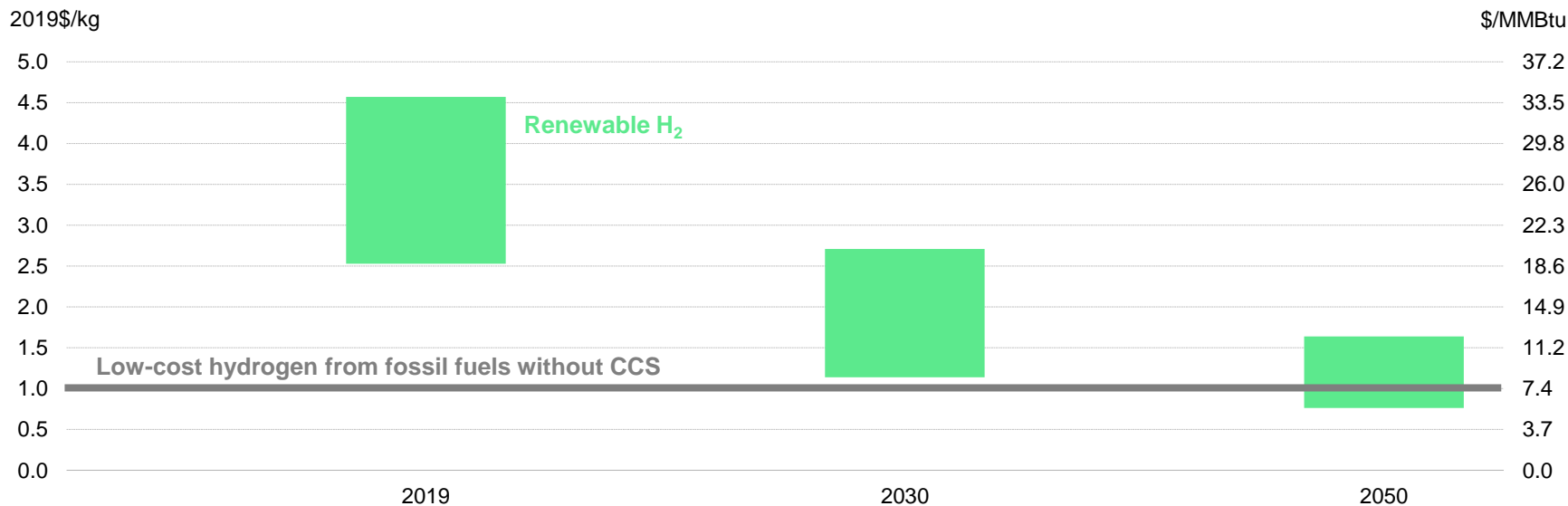
Proton exchange membrane electrolysis



Source: BloombergNEF

Renewable hydrogen is currently expensive, but costs are coming down

Forecast global range of levelized cost of hydrogen production from large projects

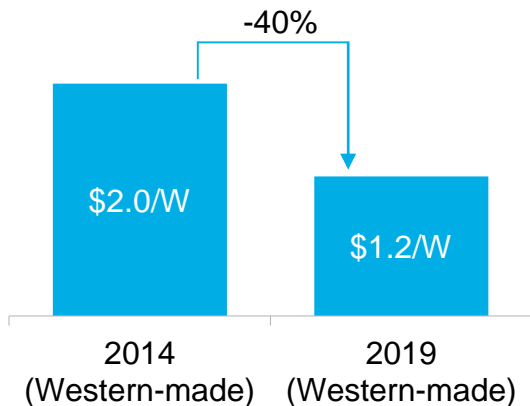


Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex.

The cost of electrolyzers has been falling

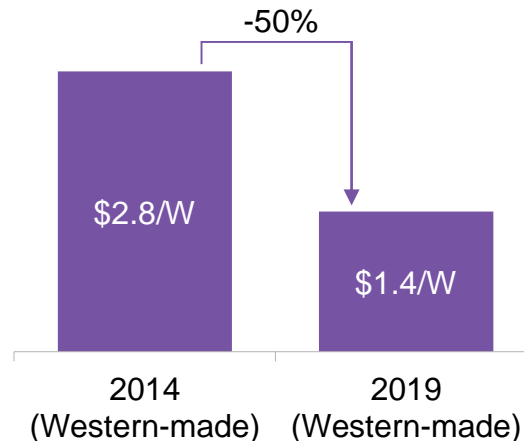
Benchmark system capex based on large-scale electrolyzers, 2014 and 2019

Alkaline



Source: BloombergNEF

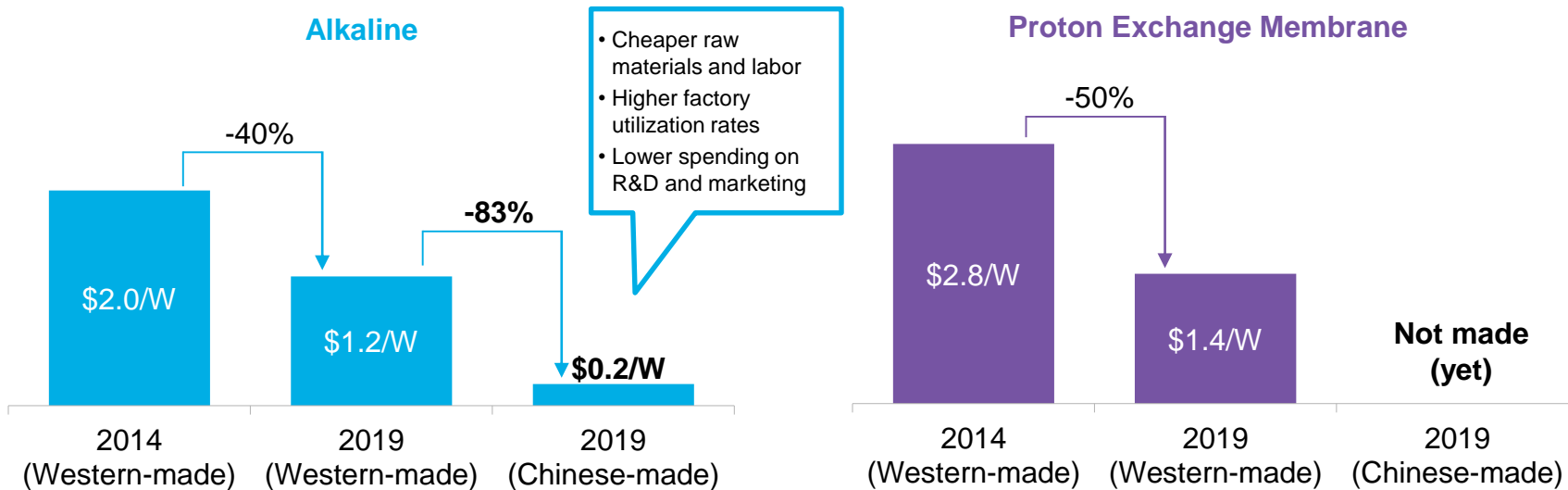
Proton Exchange Membrane



Source: BloombergNEF

Electrolyzers cost up to 83% less in China

Benchmark system capex based on large-scale electrolyzers, 2014 and 2019

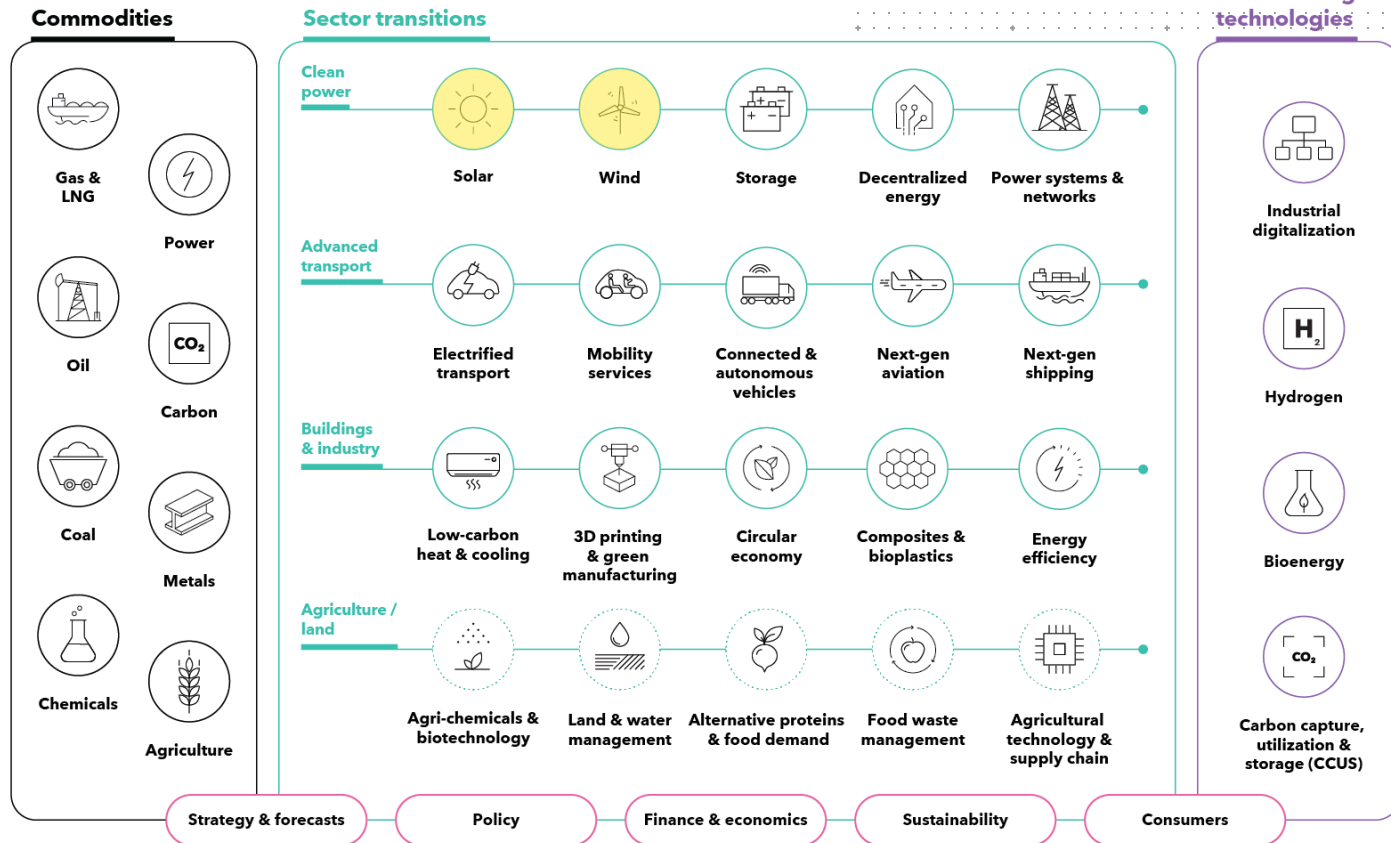


Source: BloombergNEF

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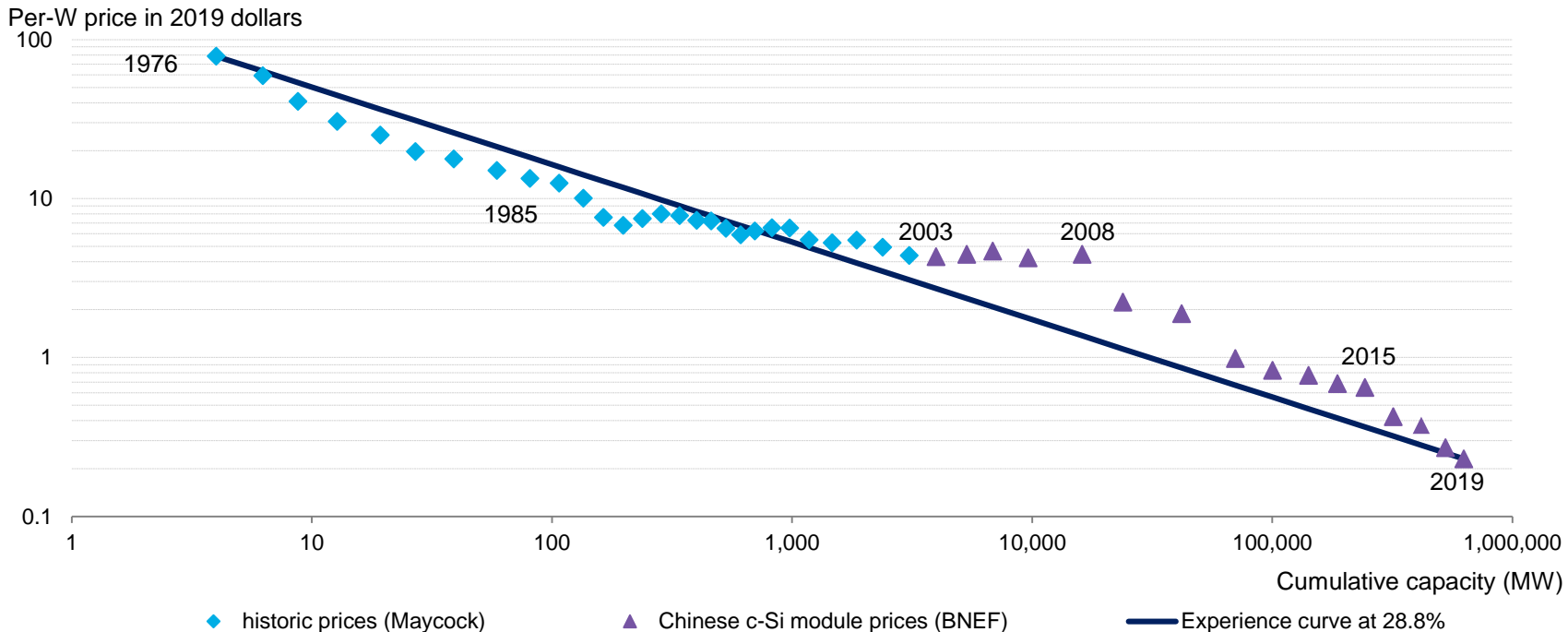
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Strategies for a cleaner, more competitive future



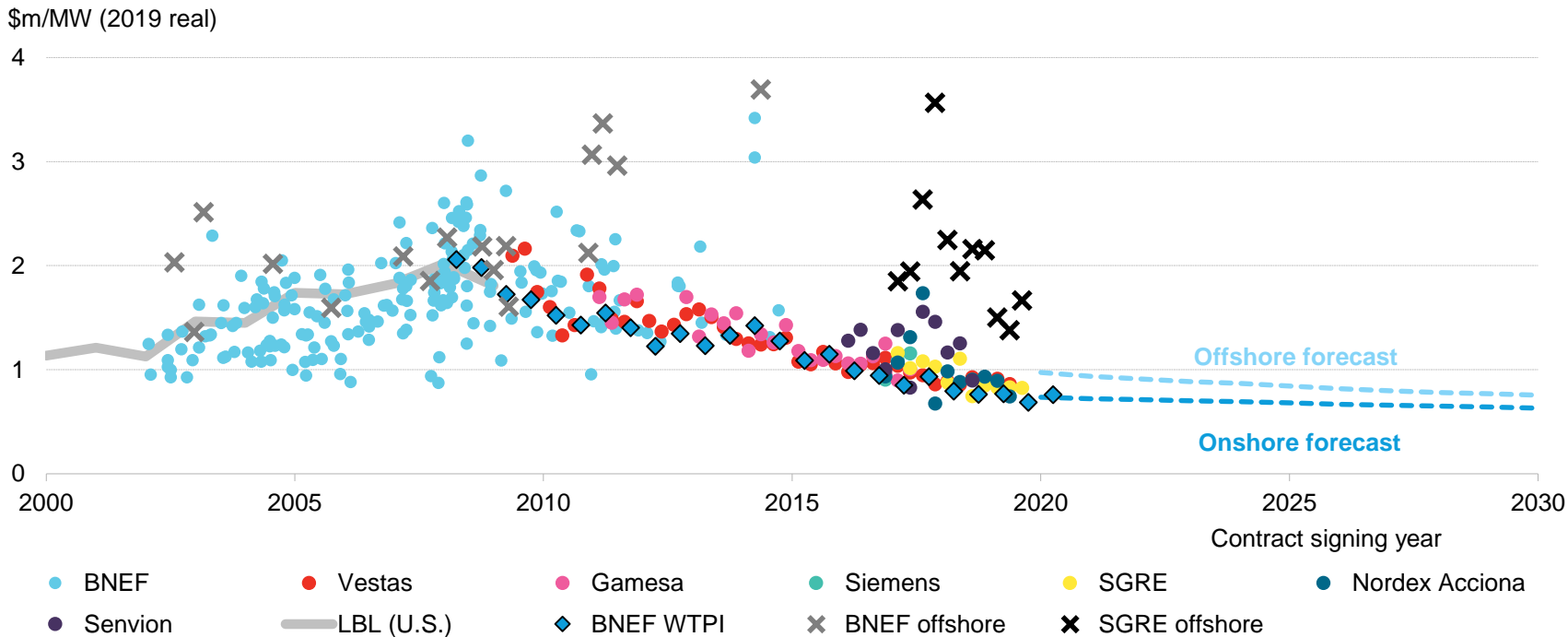
A history of solar module prices

PV module experience curve



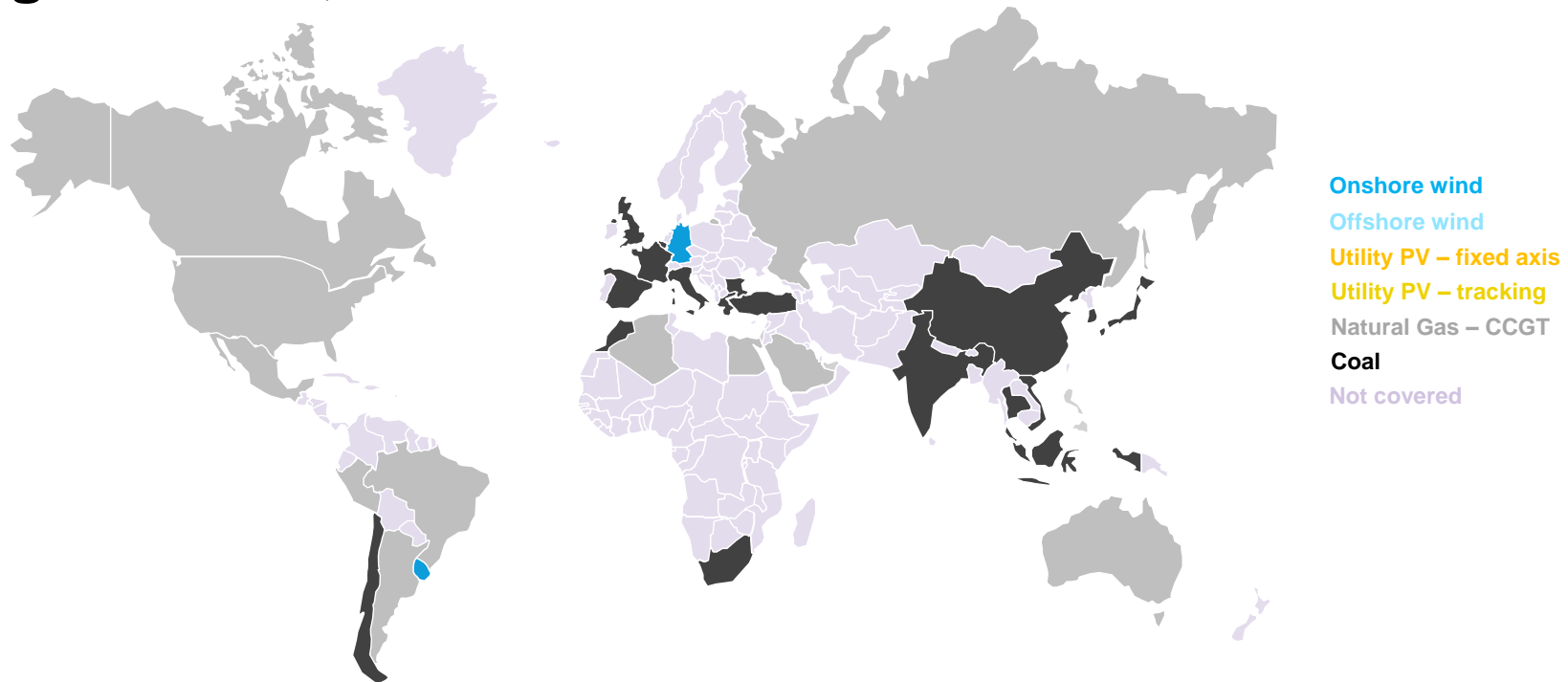
Source: Paul Maycock, BloombergNEF

A history of wind turbine prices



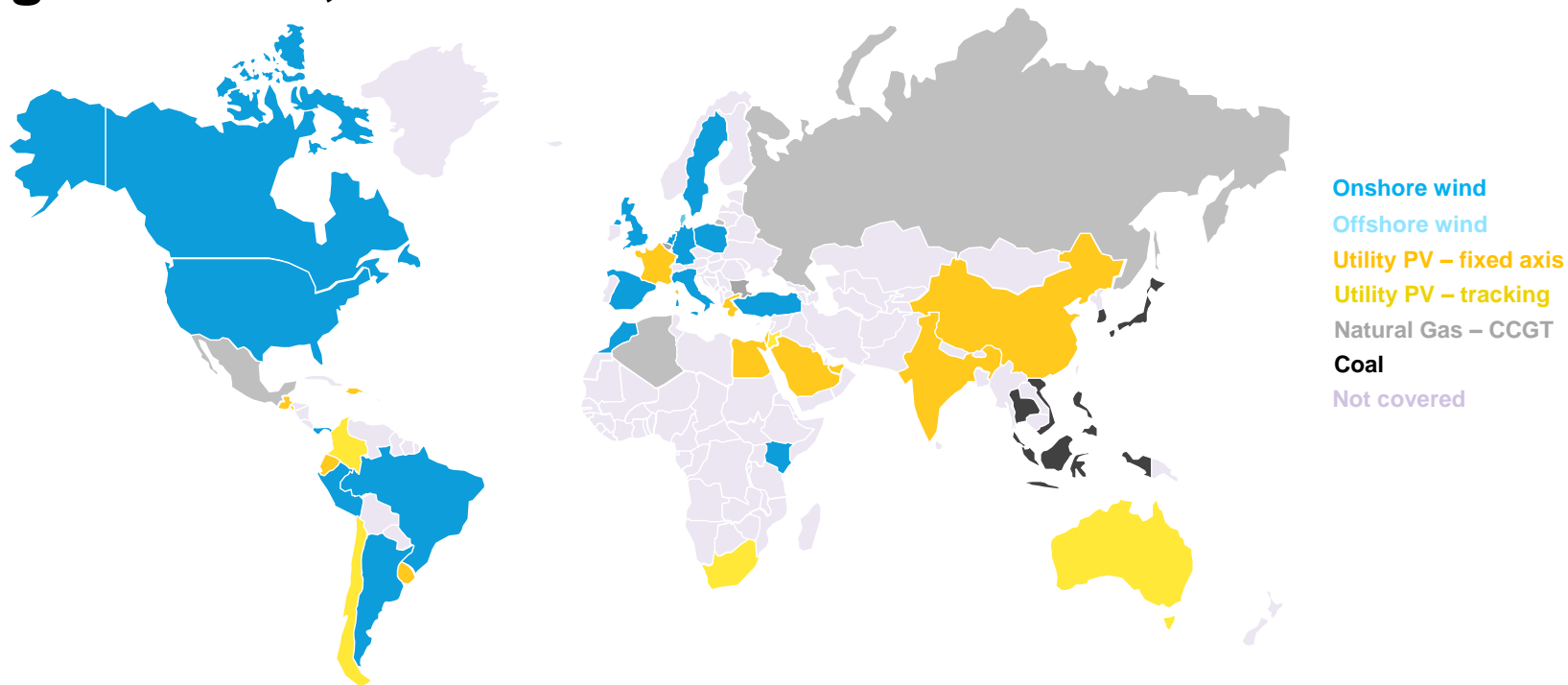
Source: BloombergNEF

Most competitive source of new bulk generation, 2014



Source: BloombergNEF

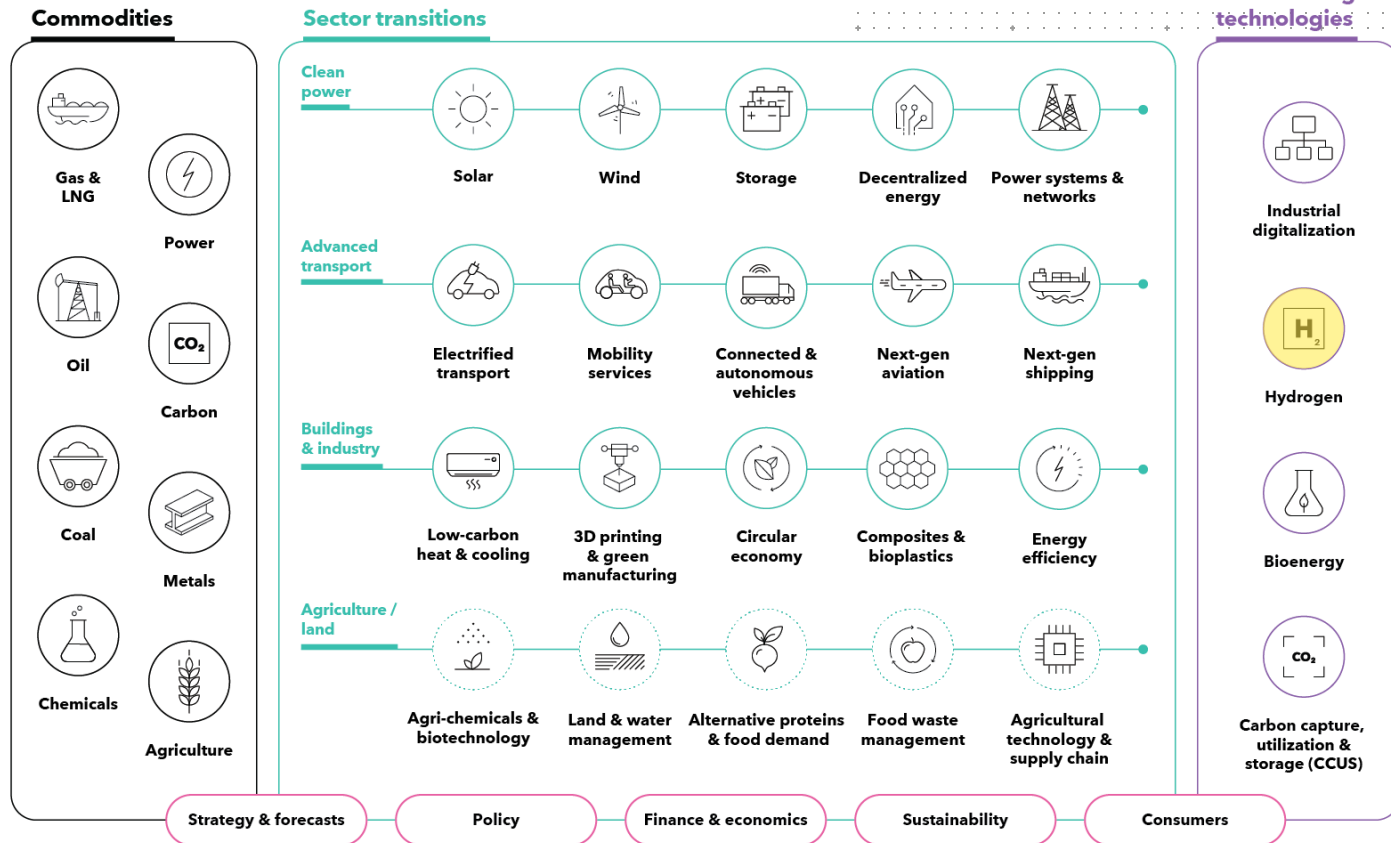
Most competitive source of new bulk generation, 1H 2020



Source: BloombergNEF

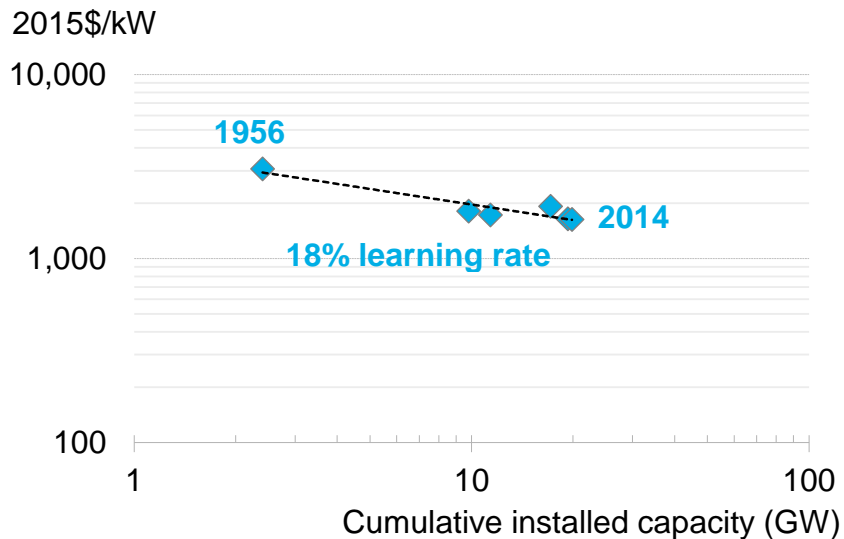
BNEF coverage

Strategies for a cleaner, more competitive future



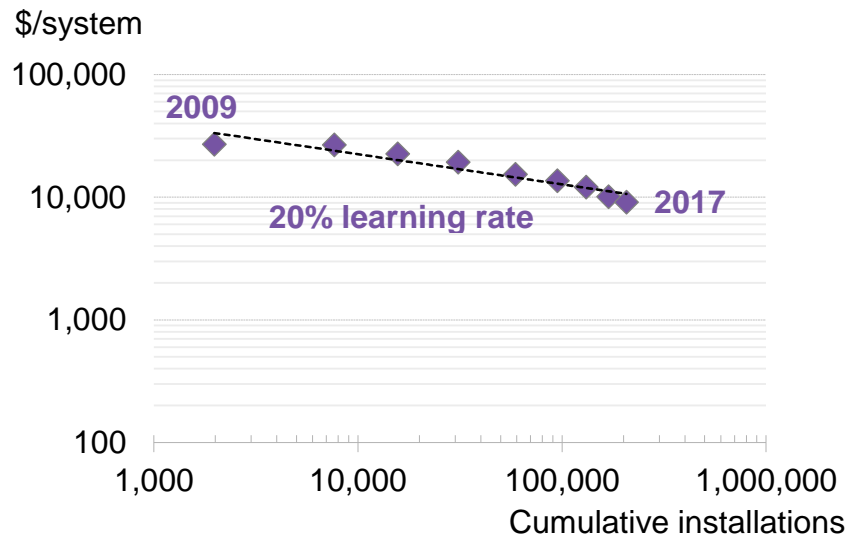
Electrolyzer costs should continue to fall if scale-up occurs

Learning rate of alkaline electrolyzers



Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell, BloombergNEF

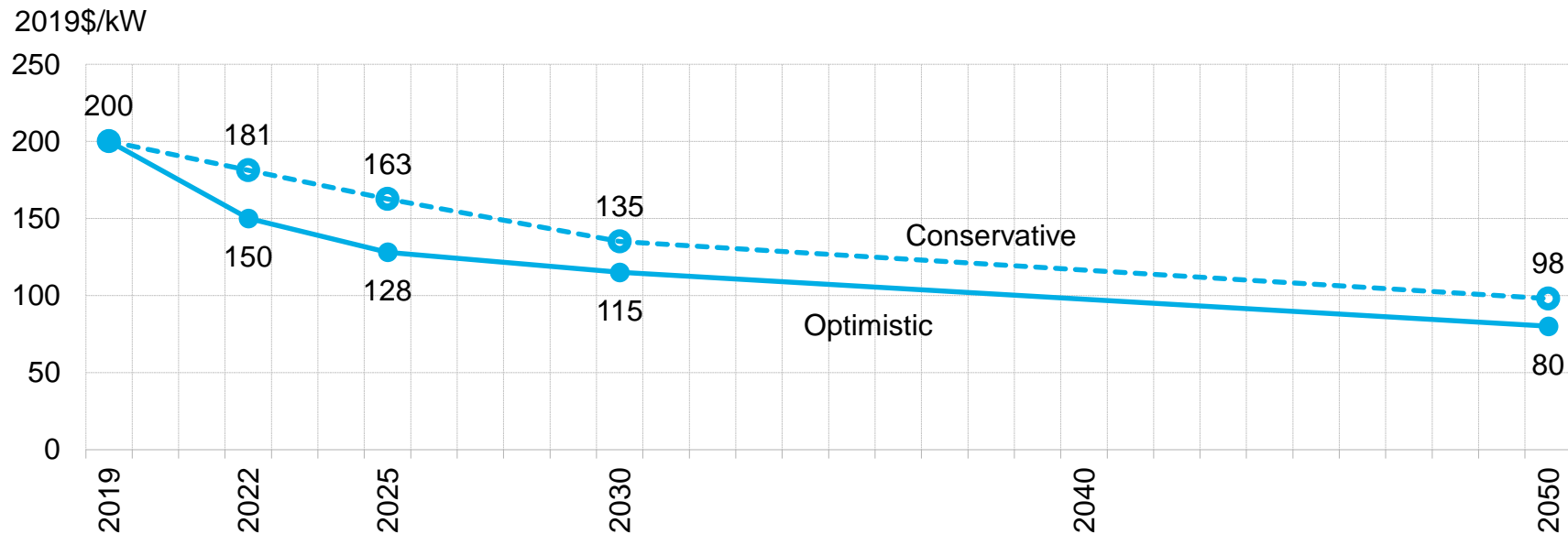
Learning rate of PEM fuel cell systems in Japan



Source: Japan METI, BloombergNEF

How much electrolyzer costs fall will depend on deployment (Chinese alkaline)

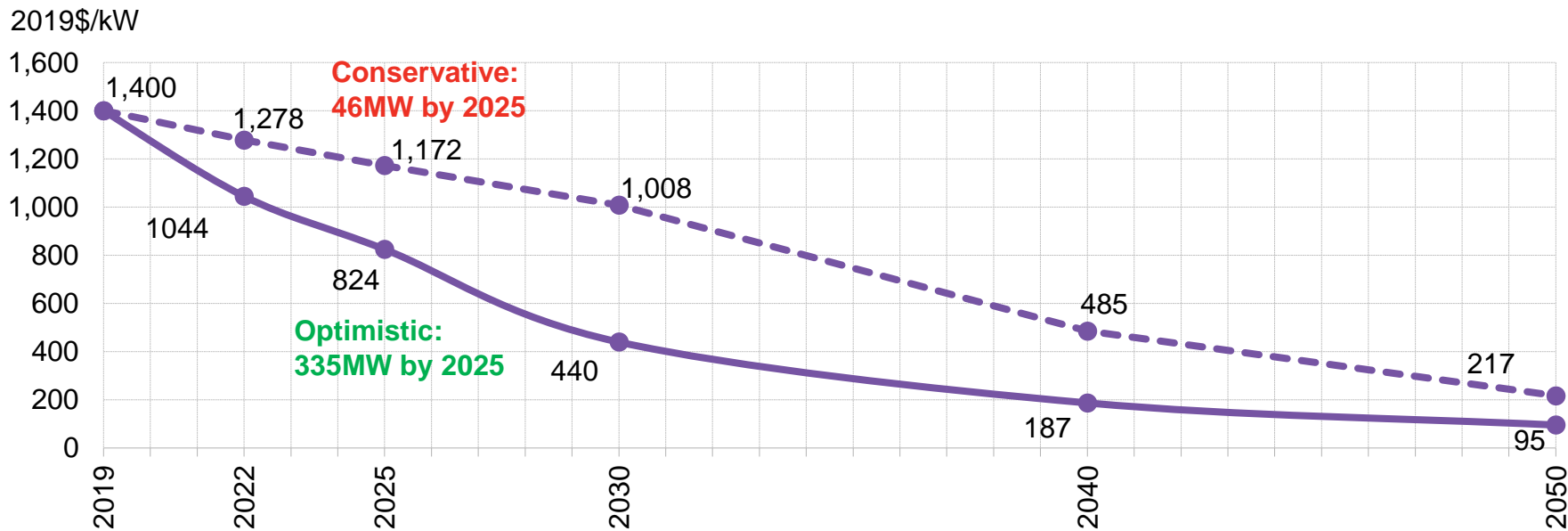
System capex forecast of Chinese-made alkaline electrolysis projects (large-scale projects)



Source: BloombergNEF. Note: Assumes large-scale system sizes of 3MW in 2019, 10MW in 2022, 30MW in 2025, 100MW in 2030 and 400MW in 2050.

How much electrolyzer costs fall will depend on deployment (western PEM)

System capex forecast of 4MW-scale PEM electrolysis projects

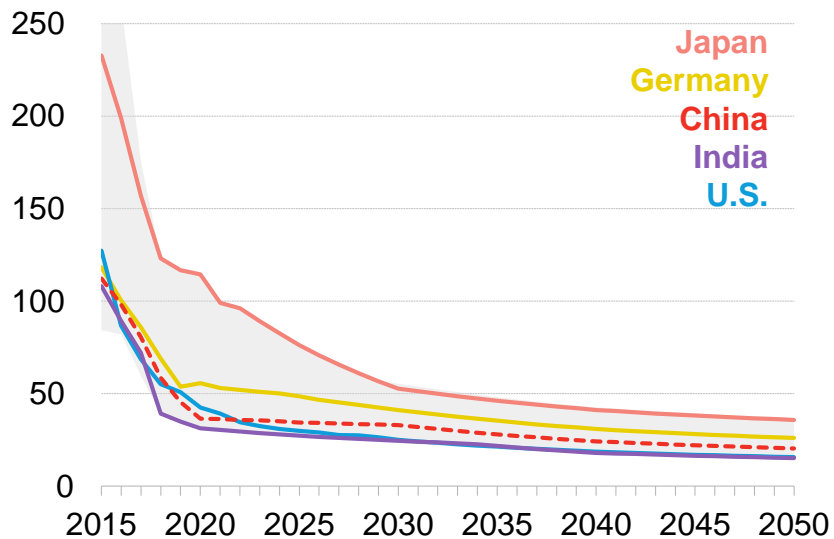


Source: BloombergNEF. Conservative: 46MW of PEM systems commissioned by 2025. Optimistic: 335MW of PEM systems commissioned by 2025.

Renewable electricity costs will keep falling

Utility-scale PV levelized cost, 2015-50

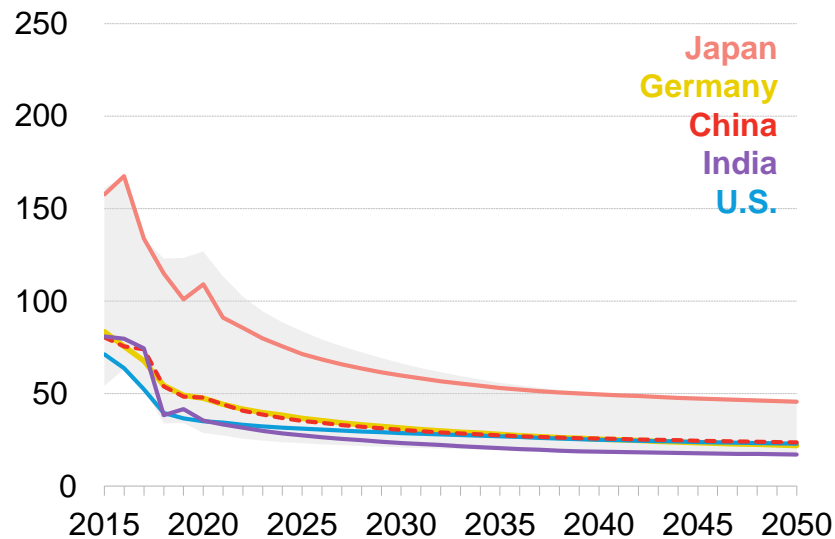
\$/MWh (2019 real)



Source: BloombergNEF

Onshore wind levelized cost, 2015-50

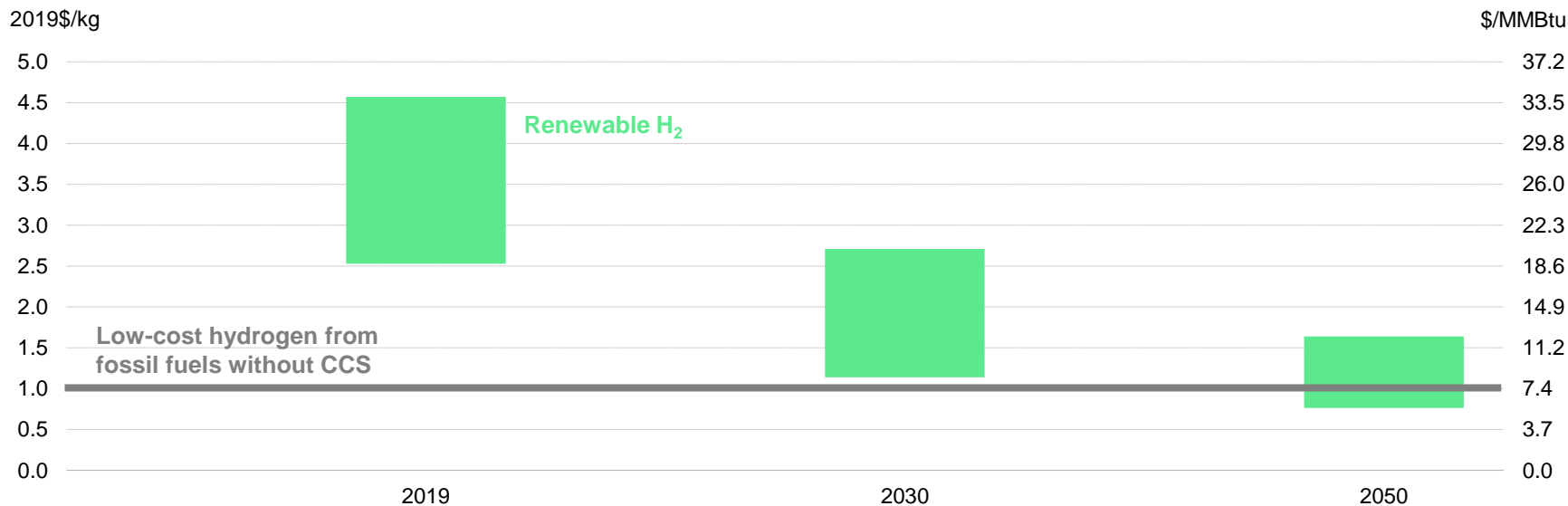
\$/MWh (2019 real)



Source: BloombergNEF

Renewable hydrogen is currently expensive, but costs are coming down

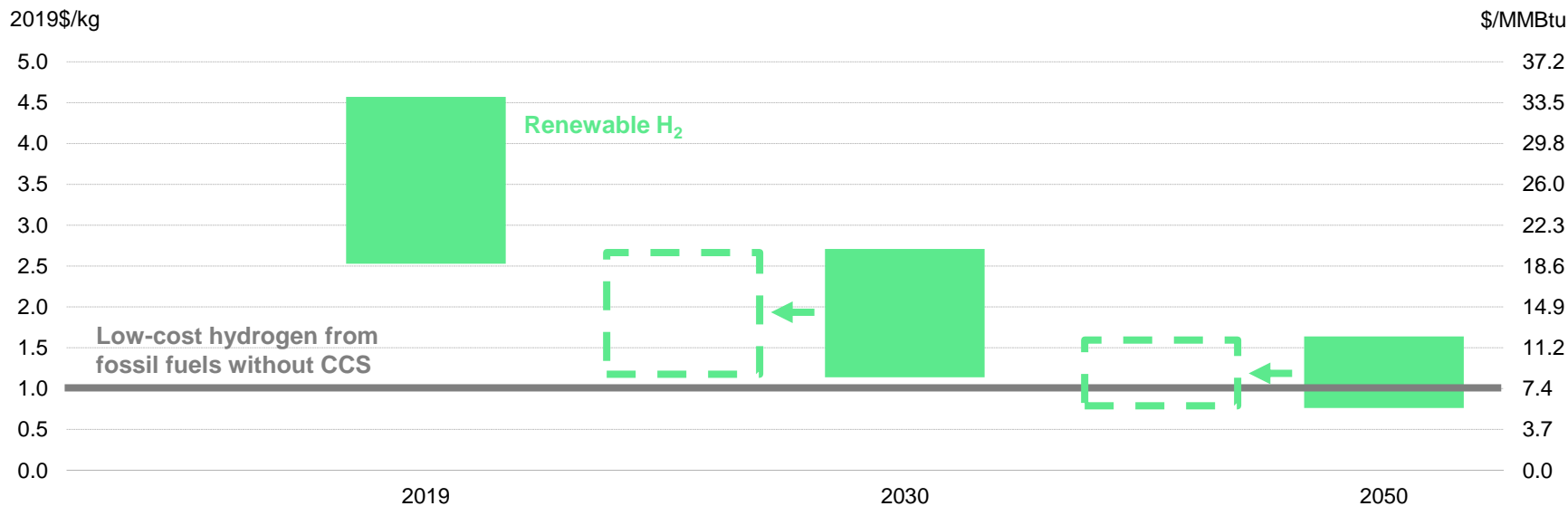
Forecast global range of levelized cost of hydrogen production from large projects



Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex.

Green H2 costs could fall even faster with larger electrolyzer deployment

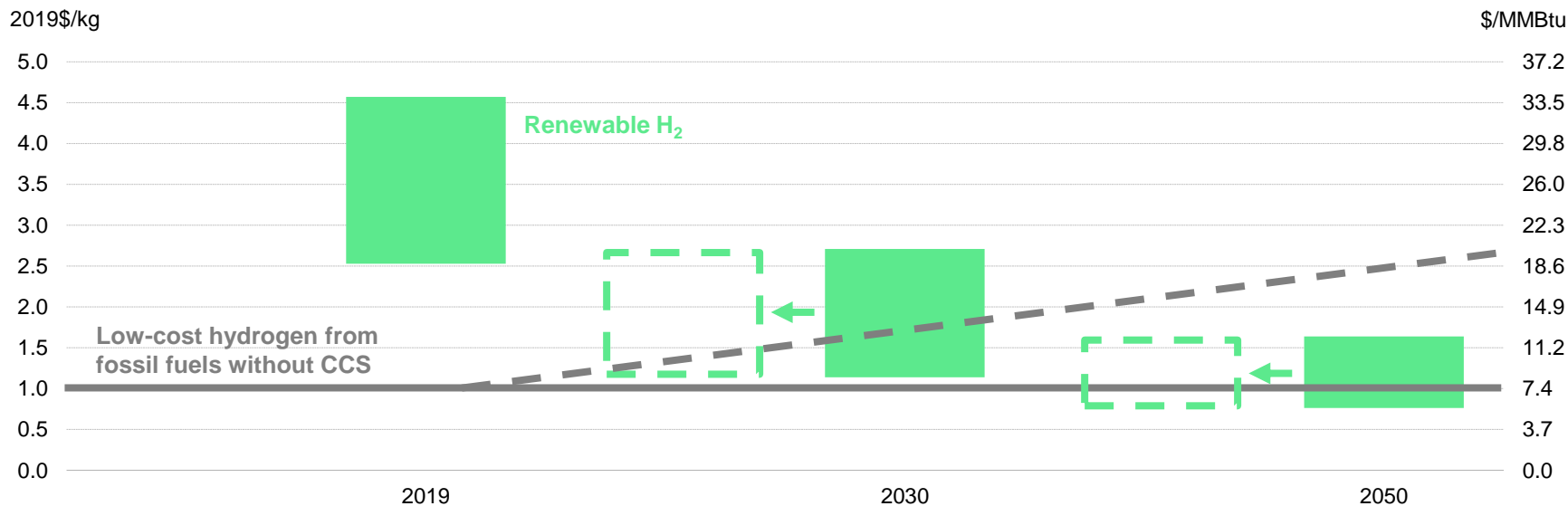
Forecast global range of levelized cost of hydrogen production from large projects



Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex. Dashed boxes are for illustration only.

Carbon pricing could make hydrogen from fossil fuels without CCS more expensive

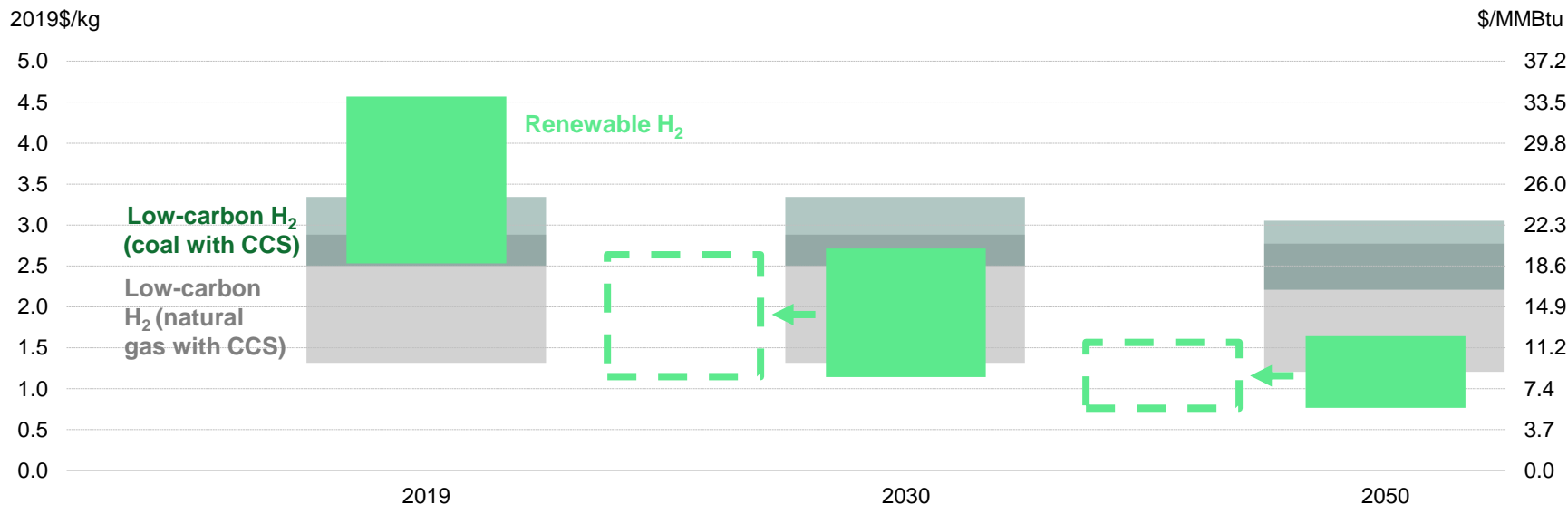
Forecast global range of levelized cost of hydrogen production from large projects



Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex. Dashed boxes and line are for illustration only.

Capturing the carbon would cost more than renewable hydrogen

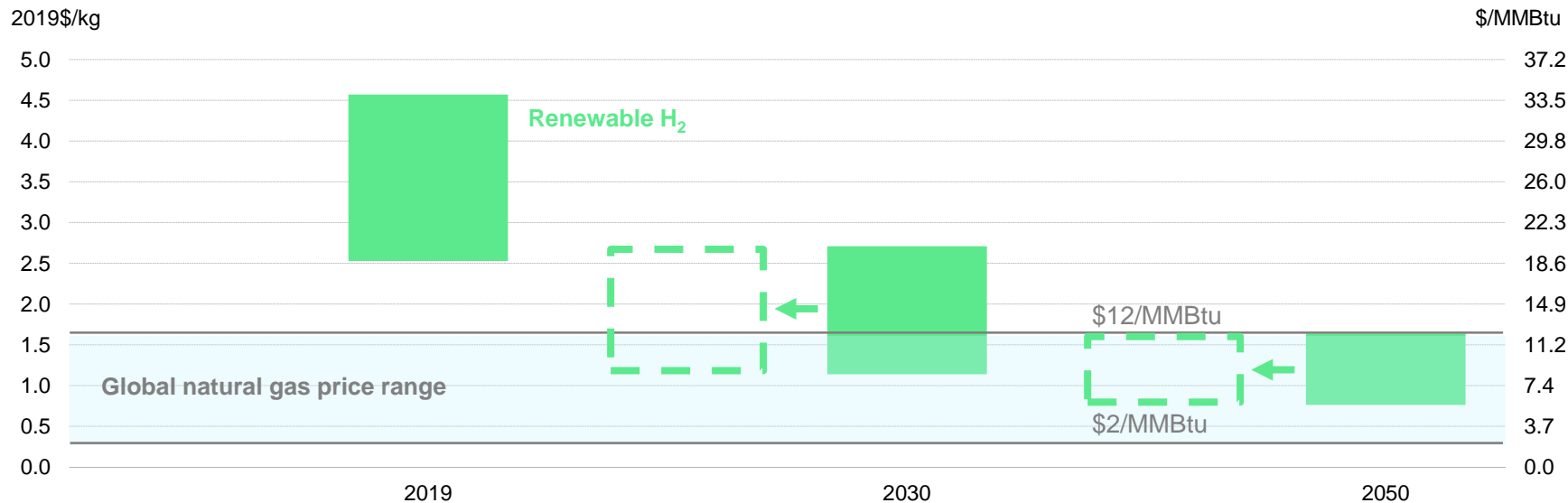
Forecast global range of levelized cost of hydrogen production from large projects



Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex. Natural gas prices range from \$1.1-10.3/MMBtu, coal from \$30-116/t. Dashed boxes are for illustration only.

Renewable hydrogen could even compete with natural gas

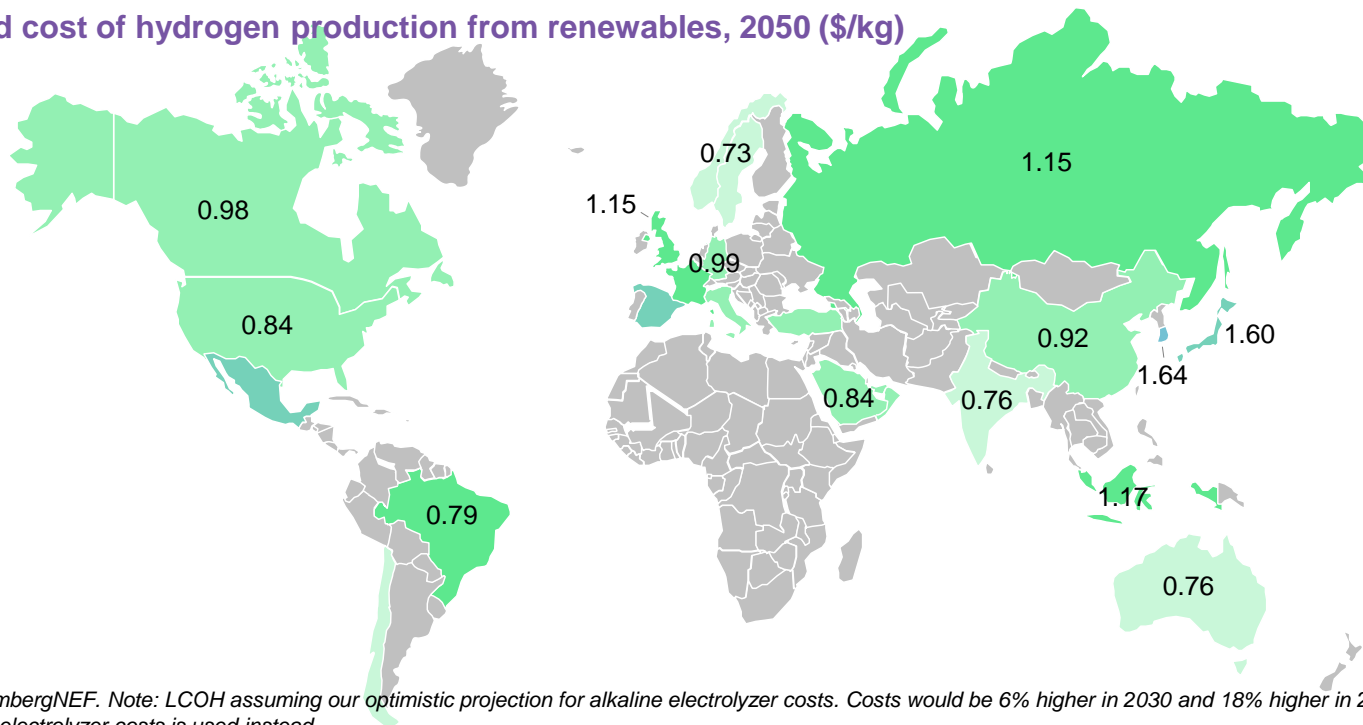
Forecast global range of levelized cost of hydrogen production from large projects



Source: BloombergNEF. Note: renewable hydrogen costs based on large projects with optimistic projections for capex. Dashed boxes are for illustration only.

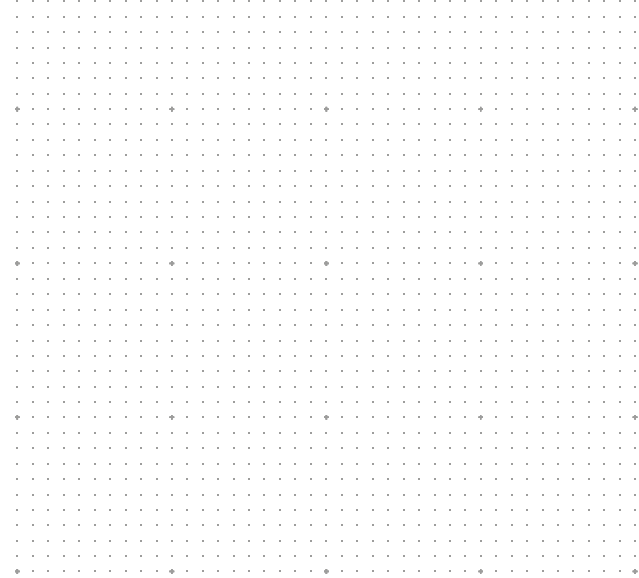
Renewable hydrogen could be produced for \$0.8 to \$1.6/kg in most parts of the world before 2050

Levelized cost of hydrogen production from renewables, 2050 (\$/kg)

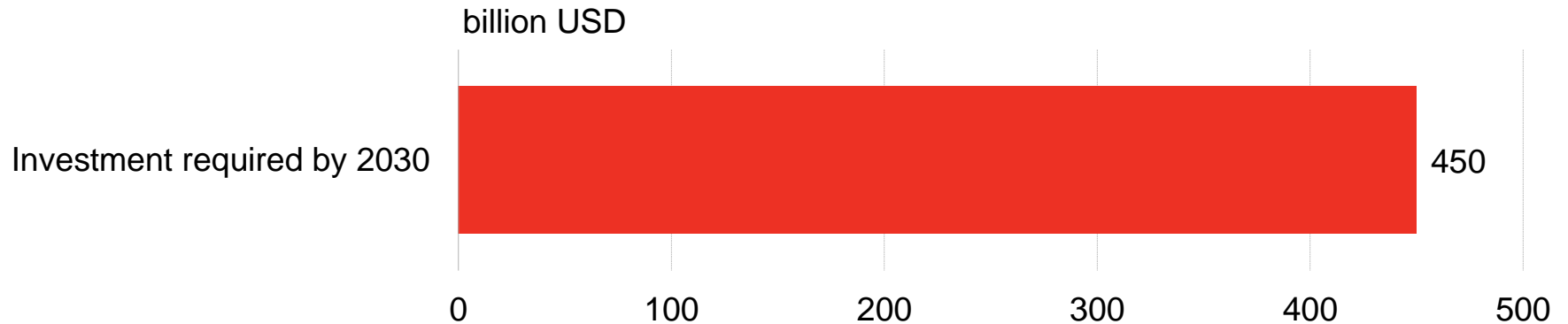


Source: BloombergNEF. Note: LCOH assuming our optimistic projection for alkaline electrolyzer costs. Costs would be 6% higher in 2030 and 18% higher in 2050 if the conservative projection for electrolyzer costs is used instead.

How are we doing on scale-up?



BNEF, March 2020: the signs that H2 is scaling up are not yet there



Source: BloombergNEF

Hydrogen roadmaps keep coming

June 2020: Germany



Source: Bloomberg

Hydrogen roadmaps keep coming July 2020: European Union



Source: Bloomberg

Hydrogen roadmaps keep coming

September 2020: France



Source: Bloomberg

Hydrogen roadmaps keep coming

October 2020: Spain



Source: Bloomberg

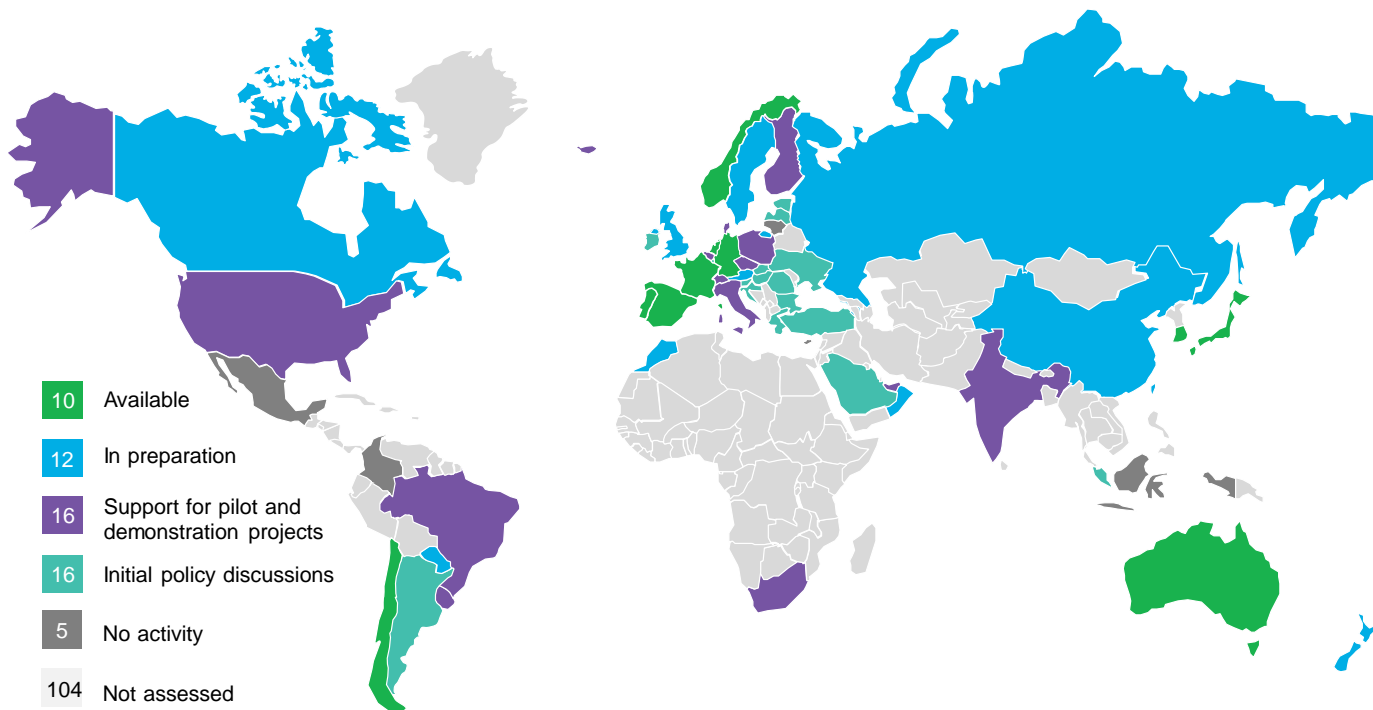
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Hydrogen roadmaps keep coming October 2020: Portugal



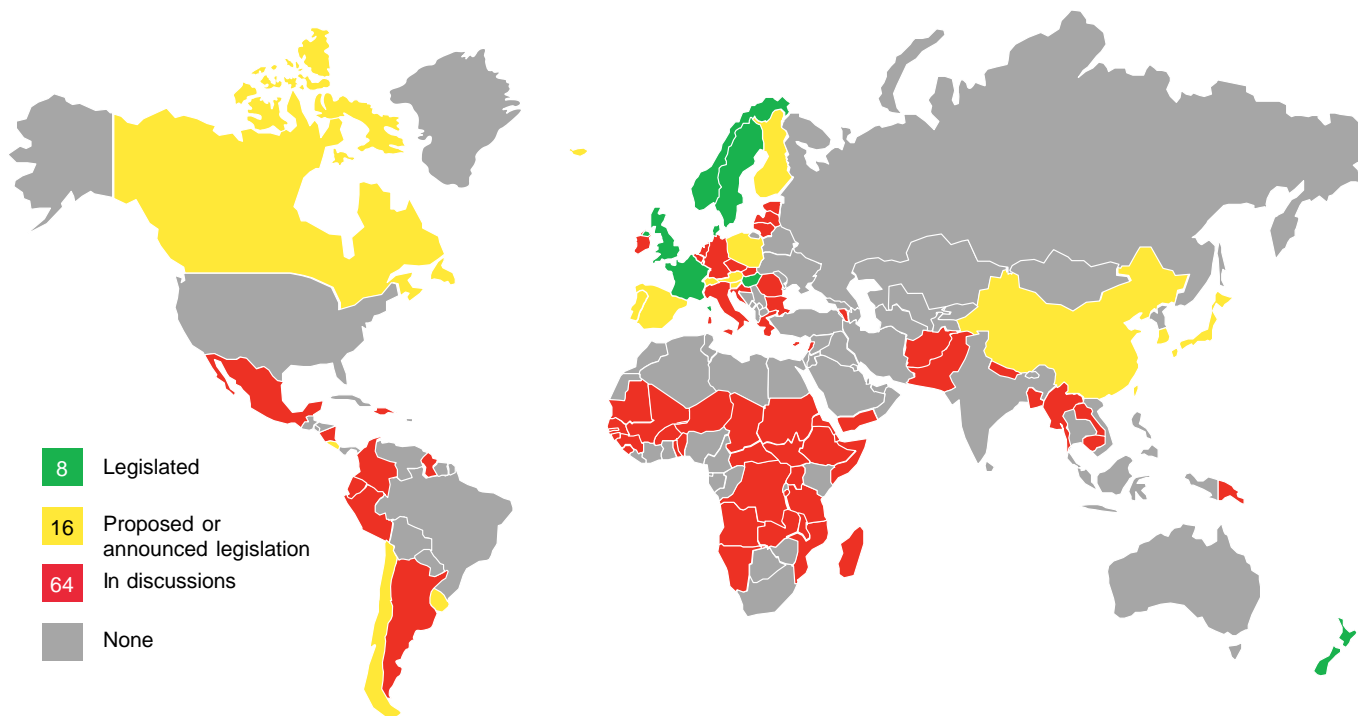
Source: Bloomberg

National hydrogen strategies as of November 6, 2020



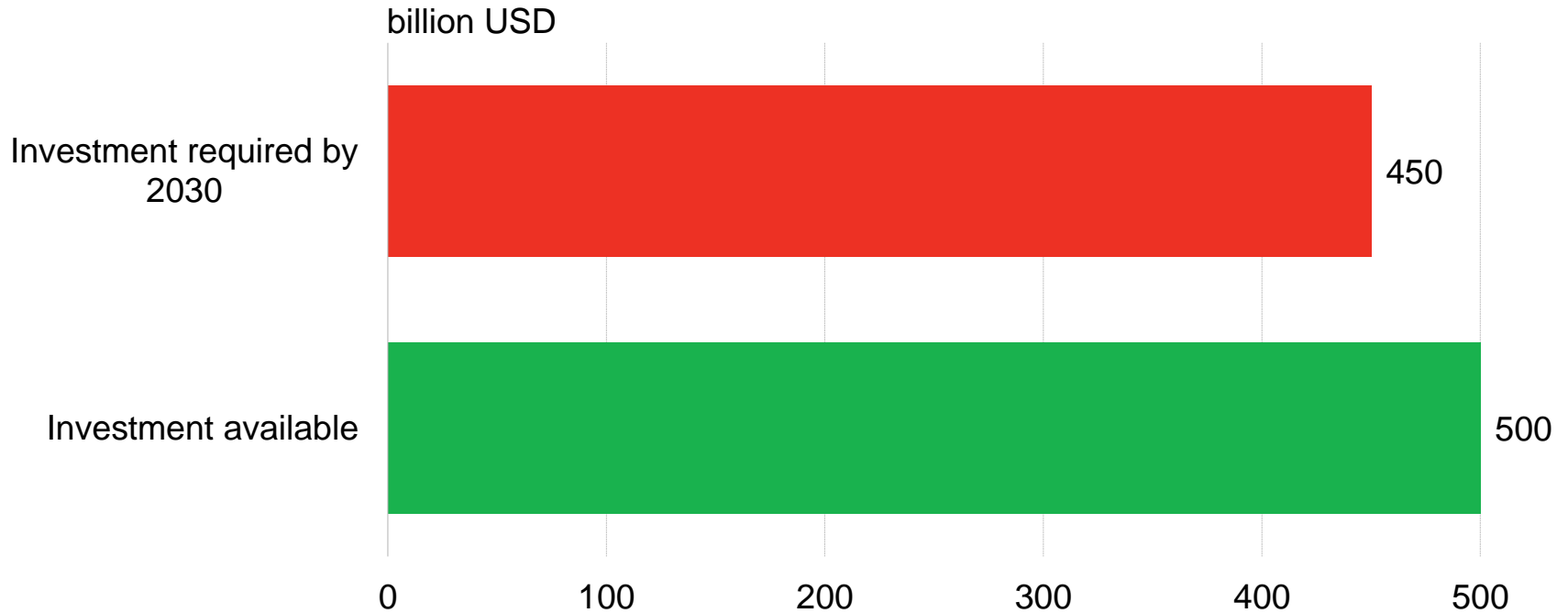
Source: World Energy Council, BloombergNEF

Countries with carbon neutrality targets as of November 2, 2020



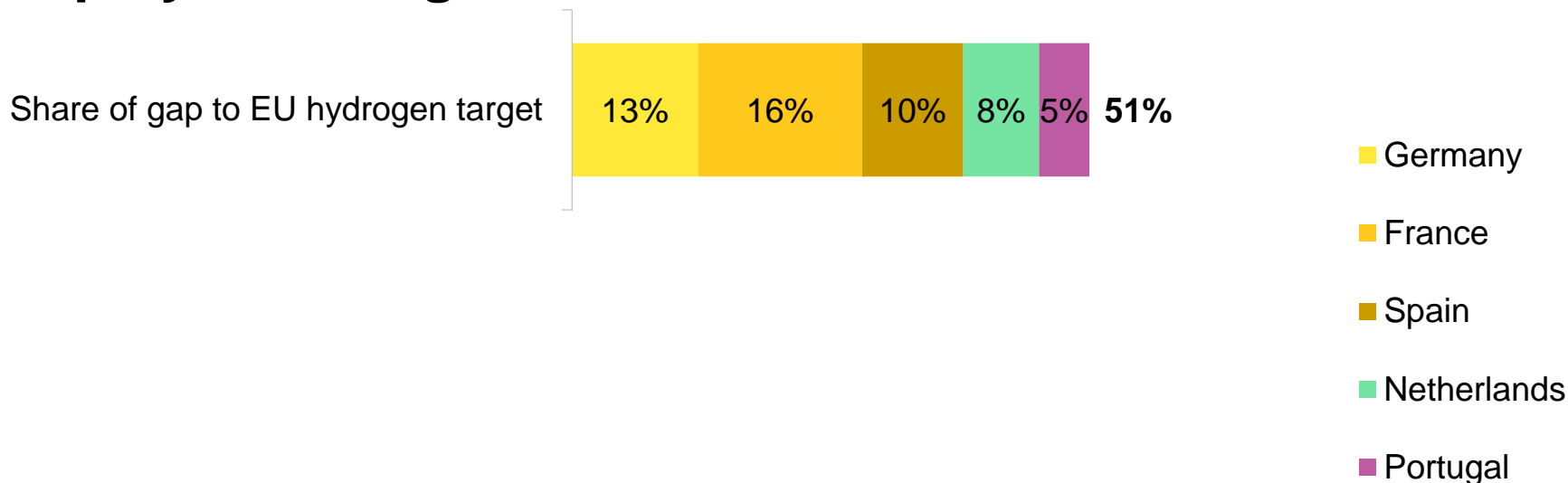
Source: BloombergNEF. Note: this map is only for illustration purpose and only shows national targets.

BNEF, November 2020: signs that hydrogen is scaling up have emerged



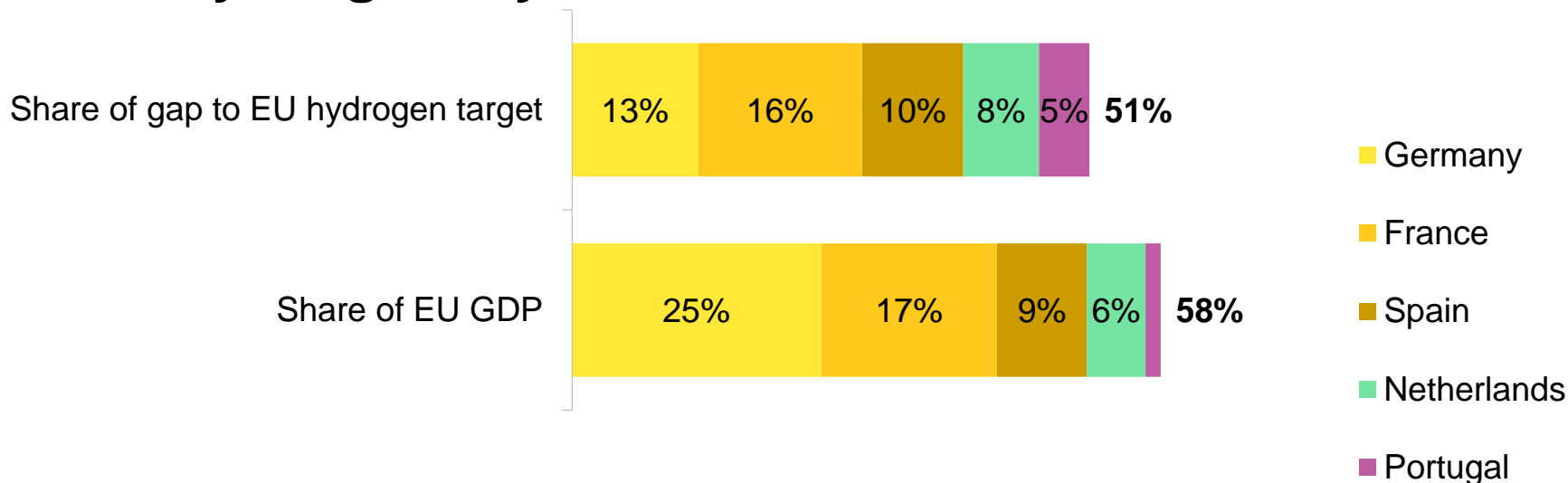
Source: BloombergNEF

EU member state electrolyzer deployment targets for 2030



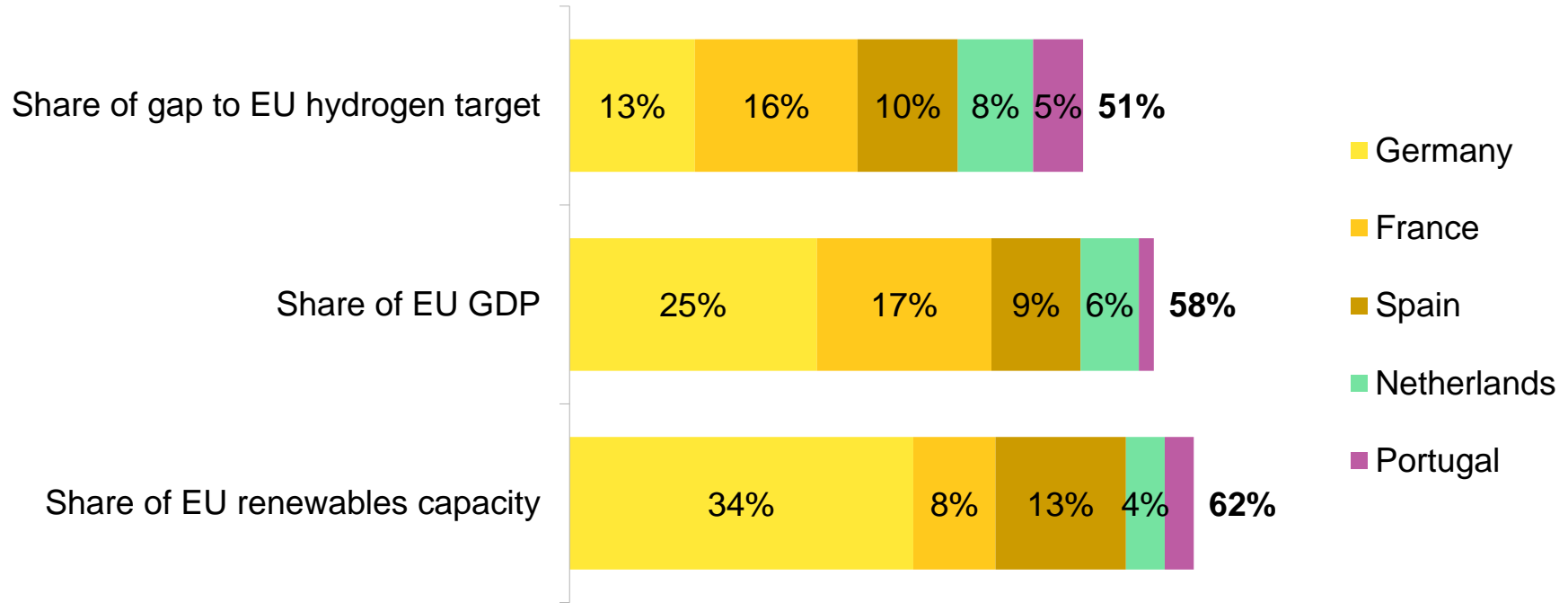
Source: BloombergNEF. Note: Portugal and Spain's targets are undergoing consultation. Lowest value used when target expressed as range. Gap to target as a share of EU's goal of 40 gigawatts of renewable electrolyzers by 2030. 2019 data used for GDP and renewables capacity.

EU not on track to meet 40GW electrolyzer goal by 2030



Source: BloombergNEF. Note: Portugal and Spain's targets are undergoing consultation. Lowest value used when target expressed as range. Gap to target as a share of EU's goal of 40 gigawatts of renewable electrolyzers by 2030. 2019 data used for GDP and renewables capacity.

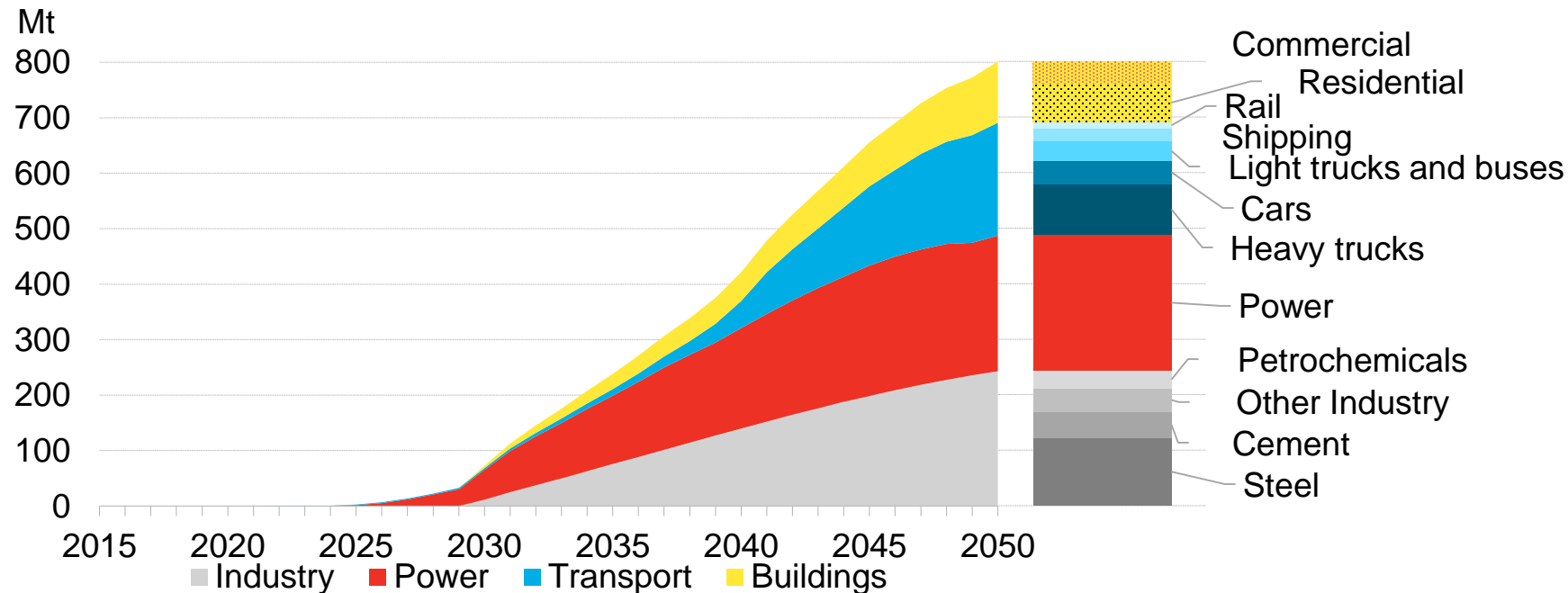
EU not on track to meet 40GW electrolyzer goal by 2030



Source: BloombergNEF. Note: Portugal and Spain's targets are undergoing consultation. Lowest value used when target expressed as range. Gap to target as a share of EU's goal of 40 gigawatts of renewable electrolyzers by 2030. 2019 data used for GDP and renewables capacity.

If we scale up production, green hydrogen demand could skyrocket

Hydrogen demand in the NEO Climate Scenario – Clean Electricity and Green Hydrogen Pathway



Source: BloombergNEF New Energy Outlook 2020

Seven signposts of scale-up

Event	Effect
1) Net-zero climate targets are legislated	Makes it clear that the hard-to-abate sectors will need to decarbonize
2) Standards governing hydrogen use are harmonized and regulatory barriers removed	Clears or minimizes obstructions to hydrogen projects
3) Targets with investment mechanisms are introduced	Provides a revenue stream for producers, increases competition, builds capacity and experience, and gives equipment manufacturers confidence to invest in plant
4) Stringent heavy transport emissions standards are set	Provides an incentive for manufactures to produce, and users to buy, fuel cell trucks and ammonia-powered ships
5) Mandates and markets for low-emission products are formed	Provides an incentive for manufacturers to produce low-emission goods (e.g. steel, cement, fertilizers, plastics) that will often require the use of hydrogen
6) Industrial decarbonization policies and incentives are put in place	Helps to coordinate infrastructure investment and scale efficient use of hydrogen. Provides incentives for hydrogen use
7) Hydrogen-ready equipment becomes commonplace	Enables and reduces the cost of fuel switching to hydrogen

Source: BloombergNEF

The European Union could set the rules
of the game for decades to come

Source: Bloomberg

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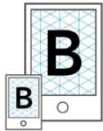
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