



CEM12/MI-6
CHILE 2021

Energy Transition Factbook

Prepared for the 12th Clean Energy Ministerial
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Bloomberg
Philanthropies

BloombergNEF

 **CLEAN ENERGY**
MINISTERIAL
Advancing Clean Energy Together

Cover letter

Your Excellencies:

The Clean Energy Ministerial has a critical role to play in driving the transition to clean energy, and we're glad to share this factbook with you on the latest and most promising changes in the energy sector.

At Bloomberg L.P. and Bloomberg Philanthropies, we often say, "If you can't measure it, you can't manage it." Data informs every decision we make – and drawing on detailed and accurate data is particularly important with an issue as complex as climate change, which has implications for countries and businesses in every part of the world. Taking on climate change and driving down emissions will require action from every sector, but the energy sector has the potential to make especially meaningful progress. And data is key to charting the path forward.

This factbook identifies some key trends that can help to accelerate the global transition to clean energy. For example: Wind, solar, and other low-carbon technologies have gotten far more efficient and far less expensive over the last decade. Today, two-thirds of the global population now live in places where wind or solar are the cheapest options for new power – representing 71% of global GDP and 85% of global power generation. This dramatic shift is good news for our health and our planet, and it foreshadows even more progress ahead.

In addition to highlighting important technological developments, this factbook shares the progress being made toward major policy commitments that support the fight against climate change. A growing number of nations and companies have committed to reaching net-zero emissions, and more than half of global emissions are now covered by some form of net-zero target by 2050 or 2060. Reaching these targets will require seismic changes in the energy sector – and the faster we act now, the better off we will be.

Climate change is an enormous challenge, and obstacles to clean energy remain. But we hope this factbook will help policymakers and other leaders accelerate the transition to a 100 percent clean energy economy. It could not be more important.

Thank you for your work, and all the best,



Michael R. Bloomberg

Founder, Bloomberg L.P.

Founder, Bloomberg Philanthropies

UN Secretary-General's Special Envoy for Climate Ambition and Solutions



Introduction: Energy Transition in 2020

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Power sector: renewables, integration, storage, grids

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Transport: electrification, heavy-duty transport

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Industry: Decarbonizing hard-to-abate sectors, hydrogen

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Finance: Asset investment, green bonds, ESG

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More than half of all global emissions are now covered by a form of net-zero target

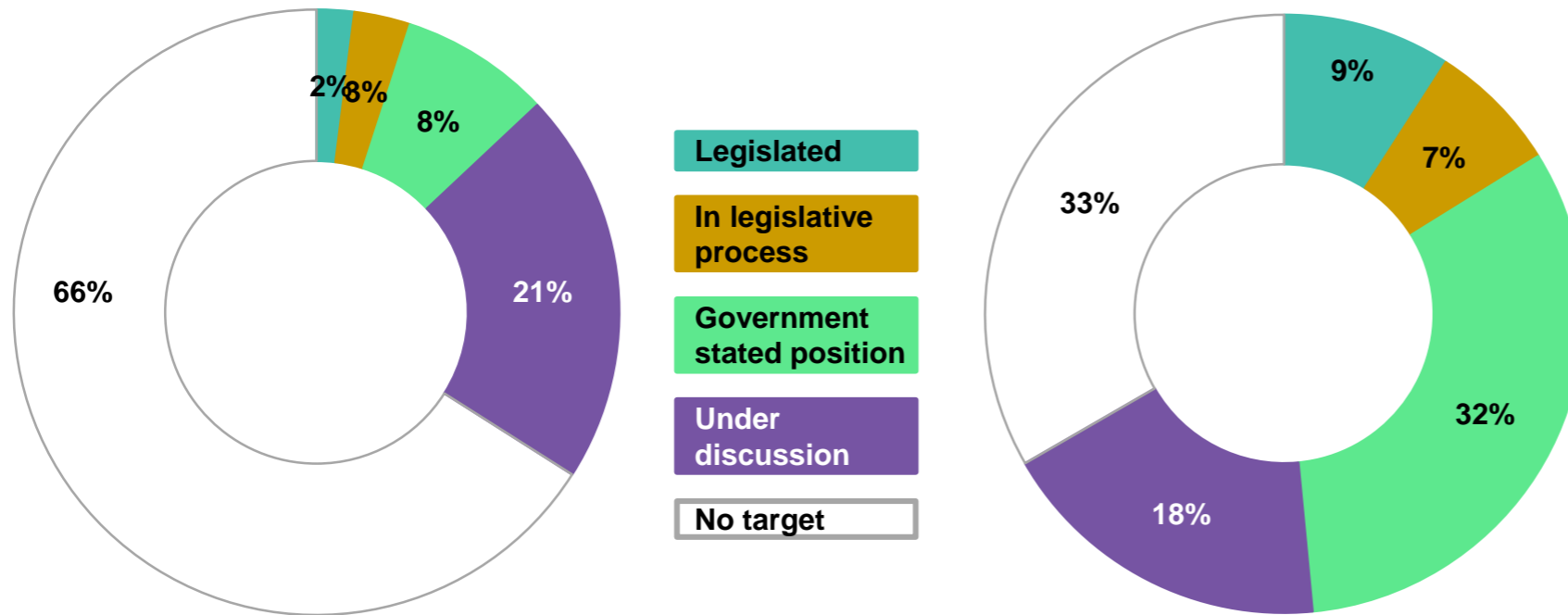


January 2020

34% with at least a net-zero discussion

May 2021

66% with at least a net-zero discussion



At the beginning of 2020, one-third of global emissions were covered by some form of net-zero target

Most of that total was only ‘under discussion’ – having been raised by governments as a policy target.

By May 2021, more than half of global emissions were covered

Not only did more governments increase their commitments, a number also firmed their commitments from under discussion, to in legislative process or legislated.

China, the EU, Japan and South Korea are all part of the ‘net-zero club’

However, these bold ambitions are still lacking in policy specifics in many cases.

The U.S. is re-establishing itself in climate negotiations

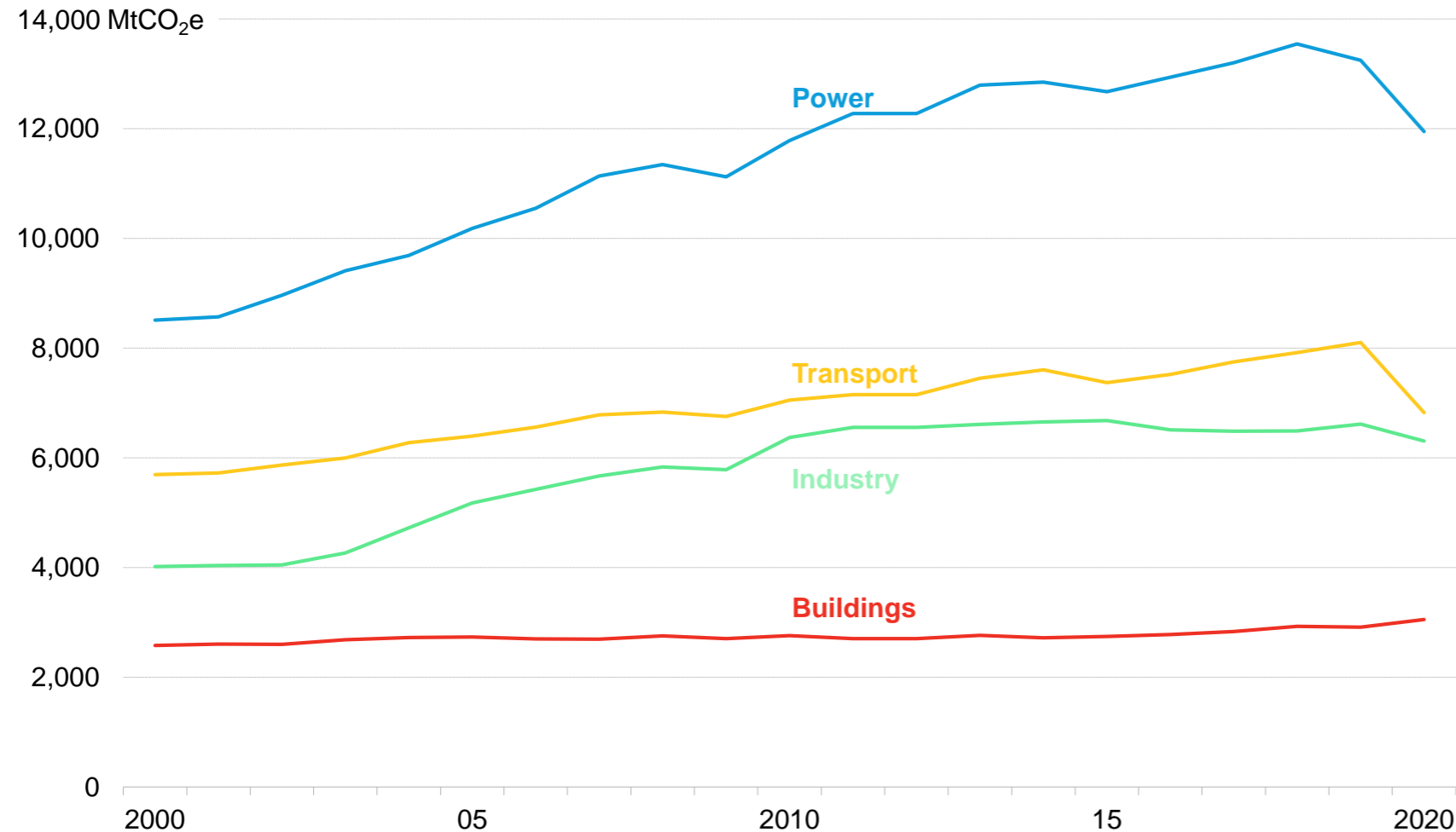
However, a significant level of concrete policy support will be required – and soon – in order to achieve any net-zero pledge.

Source: BloombergNEF. Note: “Under discussion” stage occurs when governments have begun concrete official discussions to implement a target.

Global power sector emissions peaked in 2018



Total emissions by sector



Power sector emissions peaked in 2018

Decarbonization of the world's power fleet, through renewables as well as a shift from coal to gas, means that emissions from power generation peaked in 2018.

Covid-19 accelerated power emissions' trend, but did not change it

Emissions fell sharply in 2020, but are expected to decline by 2% per year until 2050.

Power sector emissions will decline significantly as a percentage of total emissions.

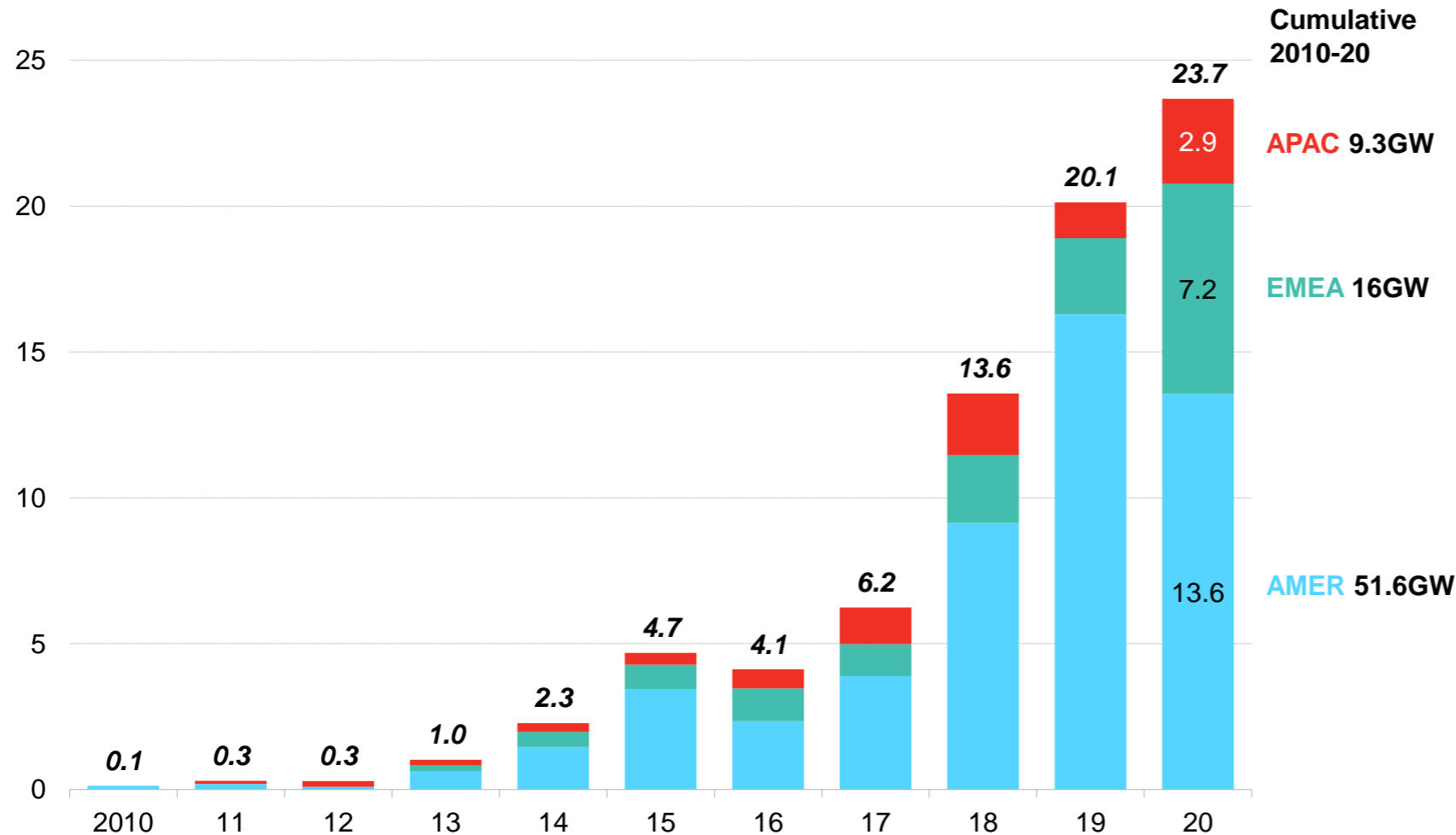
Power emissions are the largest sector of emissions from fuel combustion, at 42% today. By 2050, they are likely to be 27% of total emissions from fuel combustion.

Source: BloombergNEF New Energy Outlook 2020

Corporate renewable power purchase agreements grew 18% in 2020 despite the pandemic



Global corporate renewable power purchase agreements



Corporate renewable power purchases increased 18% in 2020

The growth comes despite Covid-19 interrupting corporate functions, and plummeting revenues in some sectors.

The U.S. was the largest market, though less dominant than in years past

U.S. companies announced 11.9 gigawatts of corporate PPAs, down from 14.1GW in 2019 and the first year-on-year decline since 2016.

The Asia Pacific region and Europe both set annual records for PPA volumes

Asian corporate PPA volumes more than doubled, and European volumes nearly tripled.

Amazon was the most active company

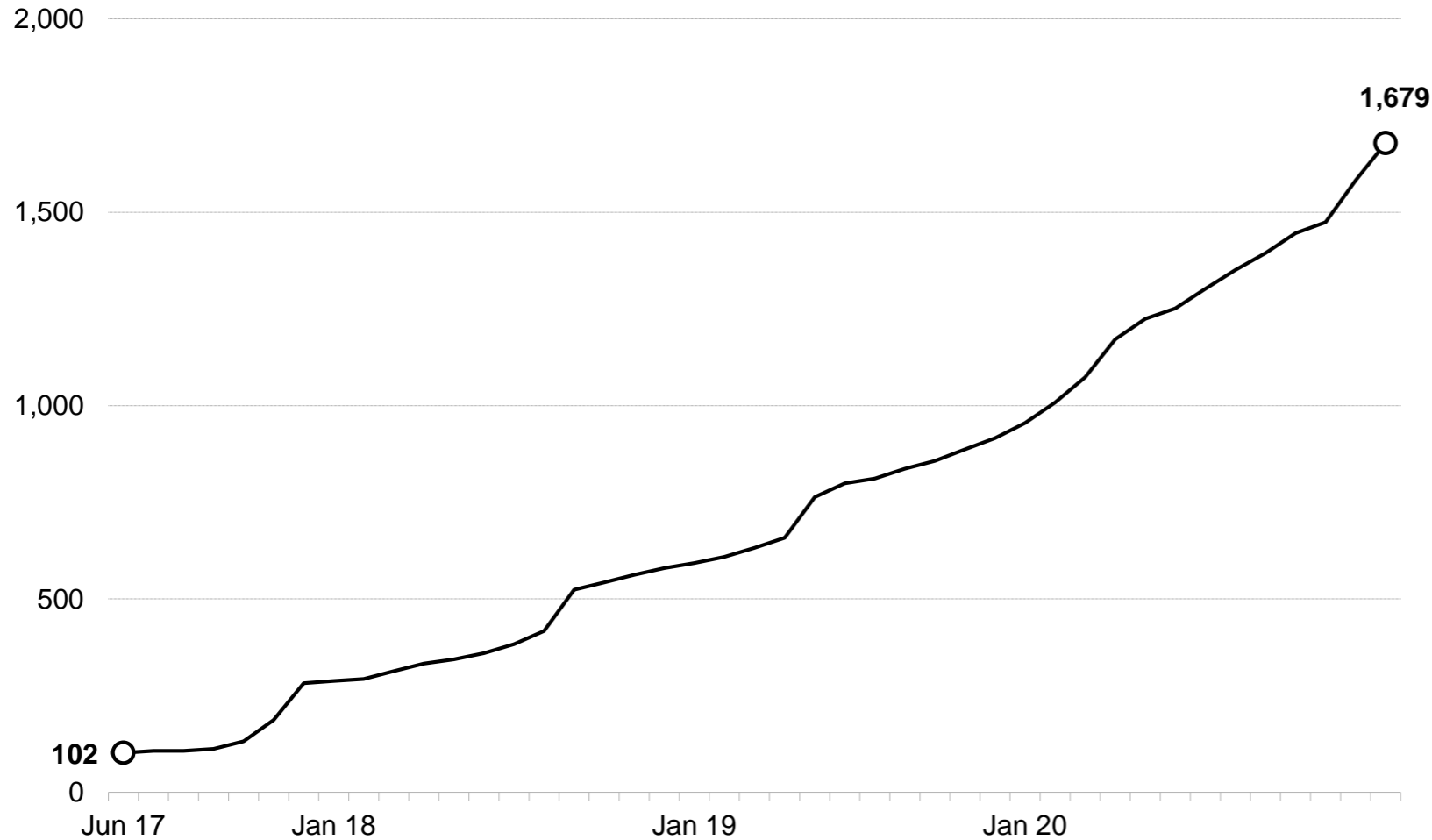
The company signed 35 PPAs totaling 5.1GW of capacity. Semiconductor manufacturer TSMC, oil supermajor Total SE, U.S. telecoms company Verizon, and Facebook rounded out the top five in capacity signed.

Source: BloombergNEF [link](#)

Financial markets are making significant climate- and carbon-related commitments



Supporting companies



\$12.6 trillion

TCFD supporting company market cap

\$150 trillion

TCFD supporting financial institution assets under management



HM Treasury

The UK will become the first country in the world to make Task Force on Climate-related Financial Disclosures (TCFD) aligned disclosures fully mandatory across the economy by 2025, going beyond the 'comply or explain' approach.

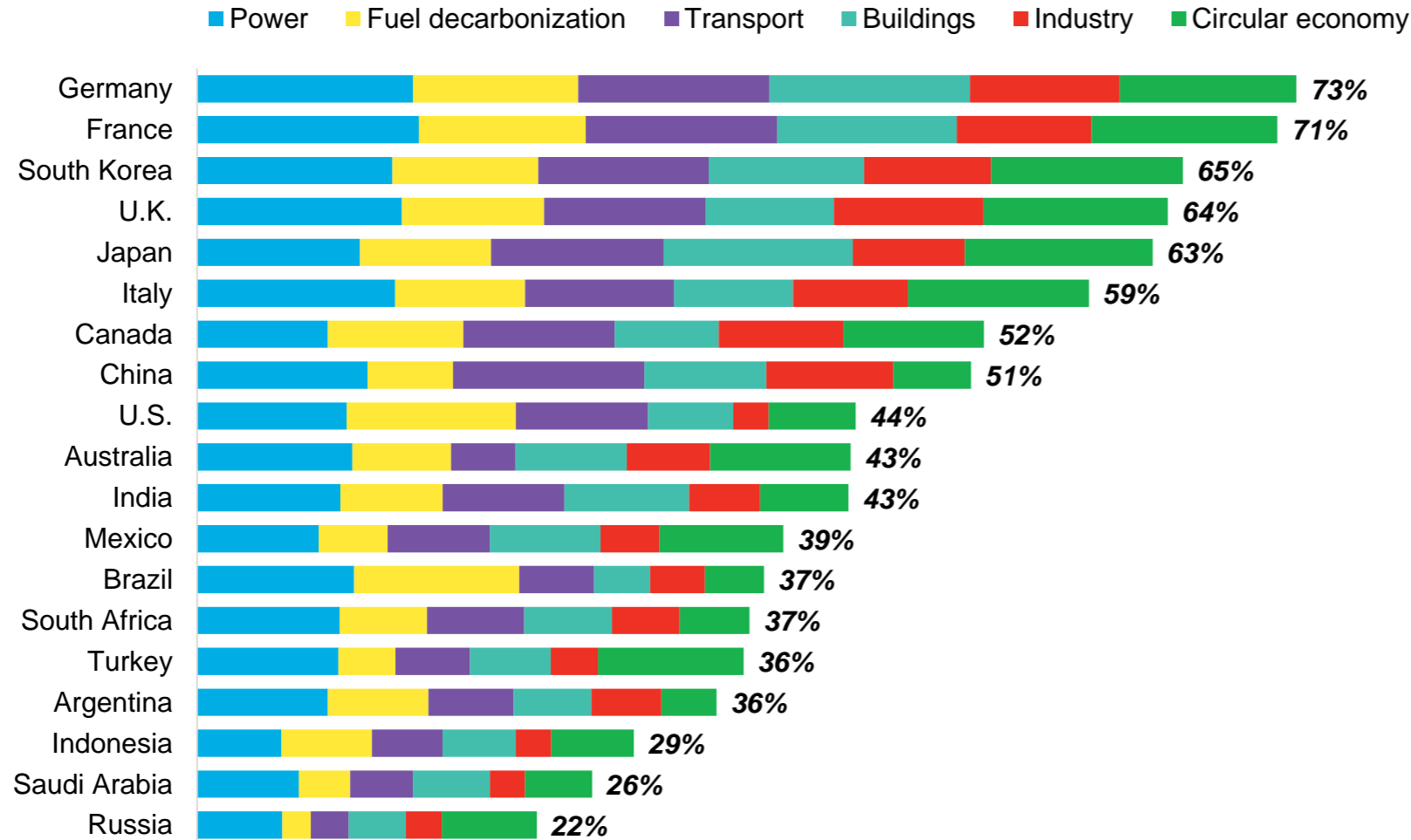
November 9, 2020

Source: TCFD

G20 Countries' climate policies are not aligned with the pledges of the Paris Agreement



2021 G20 policy scoreboard – results by sector



The world's largest economies are far from the right policy plans to meet the Paris Agreement

BNEF's G20 Zero-Carbon Policy Scoreboard evaluates the G20 countries' decarbonization policies to measure which governments have implemented regimes to realize the goals of the Paris Agreement.

Much of the progress in cutting the rate of growth of CO₂ to date has come in the power sector

However, most countries have done little elsewhere in the economy – and even within the power sector, multiple pathways are needed.

The nations at the top have executed a higher number of robust, concrete measures

These countries have introduced policies to drive change on both the supply and demand side. Their policy-making processes are relatively transparent and predictable, and their initiatives are starting to have a measurable impact.

Source: BloombergNEF [link](#). Note: maximum score is 100%.



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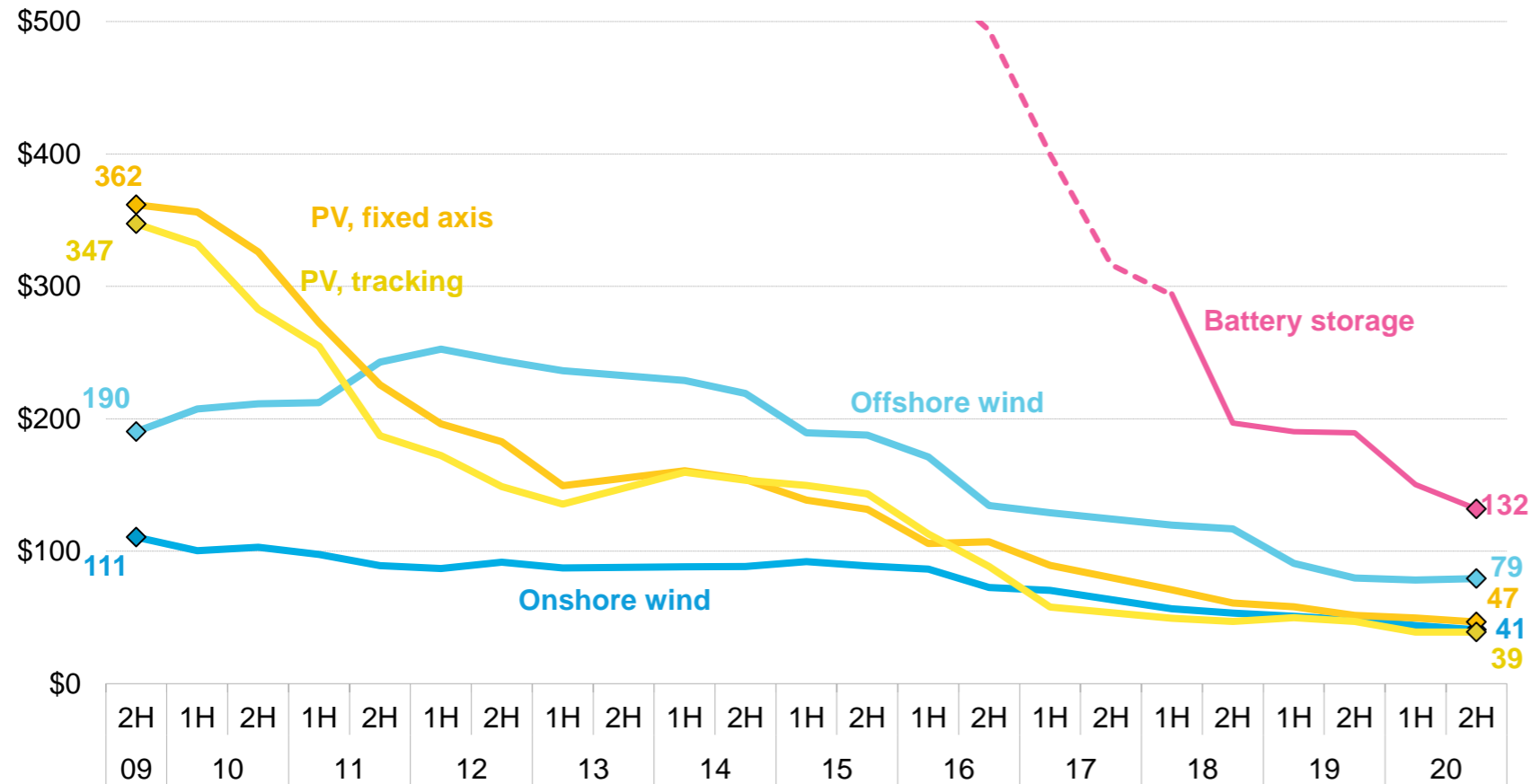
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Wind and solar generation costs have converged, and compete with (or outcompete) fossil fuel generation



Global levelized cost of energy benchmarks

LCOE (\$/MWh, 2019 real)



The benchmark cost of electricity generation from onshore wind and solar PV have converged

The cost for both is in the range of \$40 per megawatt-hour.

Offshore wind costs remain higher than onshore wind or PV, but offshore wind has operational advantages

Offshore wind has much higher capacity factor than either onshore wind or photovoltaic applications and is competitive with fossil fuel-fired power in many markets.

The cost of storage using lithium-ion batteries is on a steep downward trajectory

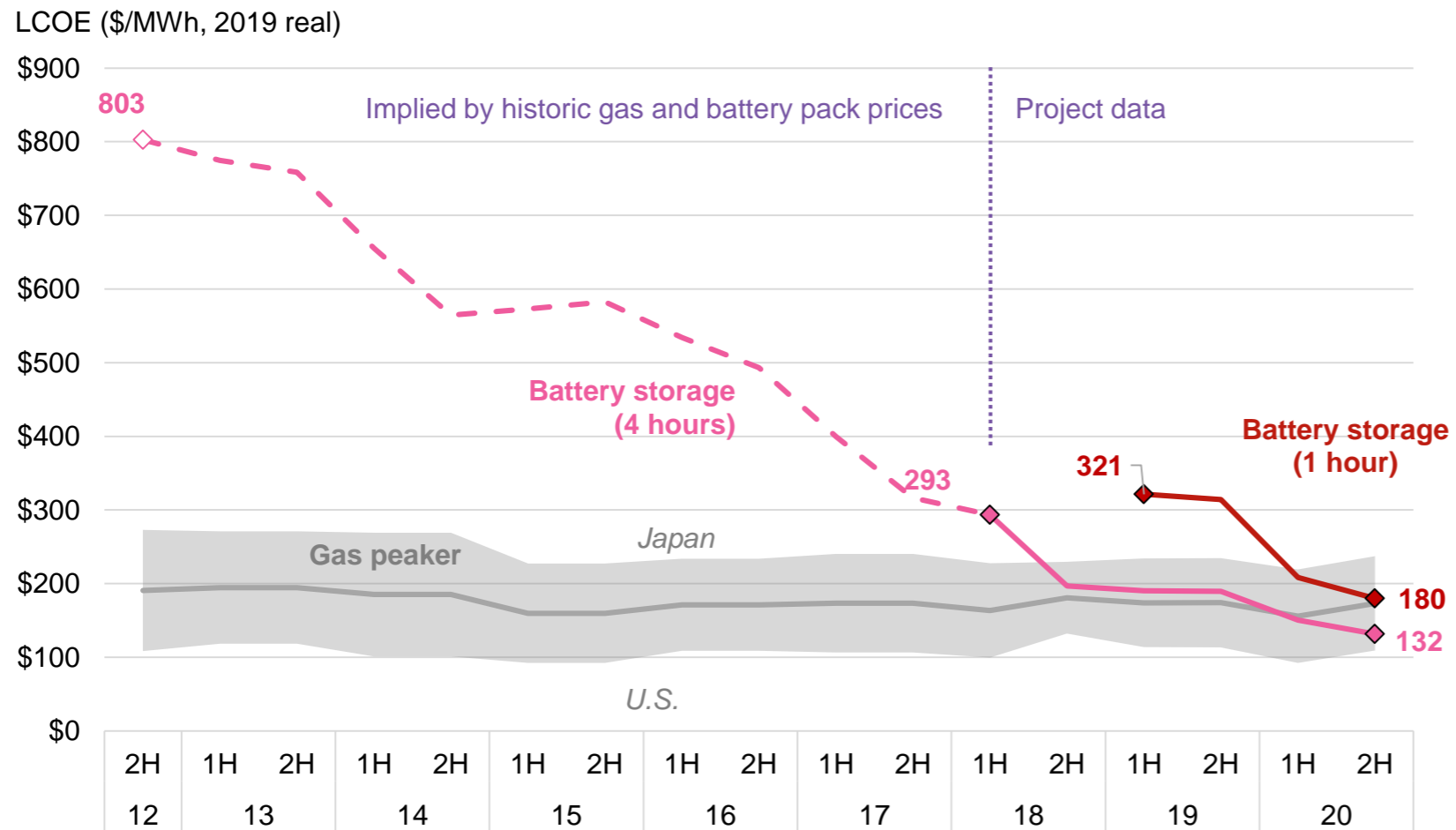
Current costs of \$132 per megawatt-hour mean that the levelized cost of energy from lithium-ion battery storage systems is competitive with many peak-demand generators.

Source: BloombergNEF

Power from battery storage systems is now competitive with open-cycle gas turbines



Global benchmark utility-scale battery storage and open-cycle gas turbine levelized cost



Four-hour duration battery storage today can compete on cost with gas-fired peaking power in some markets

In markets where natural gas is imported, such as Japan or Europe, both one-hour and four-hour storage applications compete with the cost of gas-fired peaker plants.

The levelized cost for battery storage in the first half of 2020 is \$132 per megawatt-hour

That cost is inclusive of the cost of charging batteries before discharging.

Upfront costs are the largest determinant of the levelized cost of storage

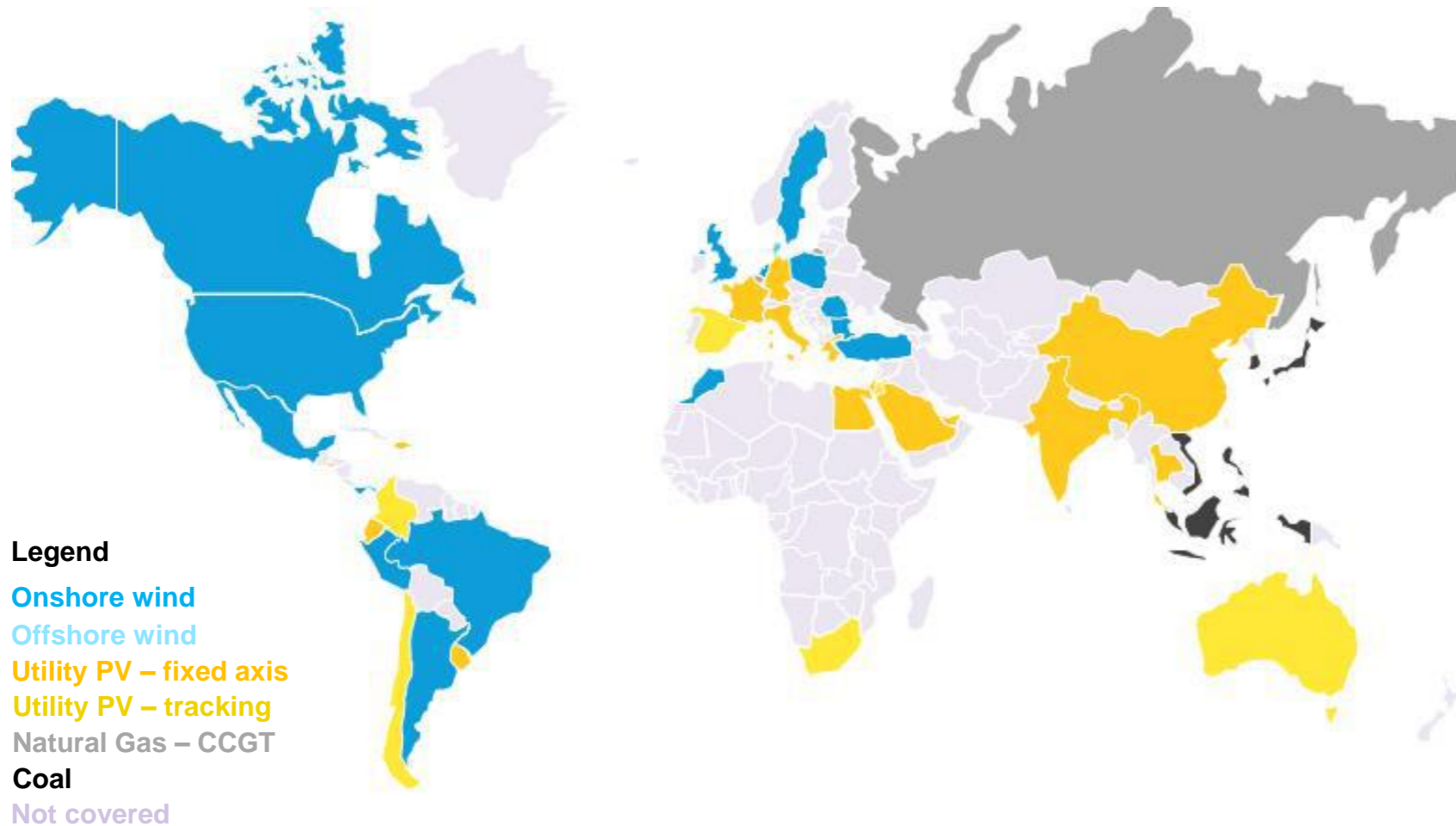
System financing costs, and the cost of charging systems, are secondary considerations.

Source: BloombergNEF

Wind and solar power are the lowest-cost new source of power for 2/3 of the global population



Lowest-cost source of new bulk power generation by technology, 2H 2020



Two-thirds of the global population lives where renewables are the cheapest new power generation option

BloombergNEF estimates that two-thirds of the global population lives in a country where either onshore wind or utility-scale PV, if not both, is the cheapest option for new bulk generation.

Renewables are the cheapest power option for 71% of global GDP and 85% of global power generation

It is now cheaper to build a new solar or wind farm to meet rising electricity demand or replace a retiring generator, than it is to build a new fossil fuel-fired power plant.

Power plant developers can make a clear economic choice for renewables

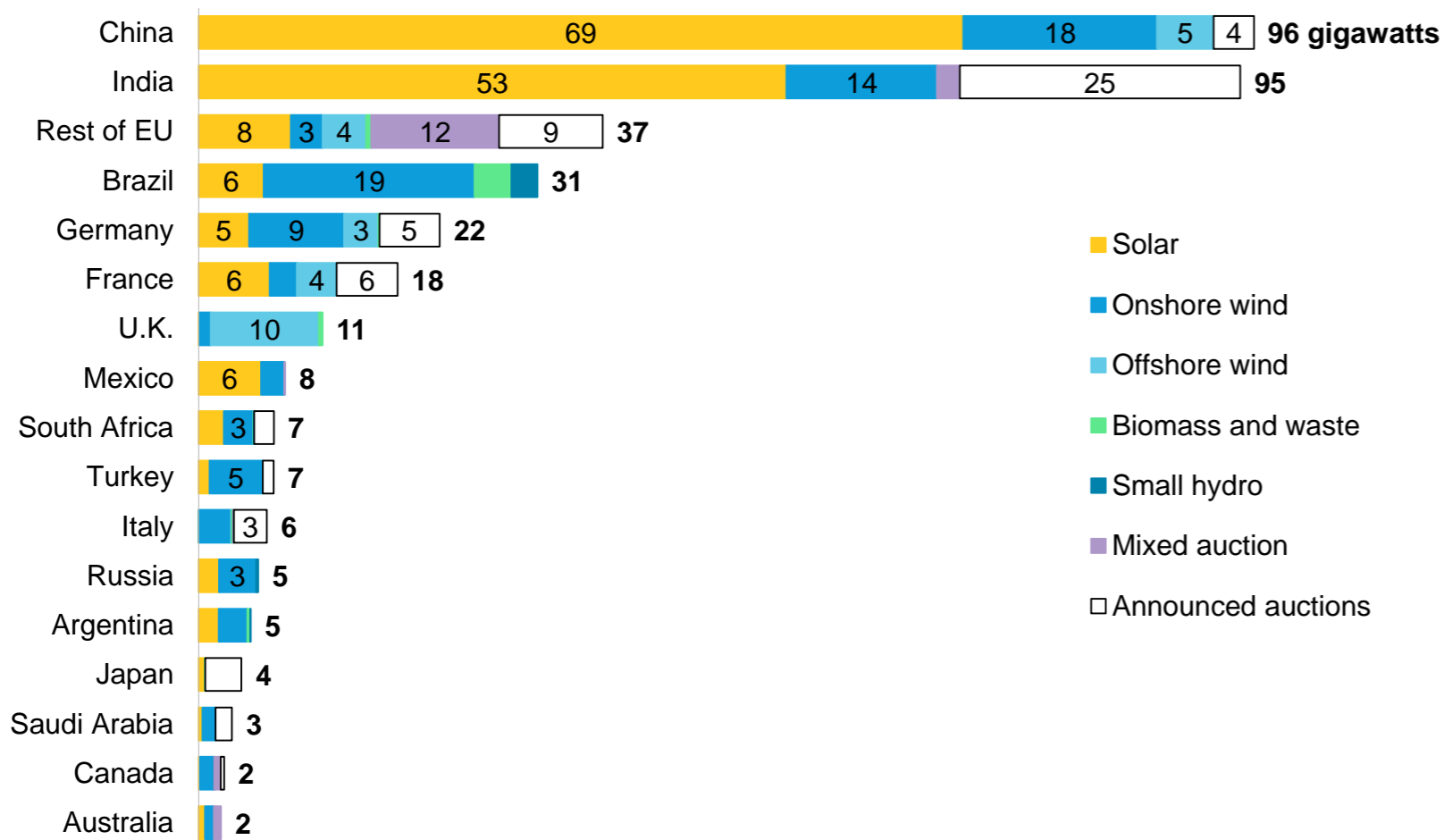
On a cost basis, wind and solar is the best economic choice in markets where firm generation resources exist and demand is growing.

Source: BloombergNEF

G20 countries have awarded more than 350 gigawatts of renewable capacity via auctions



G20 renewable energy auctions, awarded and announced



Renewable energy auctions are the policy mechanism of choice for 14 members of the G20

Auctions allow governments to better control their spending and to competitive allocate capacity.

Competitive allocation is a key attribute of auctions

Where other support mechanisms such as feed-in tariffs award all projects that meet eligibility criteria, auctions give countries control of both winning bid conditions and capacity to be built.

In many countries, auctions are the primary route to market for utility-scale projects

China and India, in particular, have successfully used auctions to attract developers and investors with a high level of competition and low prices.

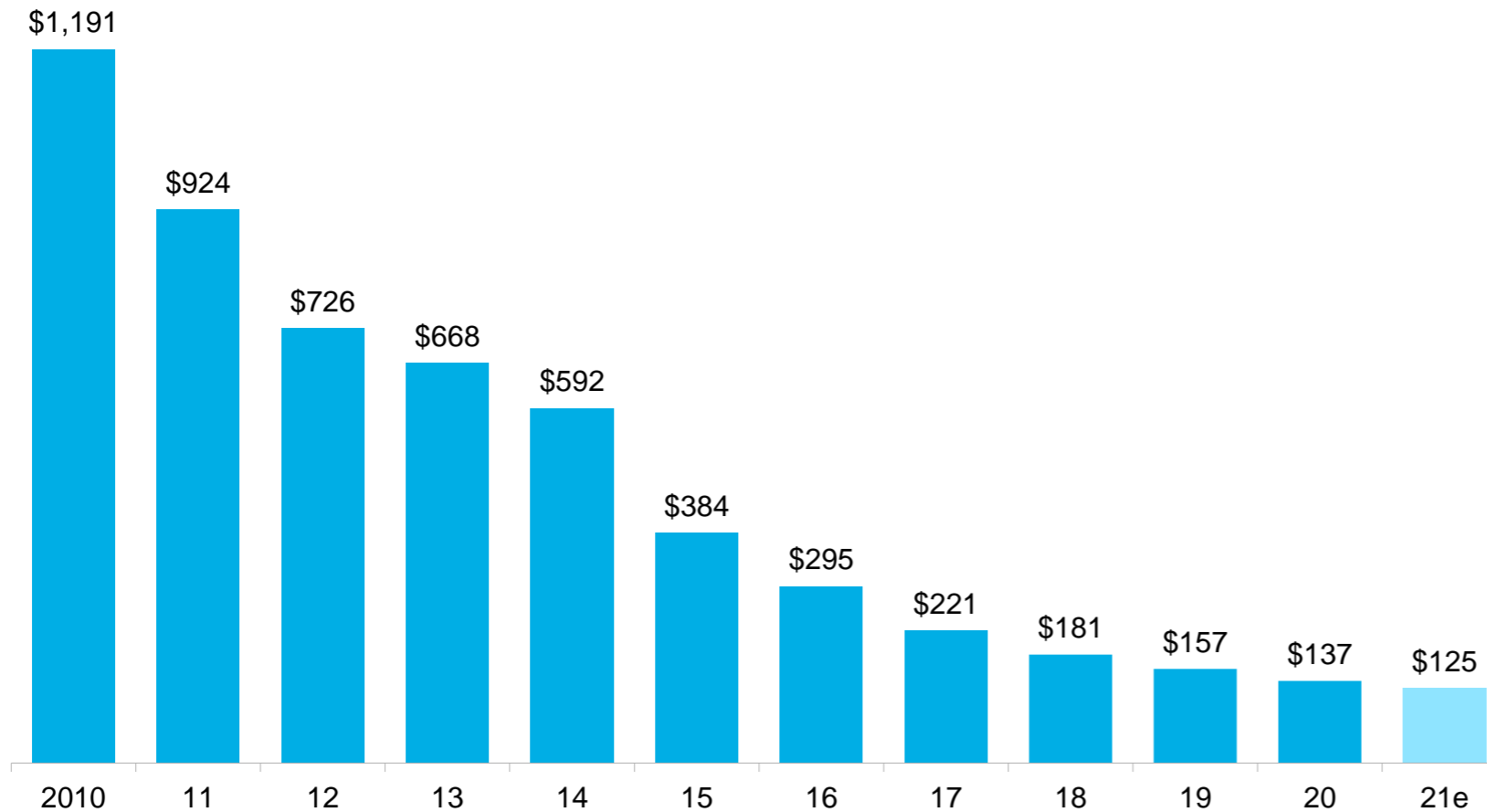
Source: BloombergNEF

Lithium-ion battery costs fell 89% from 2010 to 2020



Lithium-ion battery price survey results (volume-weighted average)

Battery pack price (real 2020 \$/kWh)



Lithium-ion battery pack prices fell 89% from 2010 to 2020

BloombergNEF surveys battery buyers and sellers to determine the volume-weighted average price for lithium-ion battery packs, modules, and cells.

The lithium-ion battery learning rate is 18%

For every doubling of cumulative production, the fundamental cost of manufacturing lithium-ion storage batteries declines by 18%.

BloombergNEF expects lithium-ion storage battery costs to continue to fall

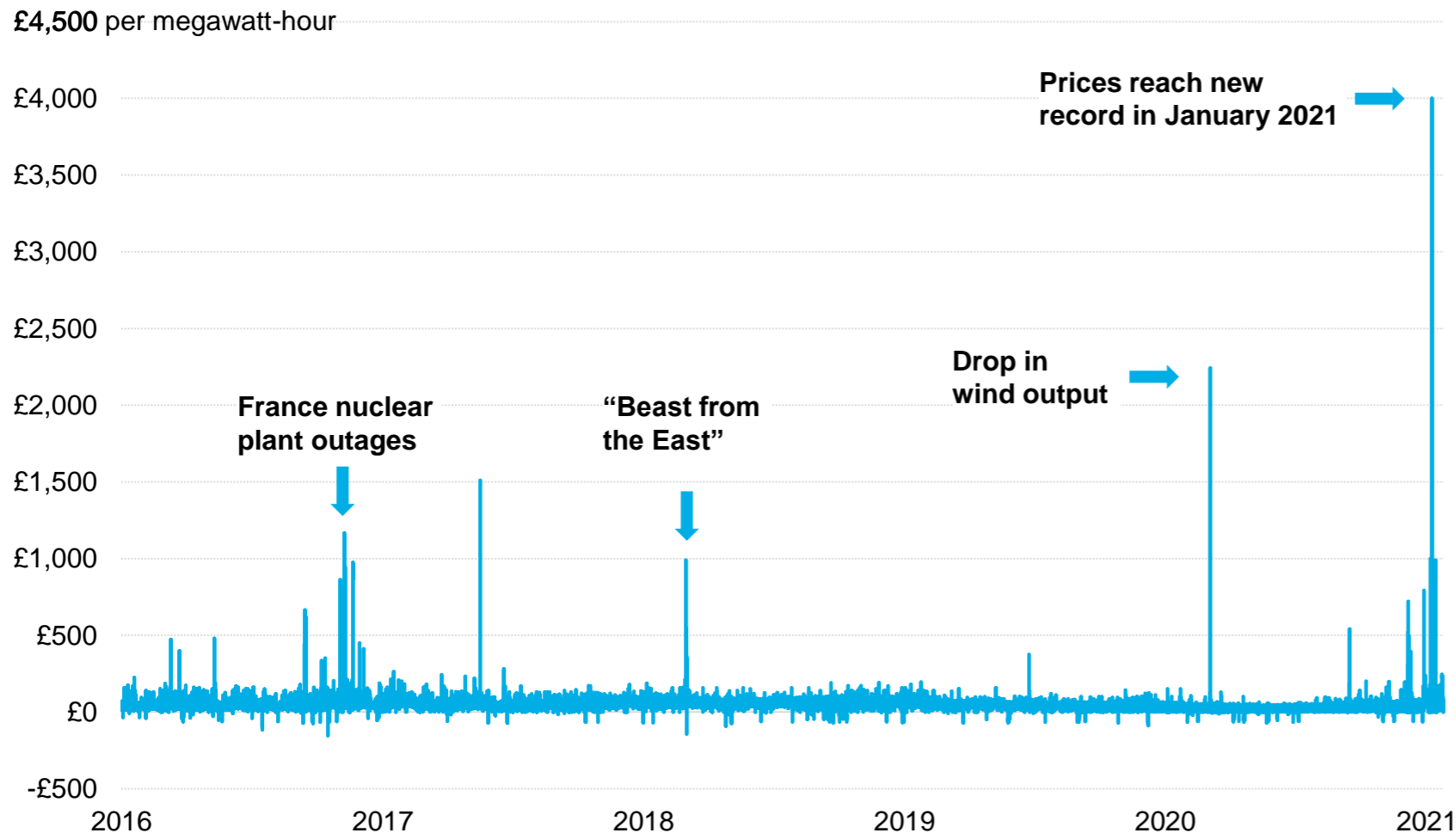
Changes to cell chemistry have been important drivers of price declines, new manufacturing techniques will become more important to maintain downward pressure on prices. We expect prices to be close to \$100/kWh by 2023.

Source: BloombergNEF

UK power prices spiked to record levels in early 2021, as plant outages, cold, and commodity prices hit



Half-hourly British imbalance price



European power markets are experiencing a period of unusually high volatility

Power prices have swung from record lows in March-June 2020, to record high prices in January 2021. Daily price volatility has increased as well.

Commodity prices play a role

The simultaneous increase in gas, coal and carbon prices should lead to a proportional increase in power prices. However, power prices have at times exceeded what could normally be explained by the swing in commodity prices.

Unseasonably high outages are the main reason for the U.K.’s record prices.

An unexpected outage in the interconnector to The Netherlands removed one gigawatt of capacity until at least early February.

Covid-19 contributed to outages

Maintenance has been challenging, due to reduced staffing and social distancing.

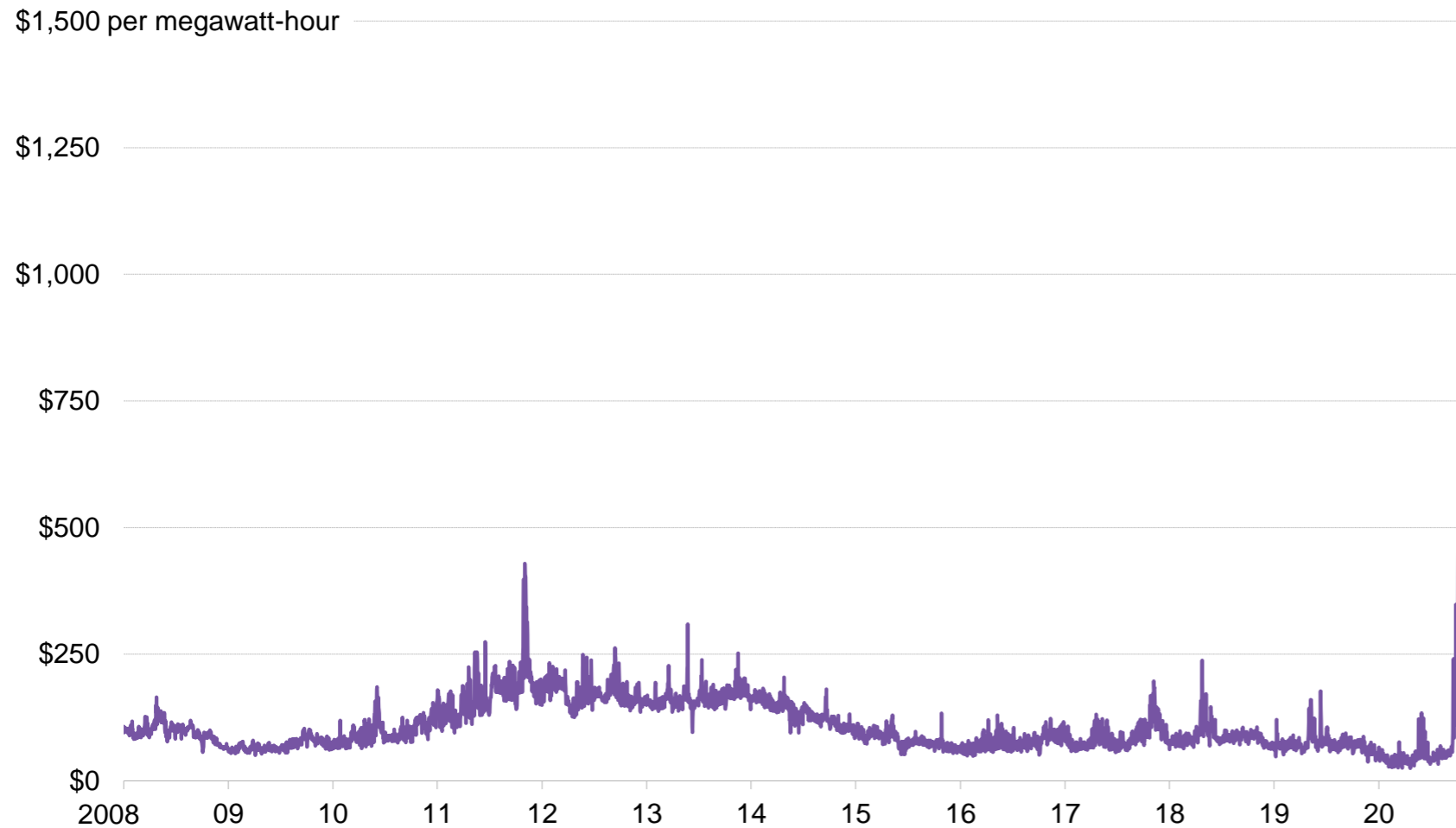
Source: Elexon, BloombergNEF.

Note: The ‘Beast from the East’ was a spell of cold weather in February-March 2018, when European gas markets were very tight.

Japan's power price reached an all-time high in January 2021



Japan system power prices



Japan's wholesale power price hit an all-time high in January 2021

Prices spiked to nearly \$1,500 per megawatt-hour, more than three times the previous record price in 2011.

A shortage of LNG led to the price spike

Spot liquefied natural gas prices also hit a record high price in January 2021 with demand in North Asia very high due to cold weather and in Japan, lower availability of nuclear power.

The price spike highlights Japan's dependence on imported fuels

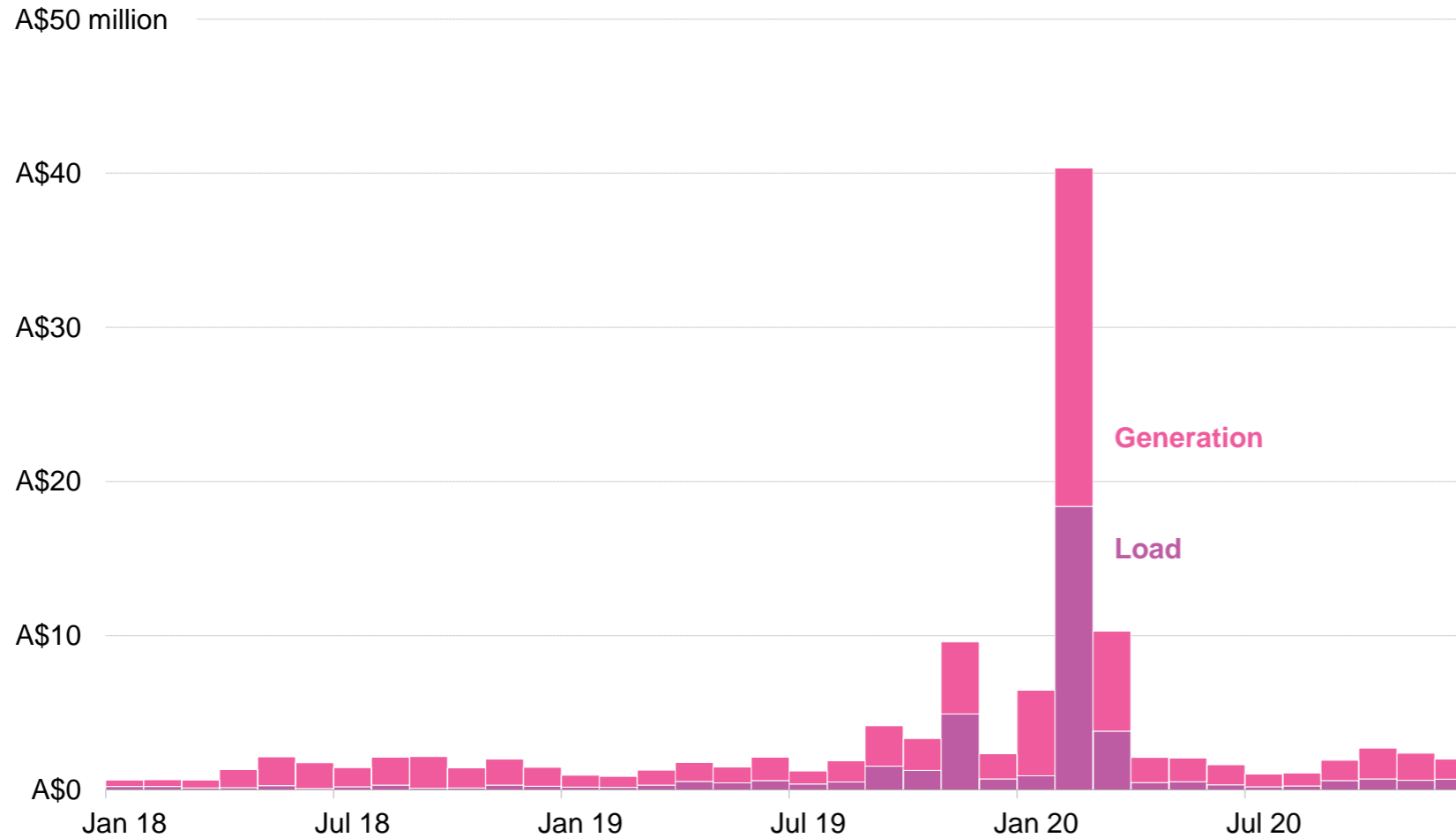
Japan's power generators and fuels importers are likely to ramp up spot LNG purchases when prices have declined.

Source: Japan Electric Power Exchange

Keeping the lights on is a lucrative business for Australia battery systems



Australia battery revenue from frequency control and ancillary services



Australia battery operators doubled their annual revenue in 2020

Operators had A\$83 million in revenue from frequency control and ancillary services in 2020.

Climate change has increased the risk of disruptive weather events

Risk of disruption has increased the value of grid balancing via the services which batteries provide.

Half of 2020's revenue came during one windfall month

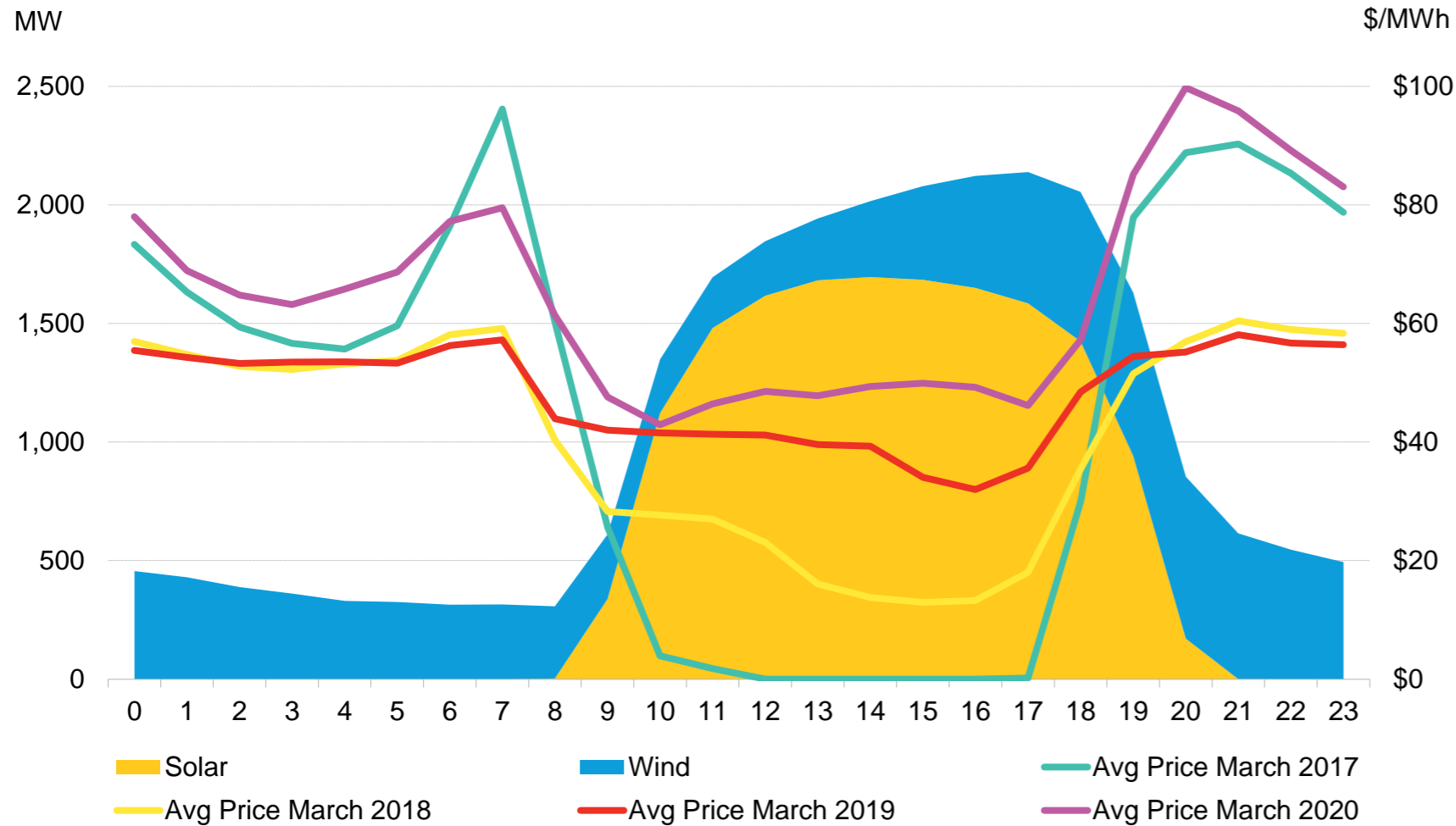
In February, the South Australia temporarily separated from the rest of the country's grid, meaning that demand for grid balancing skyrocketed. Revenue for the state's three large batteries equaled 17-33% of their initial capital costs.

Source: BloombergNEF

Integrating renewable energy is an ongoing concern in high-penetration markets like Chile



Average wind and solar hourly generation and daily average power price, Diego de Almagro



Wind and solar generation has grown from near-zero in 2013 to meeting 15% of Chile's power demand in 2020

Chile's wind and solar fleet generated well over one terawatt-hour of power in 2020.

Infrastructure upgrades have been essential to integrating renewables

Chile has completed a number of major transmission upgrades, integrated its two main power grids, and introduced a flexibility strategy as well.

These upgrades have dramatically reduced curtailment, and kept power prices from falling to zero

Average curtailment in 2020 stayed below 2%, and power prices stayed about \$40 per megawatt-hour even during peak generation.

Source: CNE, Coordinador Electrico Nacional, BloombergNEF. Note: Node is Diego de Almagro.

China's electricity spot market trial is leading to depressed midday power prices



Shandong province net load and real-time prices, Oct. 22, 2020



The electricity spot market in China's biggest solar province has depressed midday prices

Shandong province is trialing a spot market, which has resulted in morning and evening shoulder prices which are seven times higher than midday, when solar generation peaks.

Officials have changed the regulated time-of-use tariff as a result

Shandong has used small-scale spot trials to inform tariff changes. Prices have been lowered around noon, and increased after 2:30pm, benefiting a large group of commercial and industrial consumers.

Liberalization is impacting China's market in various ways

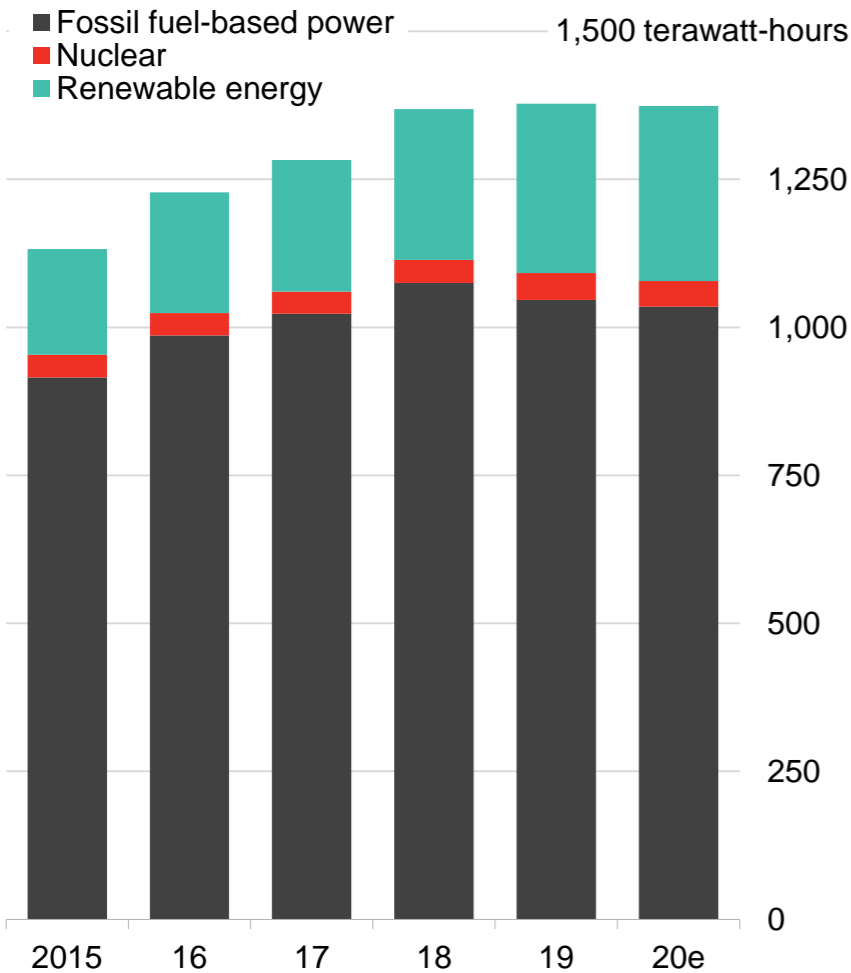
Prices for 39% of China's power demand in 2019 were determined by various markets, rather than government planning, with lower prices usually the result. A majority of price deregulation is in coal power, but renewables are also seeing market exposure in at least 20 of 31 provinces.

Source: Shandong power exchange, news media

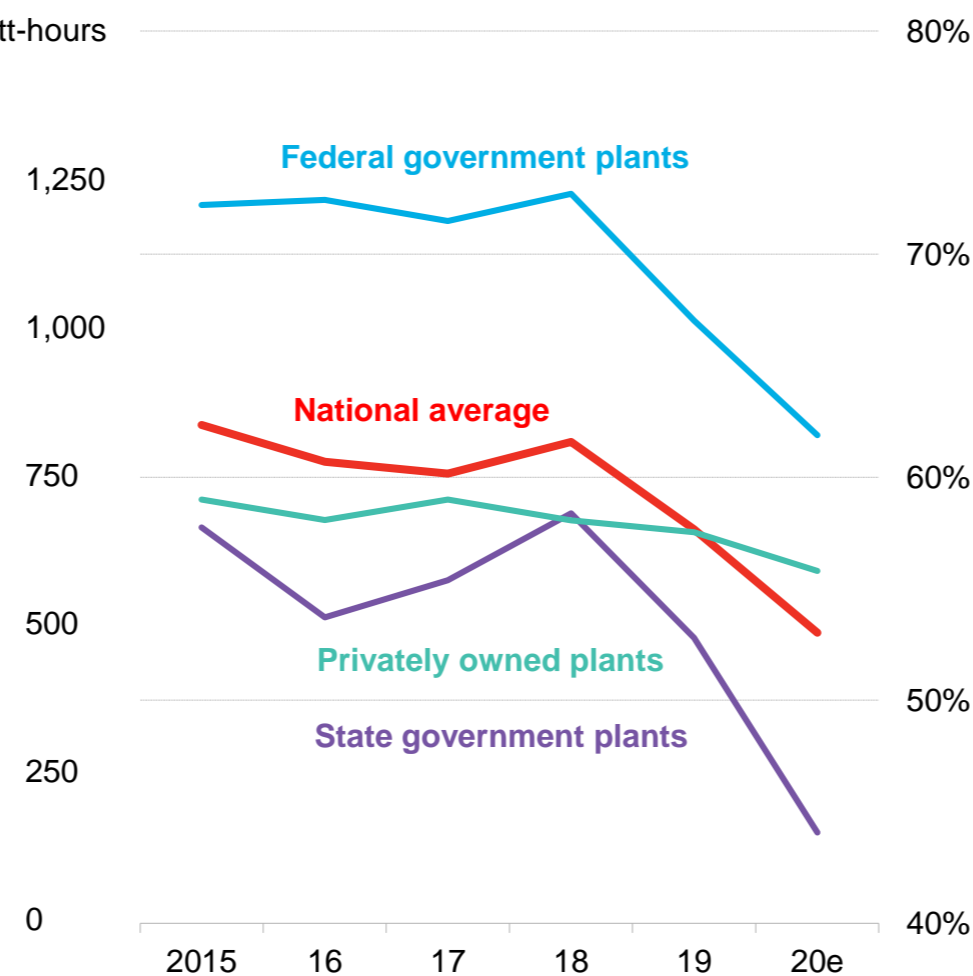
As India's renewable power generation expands, coal plant utilization falls



India power generation



India coal plant utilization



Renewable power has been almost all of India's power generation growth since 2018

Fossil fuel-fired power generation peaked in 2018, and in 2020 has fallen back to about the same level as in 2017.

The rise of renewables, and to a lesser extent nuclear, has impacted coal plant utilization

Coal plant utilization has fallen across the board, with the national average now only 53%.

Declines in coal plant utilization hit different owners in different ways

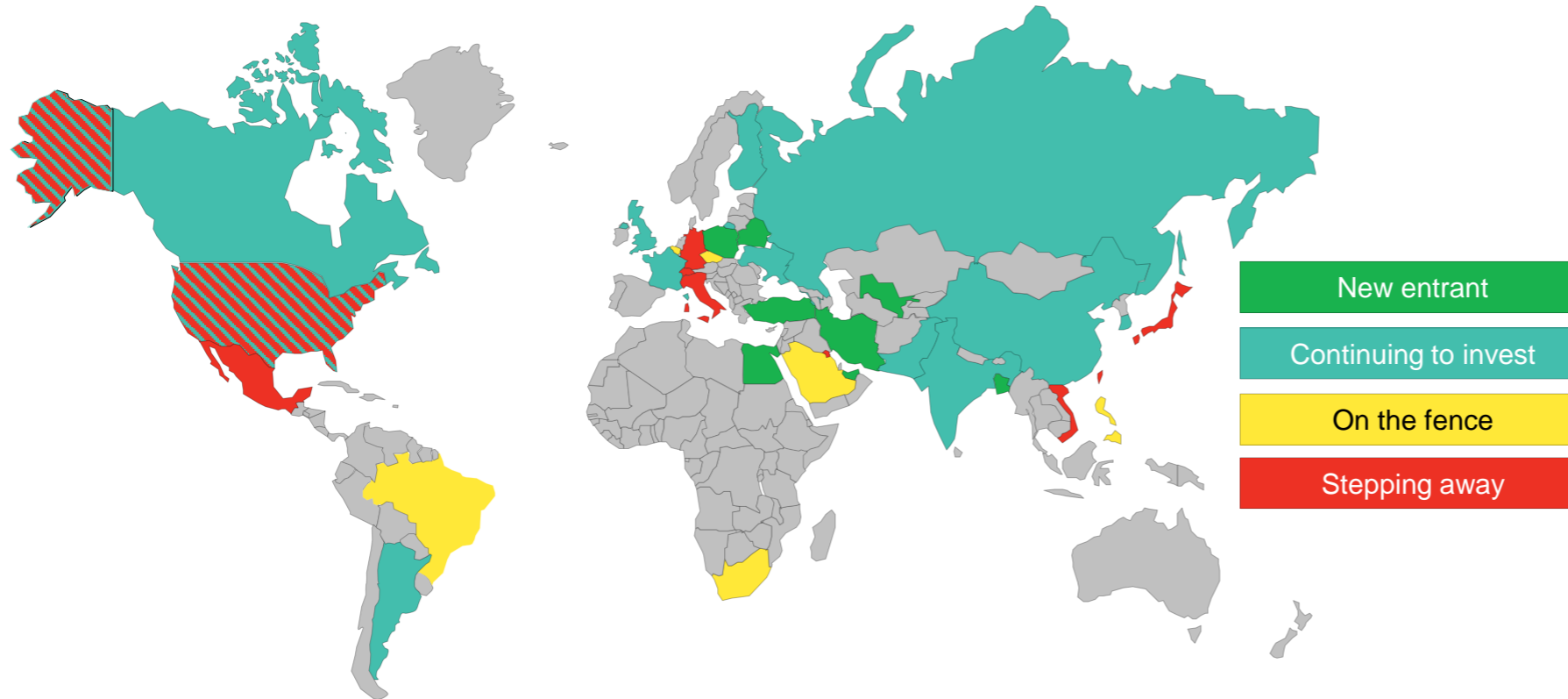
State government plants now have a utilization rate below 50%, while federal government plants are still above 60% utilization.

Source: BloombergNEF

Nuclear power development differs by country, with some investing in new reactor designs



Country nuclear energy ambitions a decade after Fukushima



The nuclear industry is focused on improving the safety of the existing fleet. Plant operators are pursuing reactor stress tests, operational best practices, and passive designs aimed at improving existing assets.

The industry is also investing in new reactor designs. Canada, China, Russia, the U.S. and U.K. are all investing in advanced reactor and small modular reactor designs.

Nuclear power can play a role in deep decarbonization. Global interest in zero-carbon power generation drives interest in advanced nuclear as countries consider the role that this baseload source could play in deep decarbonization scenarios.

Source: IAEA, BloombergNEF. Note: the U.S. is 'stepping away' from conventional nuclear power, but 'continuing to invest' in advanced nuclear technologies



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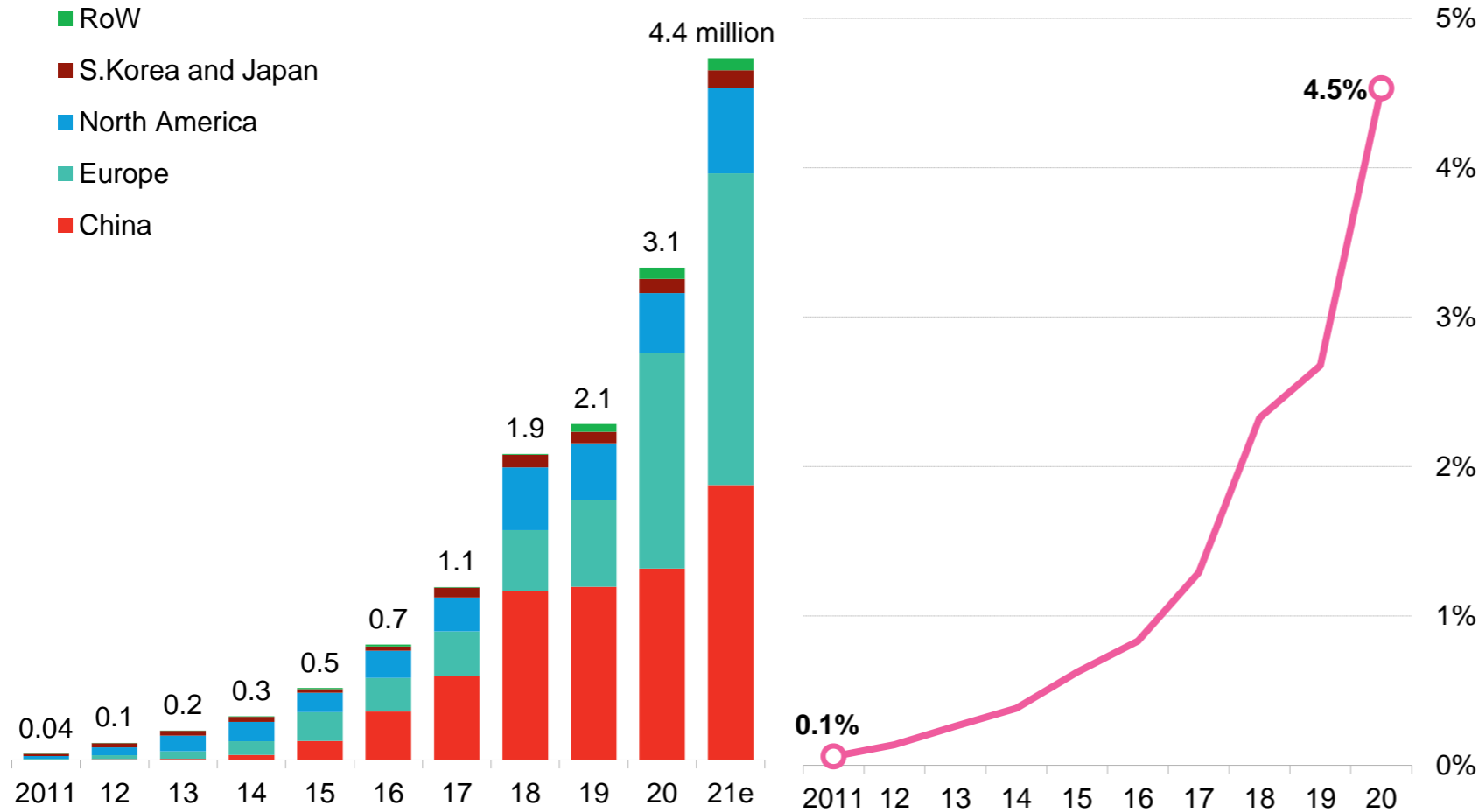
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Passenger electric vehicle sales increased 48% in 2020



Global passenger electric vehicle sales

% of total passenger vehicle sales



Global passenger electric vehicle sales defied Covid-19, and auto industry trend, in 2020

Sales increased 48%, with growth in China and the U.S. and a surge in buying in Europe

European sales more than doubled year on year, with emissions policy the main driver

Europe sales topped 1.3 million, more than 30,000 ahead of China in 2020.

North America sales rose slightly

U.S. sales declined rose from 322,000 in 2019 to 326,000 in 2020.

Sales elsewhere rose as well, in aggregate

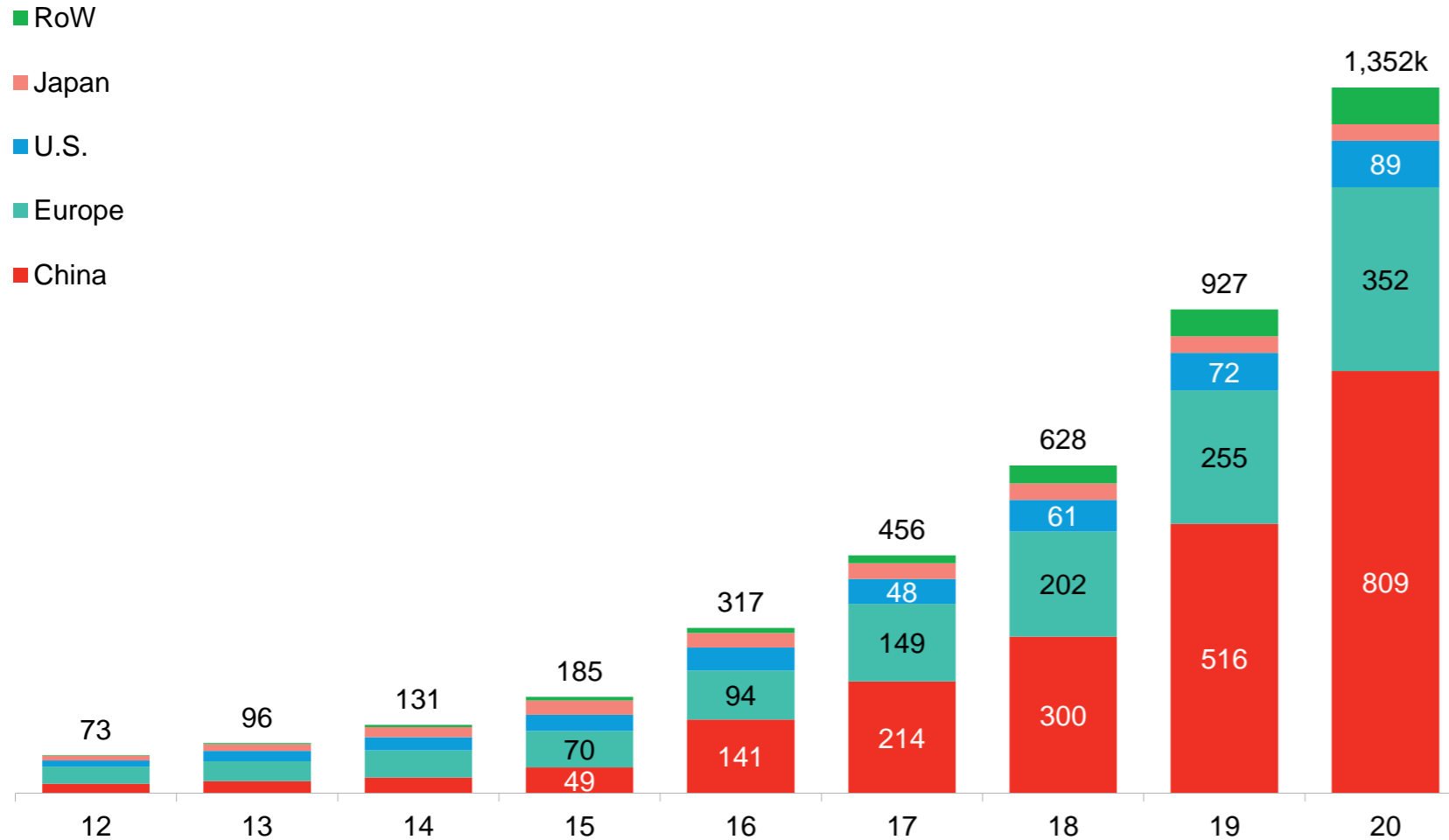
Sales in Japan fell slightly, while sales in Korea increased more than 50%, with the two countries together purchasing 98,000 passenger EVs

Source: BloombergNEF. Note: Includes plug-in hybrids

There are more than 1 million public electric vehicle charging connectors worldwide



Total number of public EV charging connectors installed



There are now 1.35 million electric vehicle charging connectors worldwide

Electric utilities, oil and gas majors, governments and pure-play charging network operators are all investing heavily.

The charging market remains fragmented

An absence of network standards and physical format standards mean that the market has yet to consolidate, and is likely to remain fragmented for another 3 to 5 years.

Viable business models are emerging

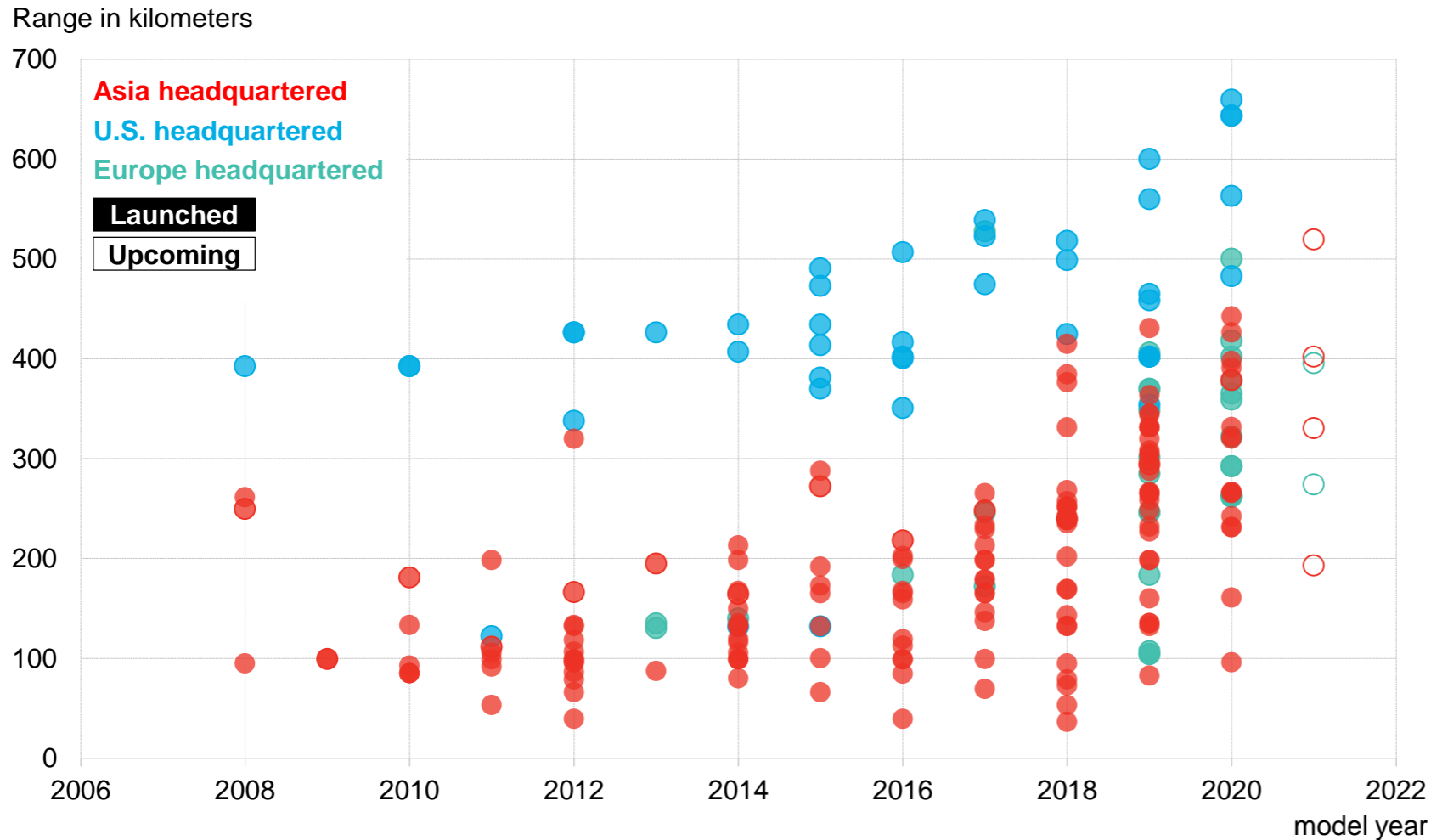
However, there are a number of critical questions outstanding for network operators, such as the optimal speed for charging, ideal location of public chargers, and the approach to billing customers.

Source: BloombergNEF

Electric vehicle ranges continue to increase



Range of launched and upcoming BEV models by launch year



Electric vehicle ranges have increased markedly in a decade

Prior to 2010, Tesla models had by far the longest vehicle range, with Asian models a small fraction of Tesla range.

Asian manufacturer ranges have more than doubled

2019 and 2020 Asian electric vehicle ranges cluster around 300 kilometers, much closer to that of U.S. models.

European model ranges are 300-400 kilometers

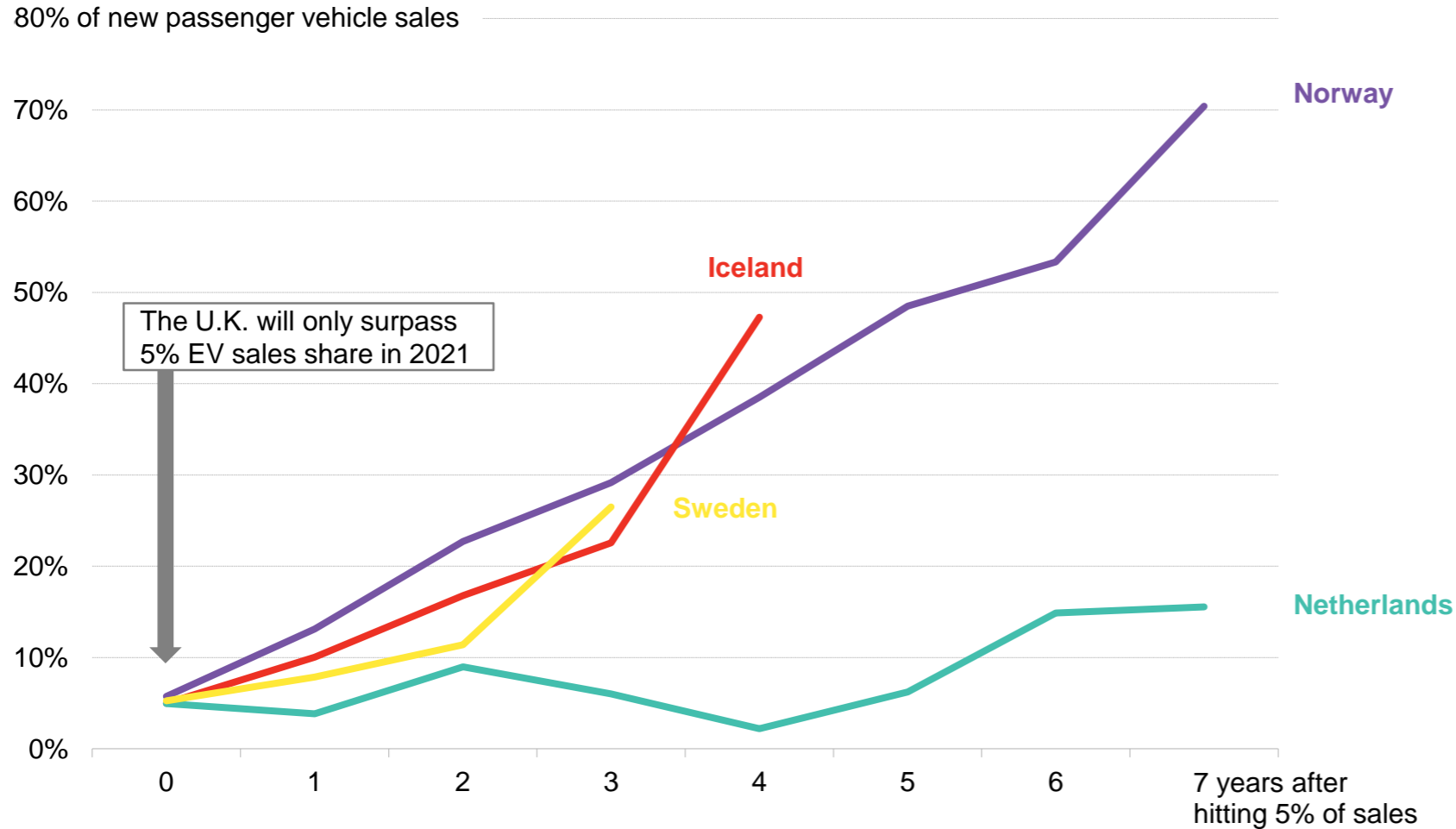
European models released in the past two years will be similar to the low end of U.S. electric vehicle ranges.

Source: BloombergNEF

Electric vehicle sales tend to keep increasing steadily after reaching 5% (with one exception)



EV share of new passenger vehicle sales after EVs hit 5% of new vehicle sales



Once markets achieve an electric vehicle new sales share of 5%, EV sales usually take off

Countries that achieve 5% EV sales usually hit 10% within a year, or less, and 20% within two to three years.

Norway now has an EV sales share of 70%

Seven years after achieving 5% sales, electric vehicles are now more than two-thirds of passenger vehicle sales

The Netherlands is the only auto market in which EV sales share has not grown dramatically

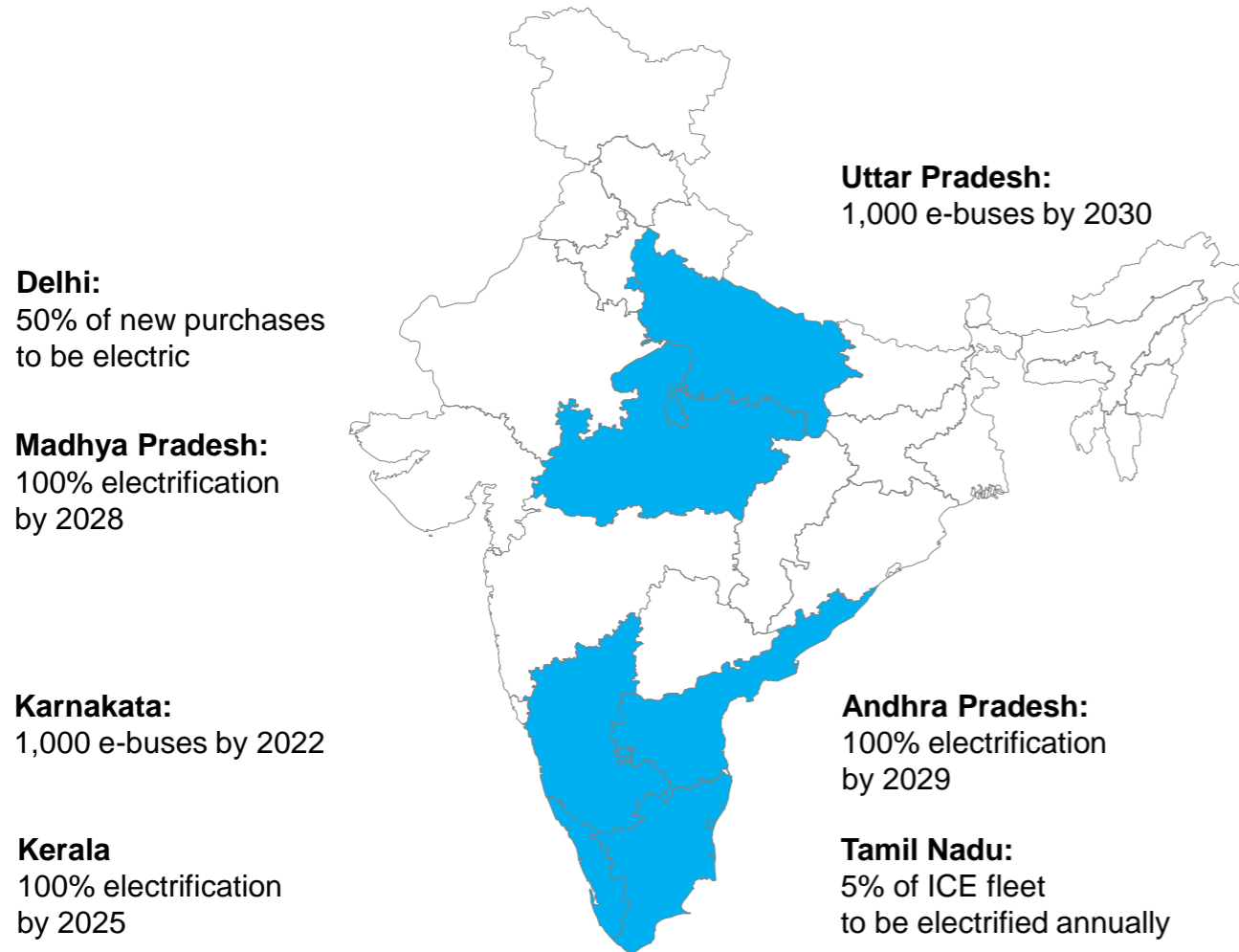
Dutch EV tax incentives have phased in and out, and a subsidy introduced in July 2020 ran out almost immediately. EV sales are still more than 10% but have not risen as in other markets.

Source: BloombergNEF

Seven Indian states or administrative areas have municipal bus electrification targets



India municipal bus electrification targets



India has a number of municipal bus electrification targets

The most aggressive, in terms of immediate action, is Kerala, which targets 100% electrification by 2025.

Targets differ in nature

Targets include percentage of new sales, a percentage of fleet electrification per year, full electrification target dates, and absolute targets by certain years.

Electric bus sales are likely to pick up next decade, based on economics

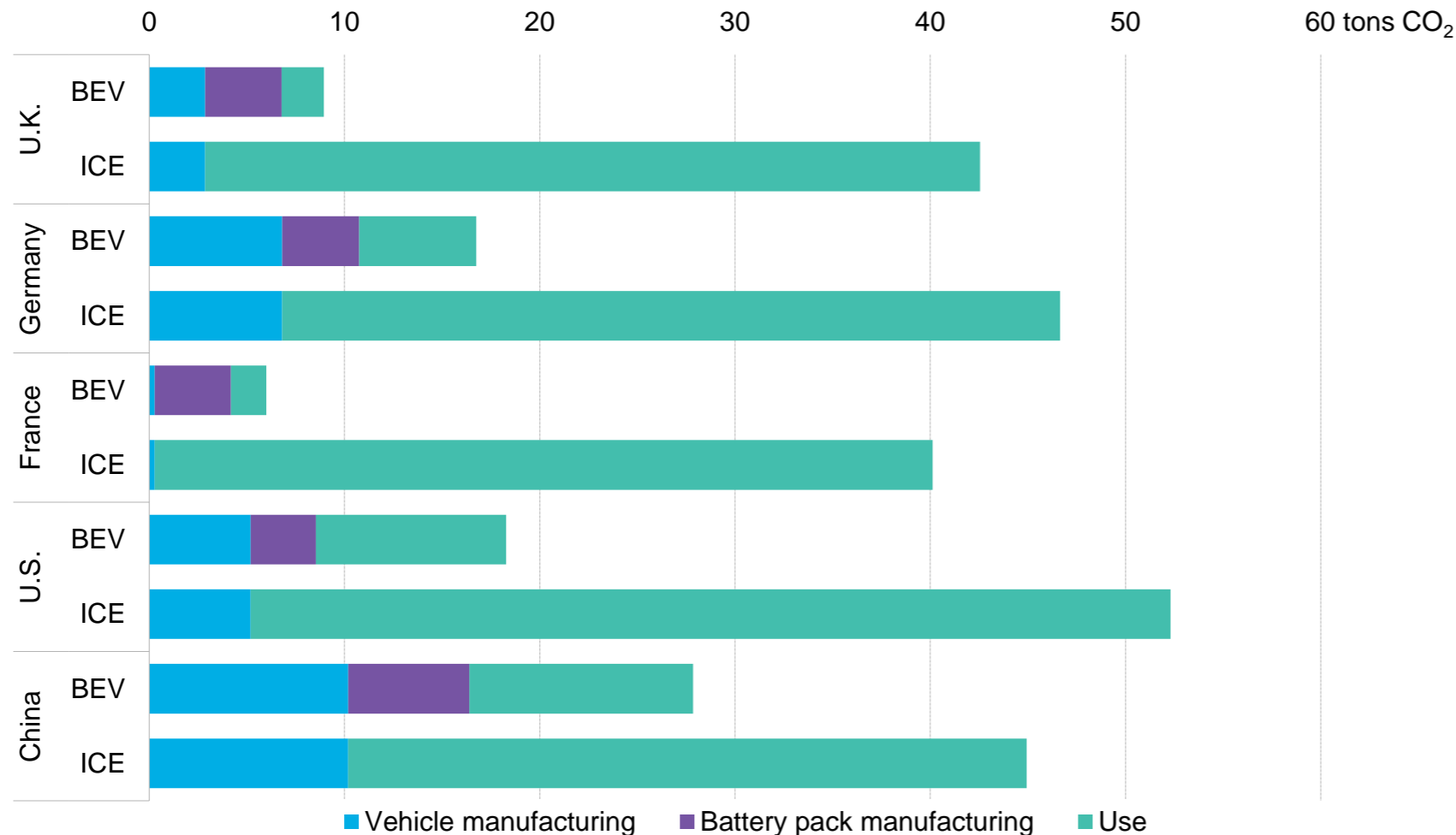
BloombergNEF expects the total cost of ownership of electric buses to be lower than that of internal combustion buses by 2030.

Source: State transport departments

Electric vehicles have much lower lifecycle emissions to comparable internal combustion engine models



Electric and internal combustion engine vehicle lifetime CO2 emissions



Battery electric vehicles have substantially lower lifecycle emissions than peer internal combustion engine vehicles

In countries with low electricity emissions, such as France, the gap is almost ten-fold. In China, with its coal-heavy power fleet, the difference is much less.

EVs have higher lifecycle emissions from manufacturing than ICE peers

Battery pack manufacture accounts for almost all of the difference, with some variation by country.

The lower the power fleet emissions intensity, the bigger the lifecycle emissions gap

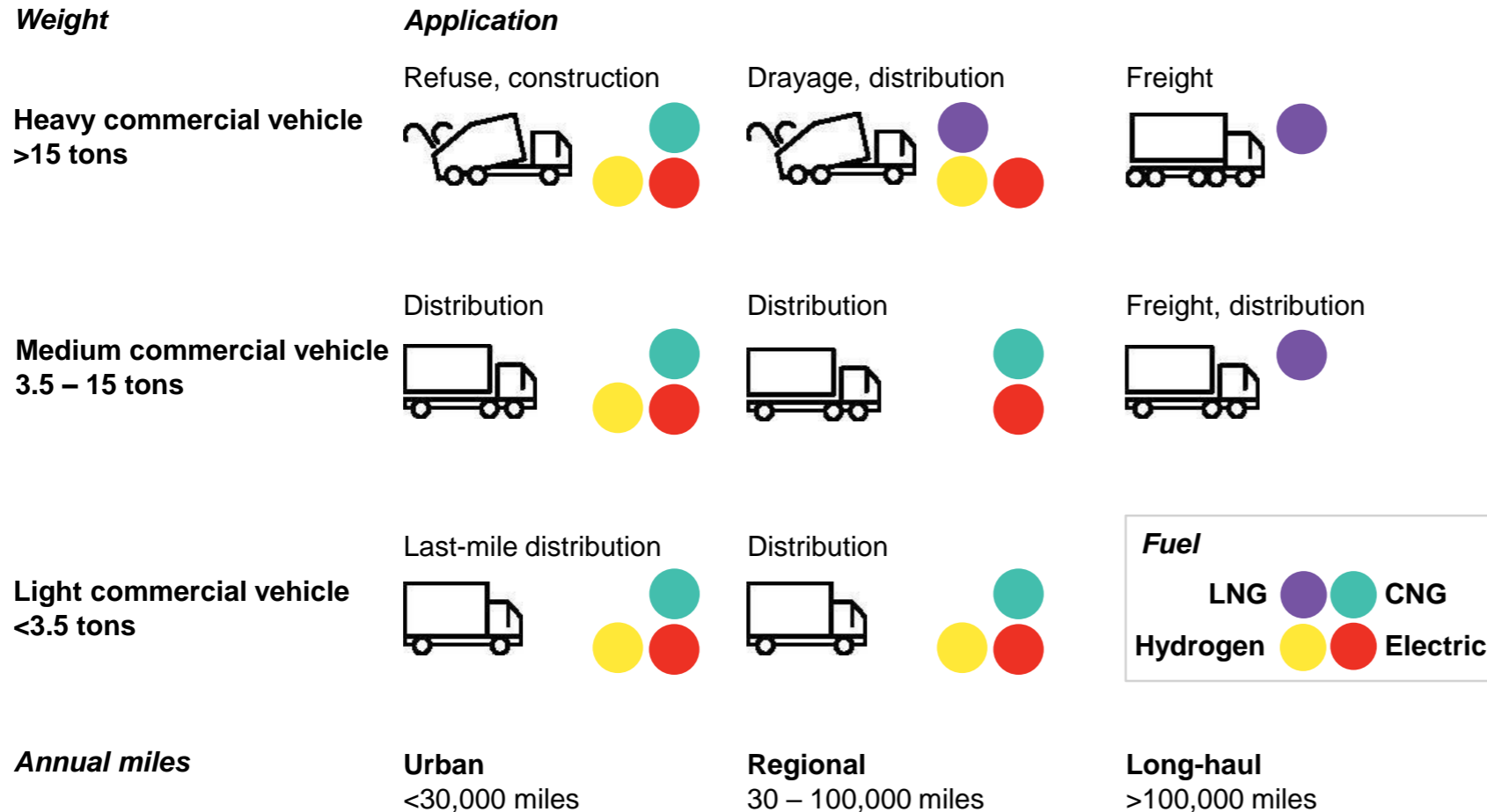
The U.K. and France, with their substantially decarbonized power fleets, have the greatest lifecycle emissions advantage.

Source: BloombergNEF

A range of fuels are now viable for commercial vehicles depending on weight, application, and annual miles



Current activity of alternative fuels, by commercial vehicle segment



Road freight underpins global trade and has powered oil demand growth over the past decade.

Trucks consume almost one in every five barrels of oil.

City fuel restrictions, noise regulations and stringent emission standards are forcing truck makers to diversify powertrains

Four energy sources – liquefied natural gas, compressed natural gas, hydrogen, and electricity – can power a range of weight and distance applications.

Diesel technology will become more expensive in the next 10 years

Costs for natural gas vehicles will drop slightly as storage options improve.

Source: BloombergNEF [link](#)



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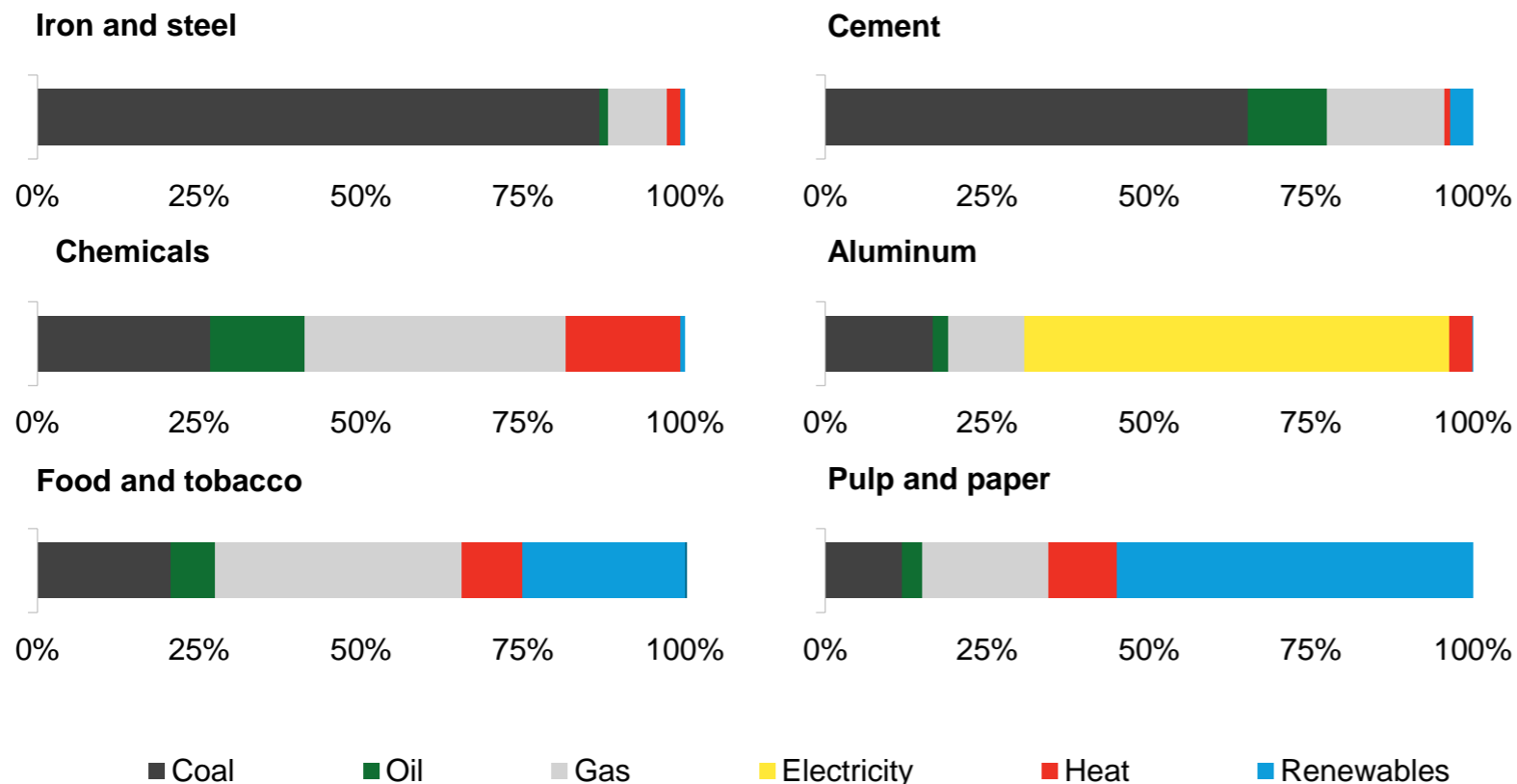
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Heat is essential for many industrial processes, and industries meet their demand in many different ways



Share of energy supply for industrial process heat, 2018



Six sectors have significant demand for process heat

Iron and steel, cement, chemicals, aluminum and non-ferrous metals, food and tobacco, and pulp and paper all require heat for essential industrial processes.

Some industries already use significant amounts of renewable energy for heat

Food and tobacco, and pulp and paper, already use a relatively high proportion of renewable heat sources such as biomass and biogas thanks to the ready availability of organic waste at their sites.

Other industries use mostly fossil fuels

Chemicals, cement and iron and steel use a higher proportion of fossil fuels. These industries have high heat requirements and use fossil fuels as feedstocks as well.

Source: BloombergNEF, IEA

Heat decarbonization potential varies significantly, but can have big rewards in big sectors



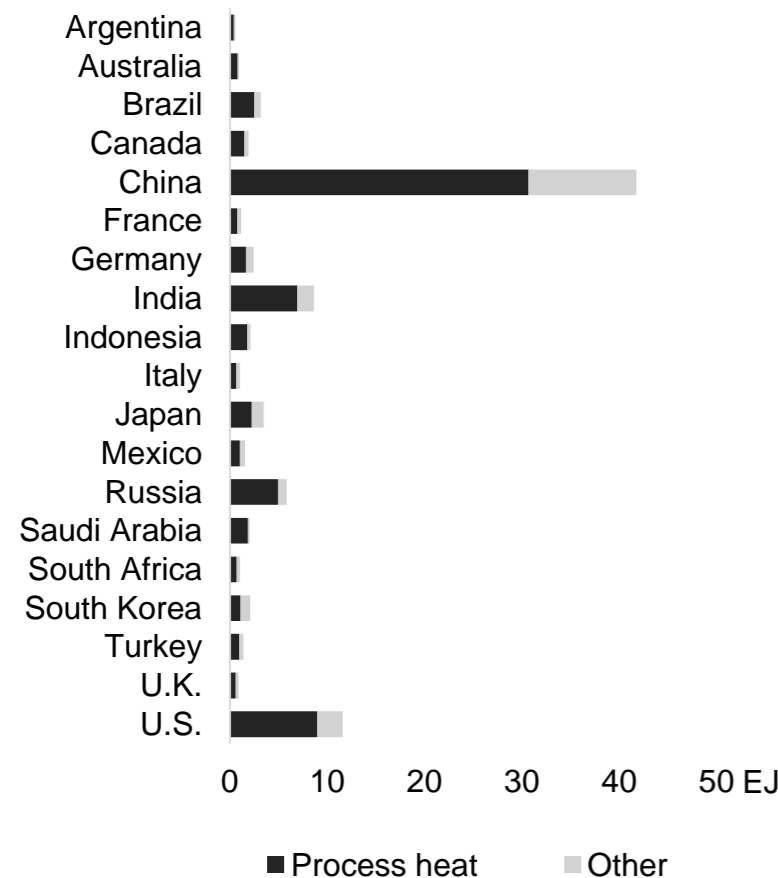
	Sector	Current status (2016)		Ease of heat decarbonization		
		Temperature	Major fuel	Efficiency gains	Fuel switching	New technology or process
Big prizes (but hard to achieve)	Iron and steel	High	Coal	Hard	Hard	Medium
	Non-metallic minerals (cement)	High	Coal	Hard	Medium	Hard
Medium prizes (medium size/difficulty)	Chemicals	High	Coal	Medium	Medium	Hard
	Non-ferrous metals (aluminum)	High	Electricity	Medium	Easier	Hard
Small prizes (but easiest to achieve)	Food and tobacco	Low	Gas	Medium	Easier	Medium
	Pulp and paper	Low	Renewables	Medium	Easier	Easier

Source: BloombergNEF, IEA

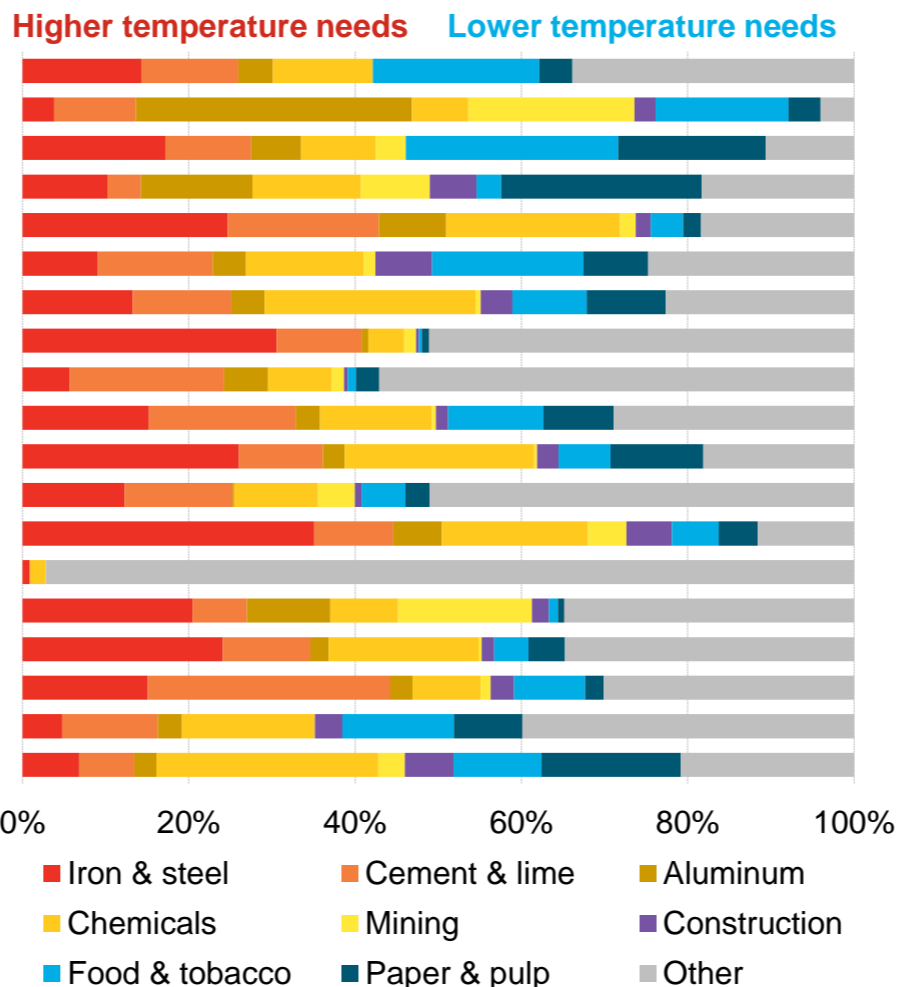
Industry has a number of specific decarbonization challenges



Industrial energy consumption, type



Industrial energy consumption, sector



Industry is a substantial share of energy use and greenhouse gas emissions

Industry is 29% of all global energy use, and around a fifth of all greenhouse gas emissions.

The majority of industrial energy consumption is used to produce process heat

Process heat is the energy input of thermal manufacturing processes such as steam reformation of methane to produce ammonia, or smelting to produce steel.

Countries face different challenges in decarbonizing industry

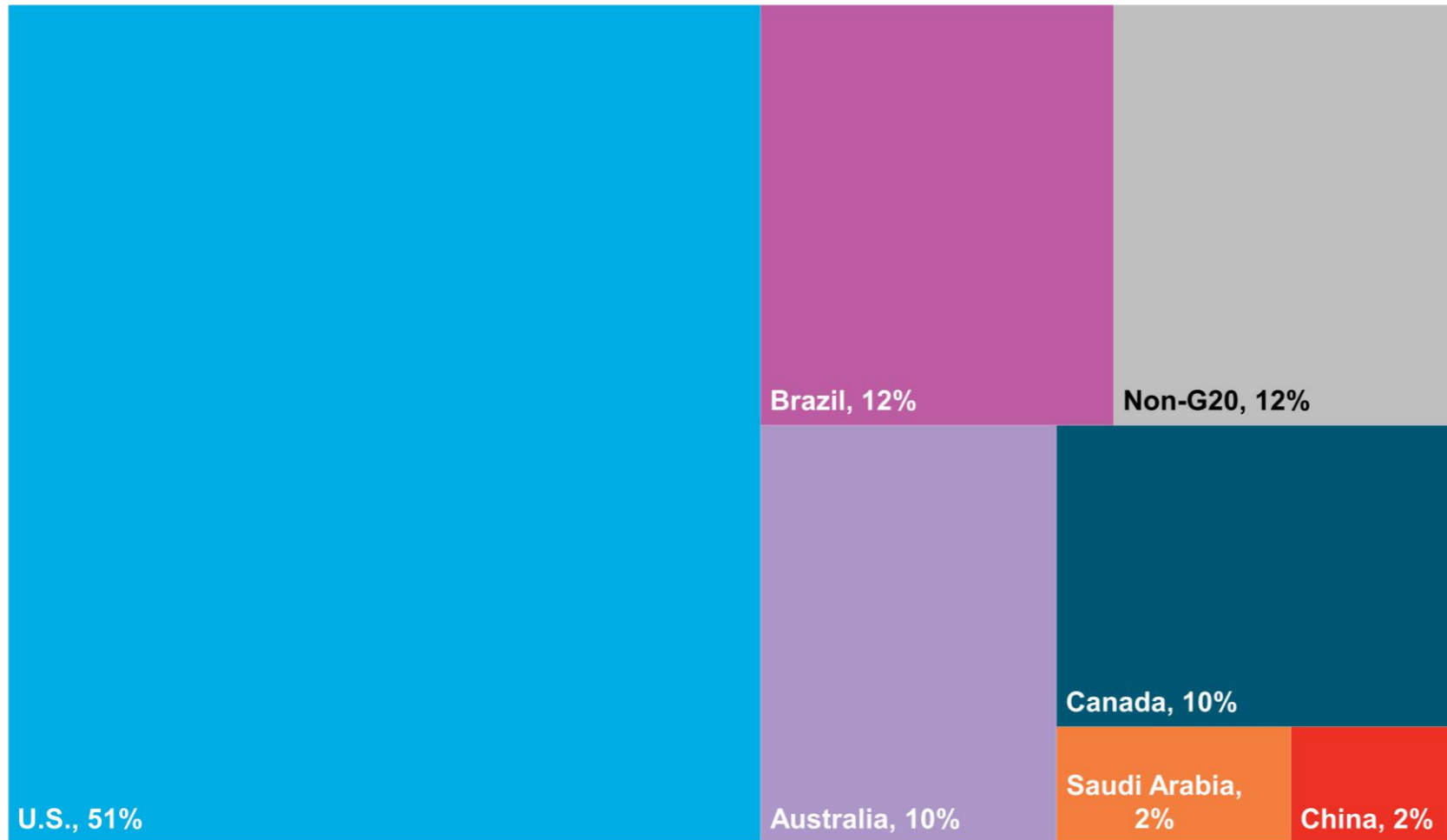
Those challenges range from scale (China is by far the largest industrial energy consumer) to particular heat demand (some countries have mostly high-temperature heat demand, which makes it harder to find lower- or zero-carbon substitutes).

Source: Global CCS Institute, BloombergNEF

The U.S. leads in operational carbon capture capacity



Share of global operational carbon capture capacity, by location, end-2020



Carbon capture, utilization, and storage (CCUS) separates industrial carbon dioxide emissions for use

The process separates, compresses, and transports the gas for use in industrial processes, drilling processes, or storage.

CCUS can contribute to the circular economy

CO₂ can be 'upcycled' into new products including concrete, carbon nanotubes, chemicals or fuels. It can also be used in the process of producing hydrogen from natural gas.

The U.S. is the leader in CCUS capacity

The U.S. has more than half of the global CCUS capacity of 38 million metric tons per annum. Current global CCUS capacity is equivalent to only 0.1% of global emissions.

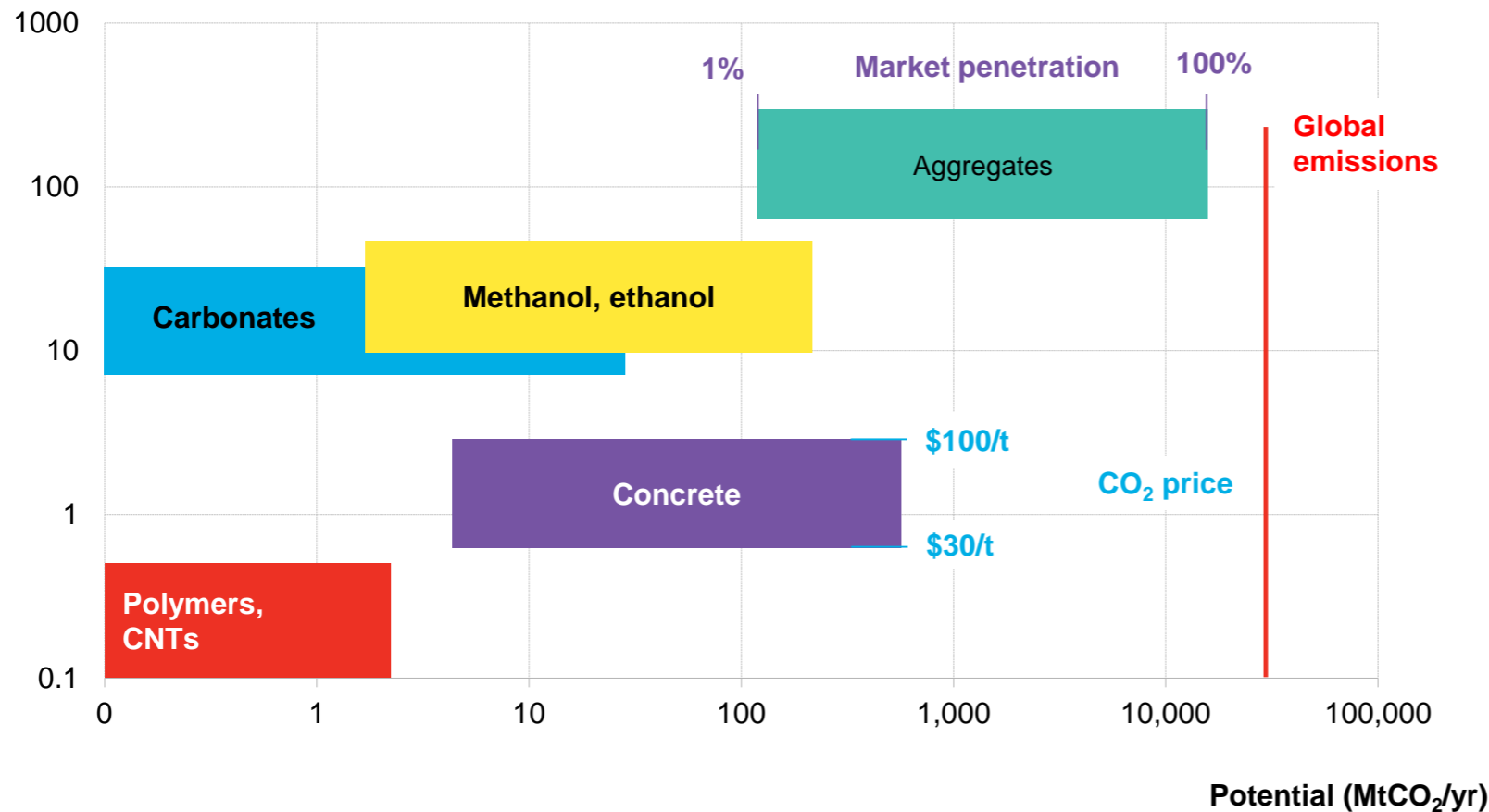
Source: Global CCS Institute, BloombergNEF

CO₂ utilization markets are too small and too cost-sensitive to significantly offset capture costs



CO₂ utilization markets and sensitivity to CO₂ prices

CO₂ cost (% of product price)



Once carbon dioxide is captured, it can be used

Uses include making new materials and chemicals, or adding to concrete to increase its strength. These applications will purchase CO₂, offsetting some of the cost of capture.

Creating new demand means new applications, or price premiums

Buyers paying a price premium for lower-emissions products will need to do so despite no added performance benefit.

Concrete is the current targeted application for a reason

Concrete demand is significant, and CO₂ use adds little, if any, cost to the final product.

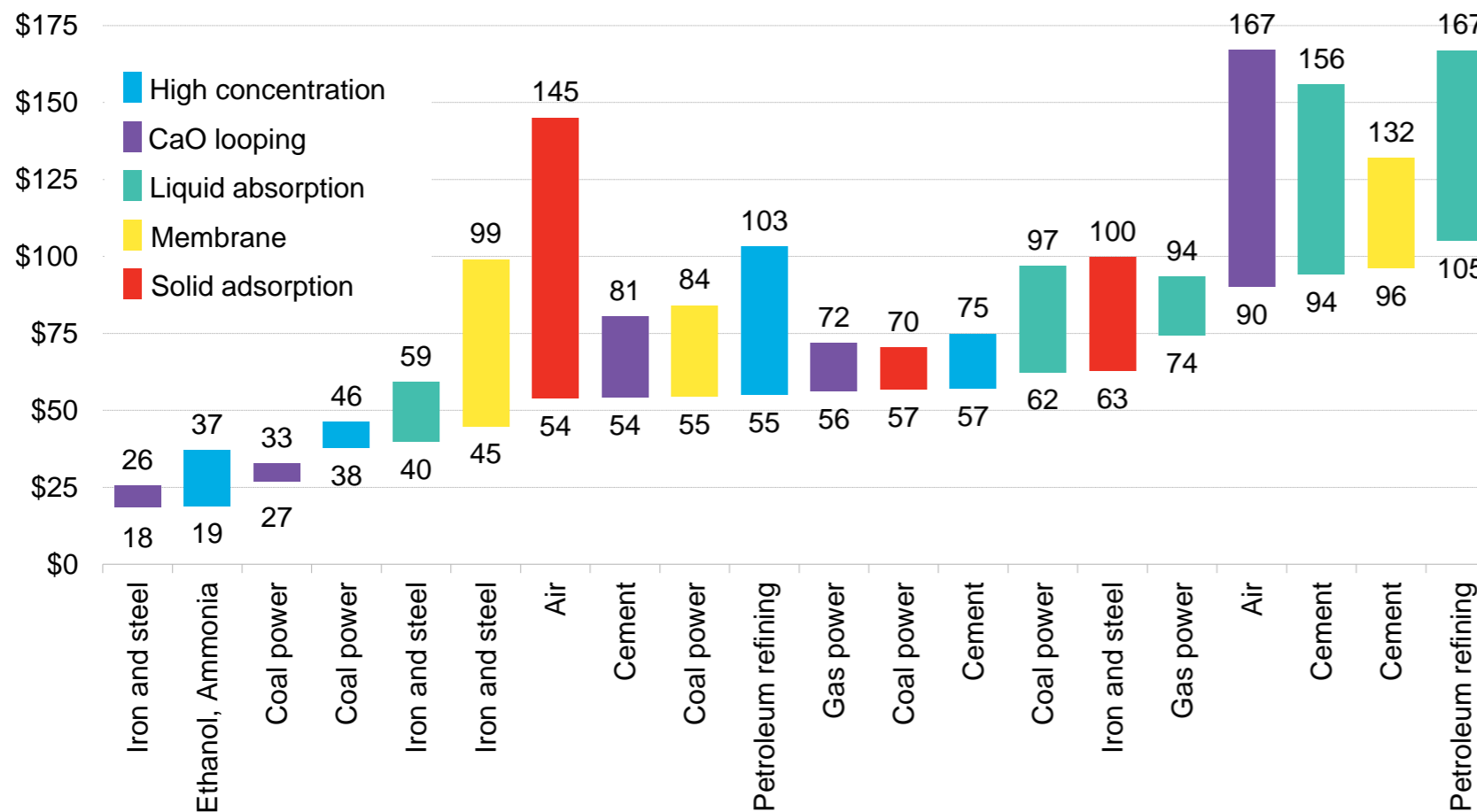
Source: BloombergNEF

Industrial carbon capture costs can fall within the carbon price range once many plants have been built



Cost of avoiding CO₂ emissions at scale (Nth-of-a-kind plants)

Avoidance Cost (\$/tCO₂, real 2019)



Future carbon capture costs could be within range of today's carbon prices

Iron, steel, chemicals, and coal-fired power could all have viable carbon capture if economies of scale are realized.

High-concentration and liquid absorption are mature capture technologies used today

CaO looping is early-stage, but the industry has high hopes for its success.

Capture costs are specific to each project

Capture costs depend highly on energy, consumable costs, and what fraction of emissions are captured.

Direct-air capture could provide negative emissions, but at a cost

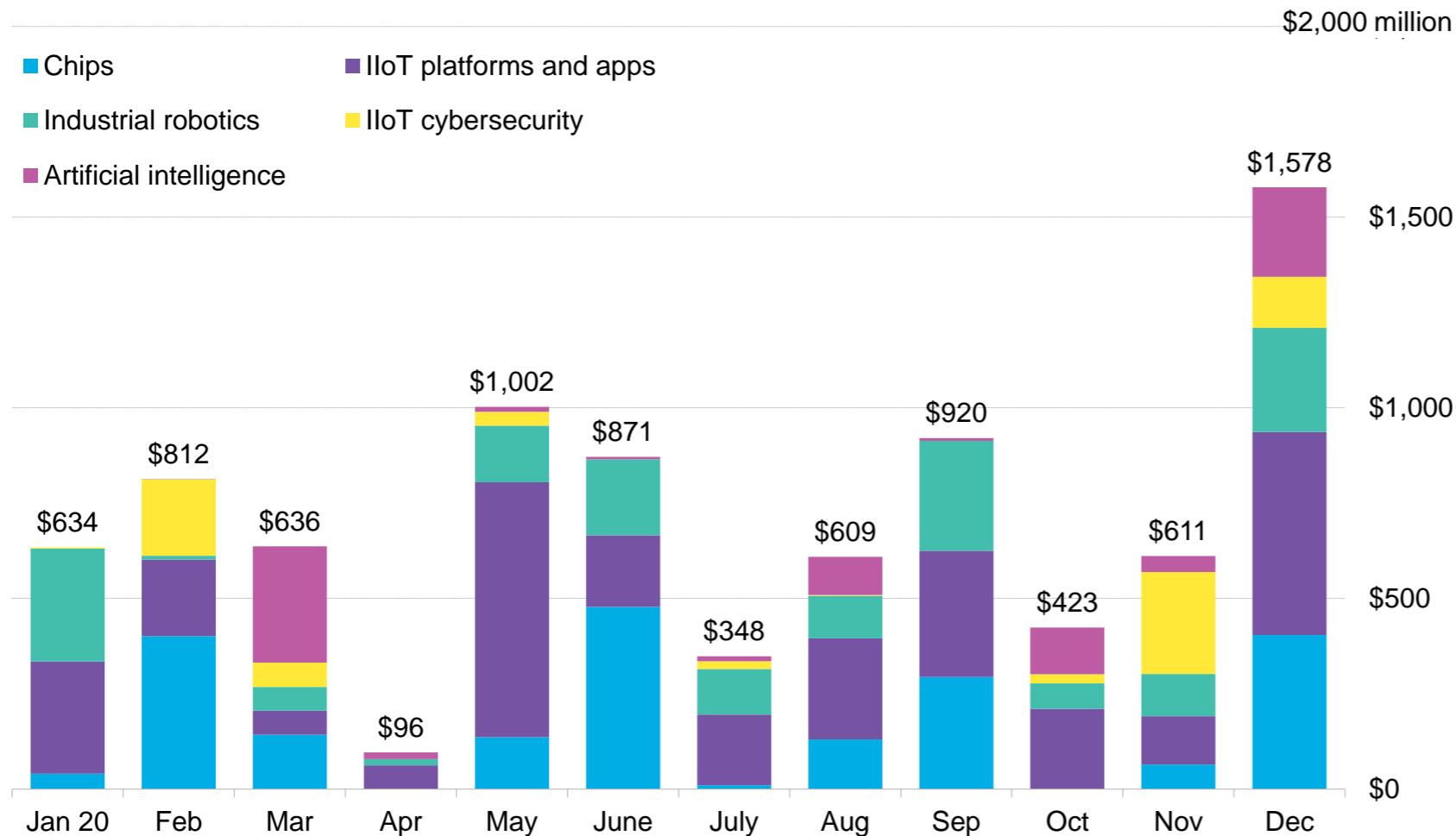
It is the only technology with potentially negative emissions, but it will remain expensive even with much iteration.

Source: BloombergNEF. Note: Nth-of-a-kind is a cost estimate that includes the economies of scale achieved by building several identical projects. CaO is calcium oxide.

Private industrial IoT, AI, analytics, and robotics companies raised more than \$13 billion in 2020



VCPE fundraising by startups selling industrial IoT, AI, analytics, robotics products



There are thousands of startups building software, sensors, chips, drones for industrial digitalization. However, most are very small, raising seed or Series A.

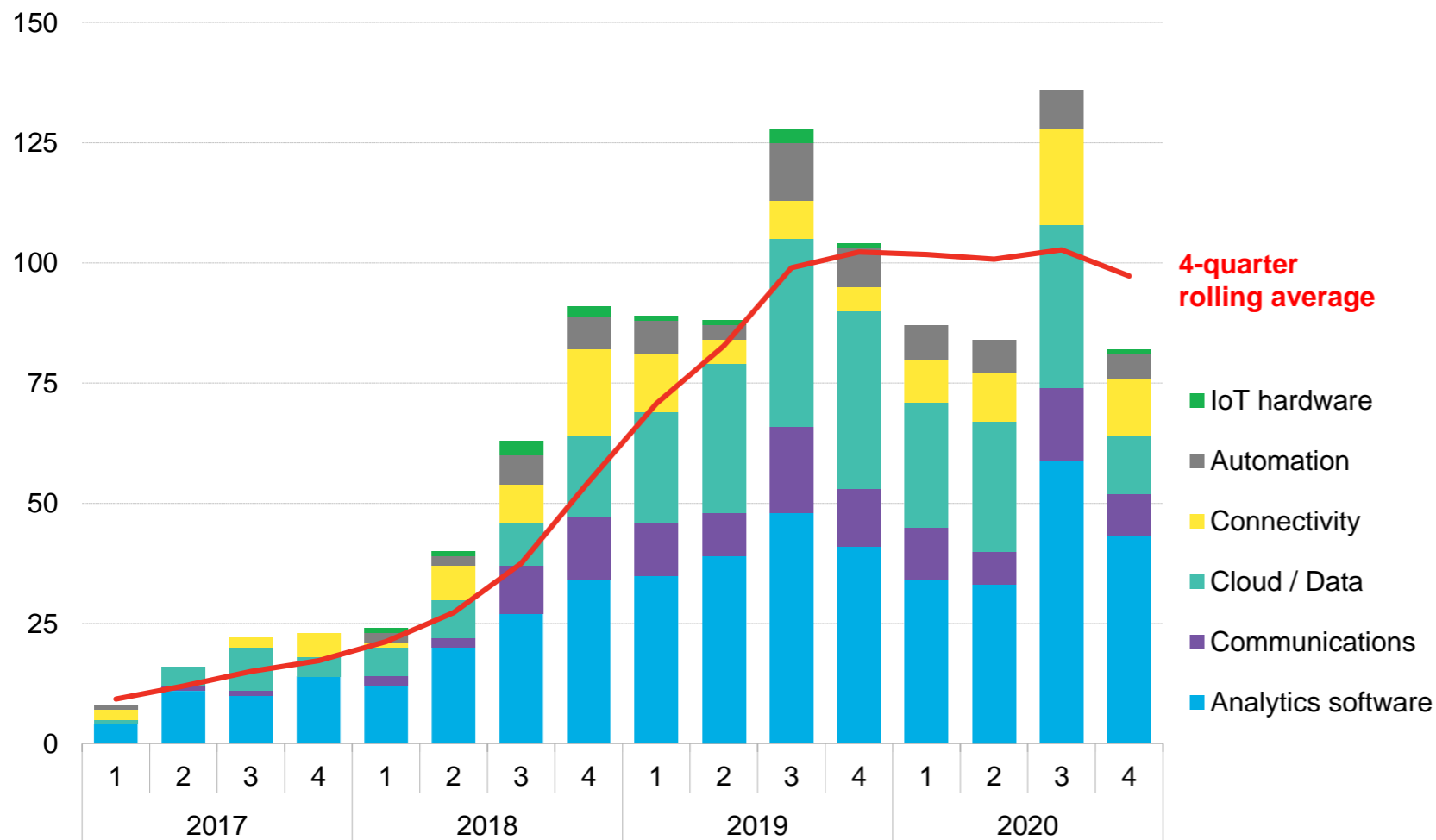
Industrial IoT and AI venture funding is a small part of the global funding landscape. Much more money is being spent by large corporations in R&D, like by GE or Siemens or Schlumberger, than is being spent on startups.

Source: BloombergNEF

Industries are rapidly digitalizing business operations



Digital industry projects and partnerships (count of activities)



Industrial companies have become more reliant on remote monitoring and cloud computing to continue operations

Covid-19 has meant cloud and data-related projects and partnerships have been growing and accounted for 25% of digitization activity in 2020.

Analytics software-related digital projects and partnerships account for the largest proportion of activity

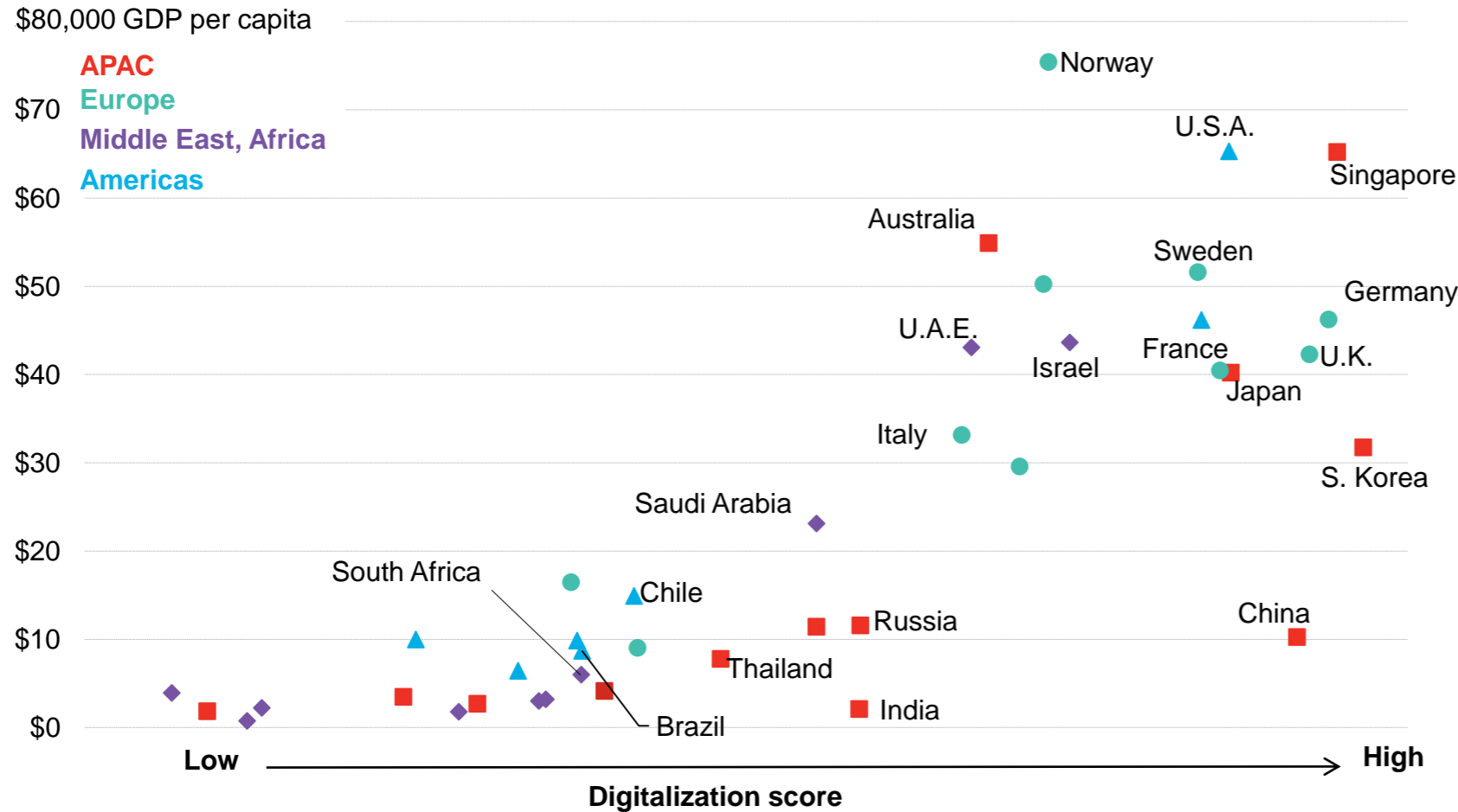
This includes technologies such as artificial intelligence, digital twins and predictive maintenance.

Source: BloombergNEF

South Korea, Singapore, and Germany top the national digitalization ranking



BloombergNEF 2020 country digital score and GDP per capita



BloombergNEF's annual country digitalization ranking measures current and future potential for digitalization of industries and workforces

The ranking uses a range of public and proprietary data sets to determine which country has the strongest digital policies, industrial policies, innovation schemes, startup communities, R&D hubs and education environments.

South Korea, Singapore and Germany top BNEF's 2020 national industrial digitalization ranking

Since our last review in 2019, leading countries have used policy to formalize ties between digitalization and overall economic growth

AI continues to attract the most policy attention

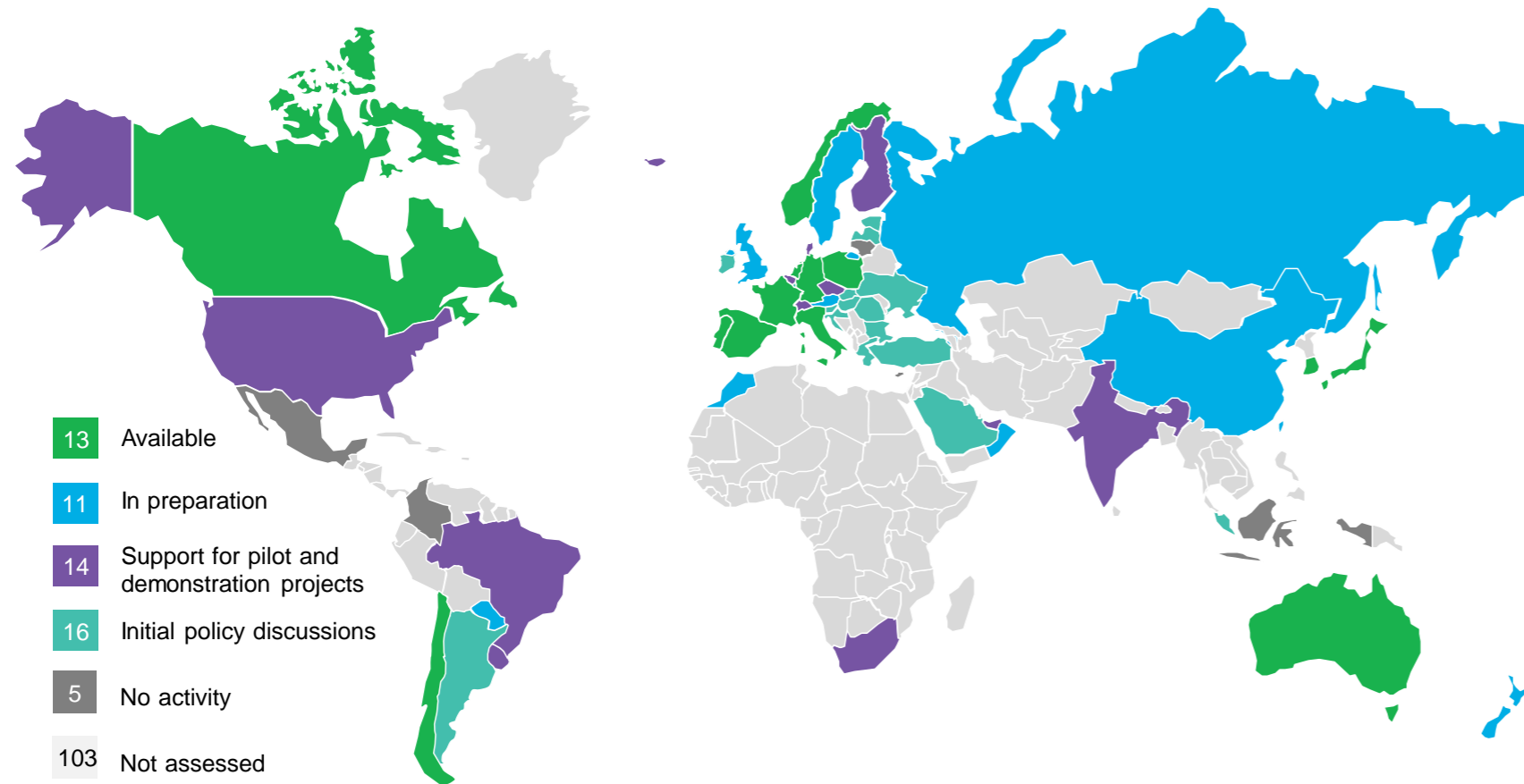
Covid-19, however, disrupted some countries' progress and ambitions

Source: BloombergNEF

Governments have begun hydrogen commitments



National hydrogen strategies as of January 19, 2021



At the start of 2021, 13 countries have national hydrogen strategies

The European Union also announced a hydrogen roadmap, which requires member states without a plan to formulate one.

A further 11 countries were preparing a hydrogen strategy during the course of last year

2021 could see even more such documents, not least from India, the U.K. and Poland – which released its draft on January 4, 2021.

If these strategies are significantly funded, they could make significant strides towards hydrogen's commercial viability

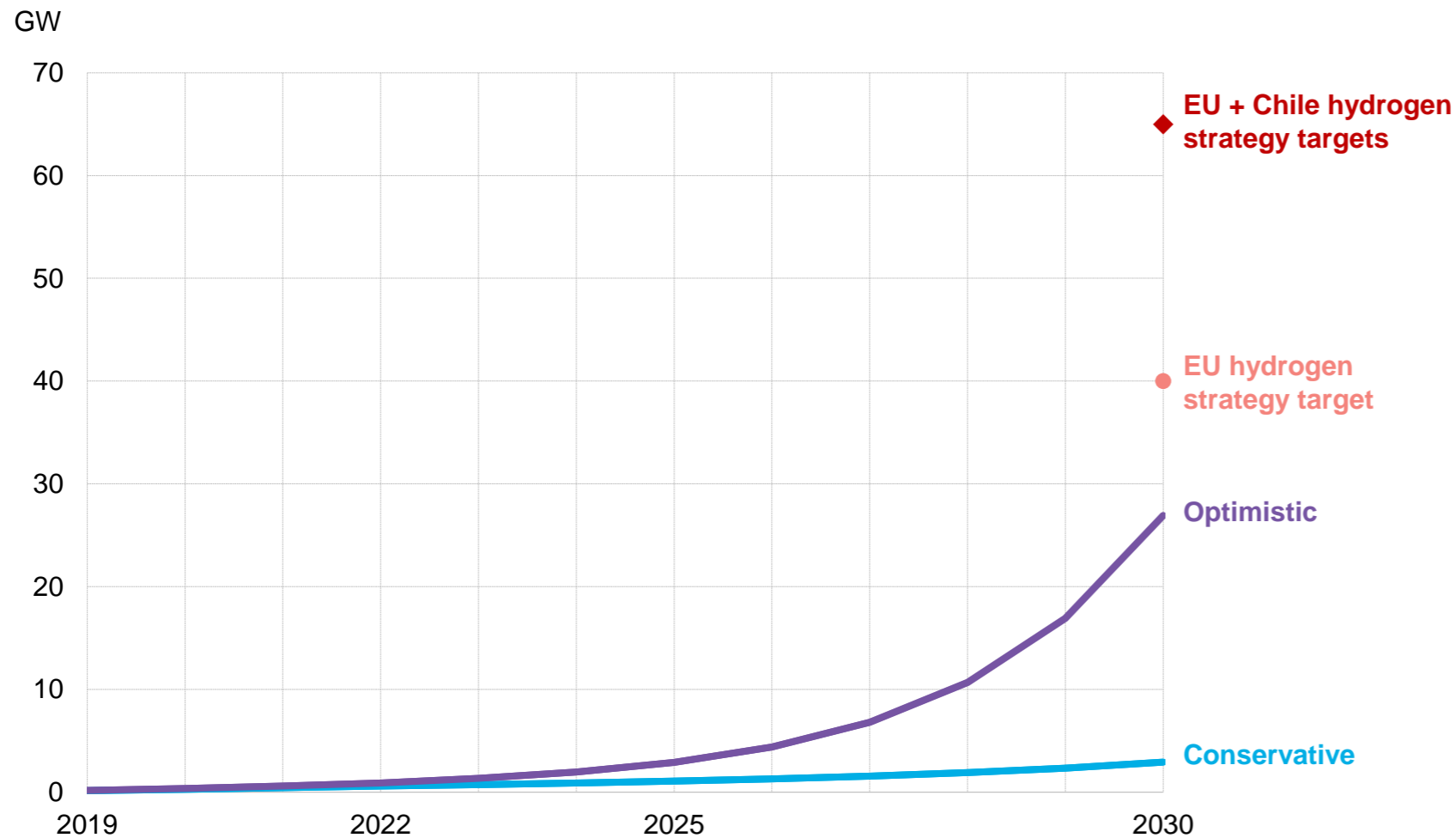
Without sufficient funding, it will be difficult to improve unit and project economics for hydrogen production.

Source: World Energy Council, BloombergNEF. Note: Italy, Portugal and Spain's strategies are currently in draft form.

National targets for electrolyzer deployment could drive electrolyzer costs below optimistic scenarios



Global electrolyzer capacity scenarios and EU hydrogen strategy target



The significance of the strategies announced in 2020 cannot be understated

By 2030, the EU calls for the deployment of 40GW of electrolyzers within its borders, Chile calls for 25GW, while Australian developers hope to build more than 8GW by 2030 despite lacking a target.

Even meeting these targets halfway will significantly impact hydrogen costs

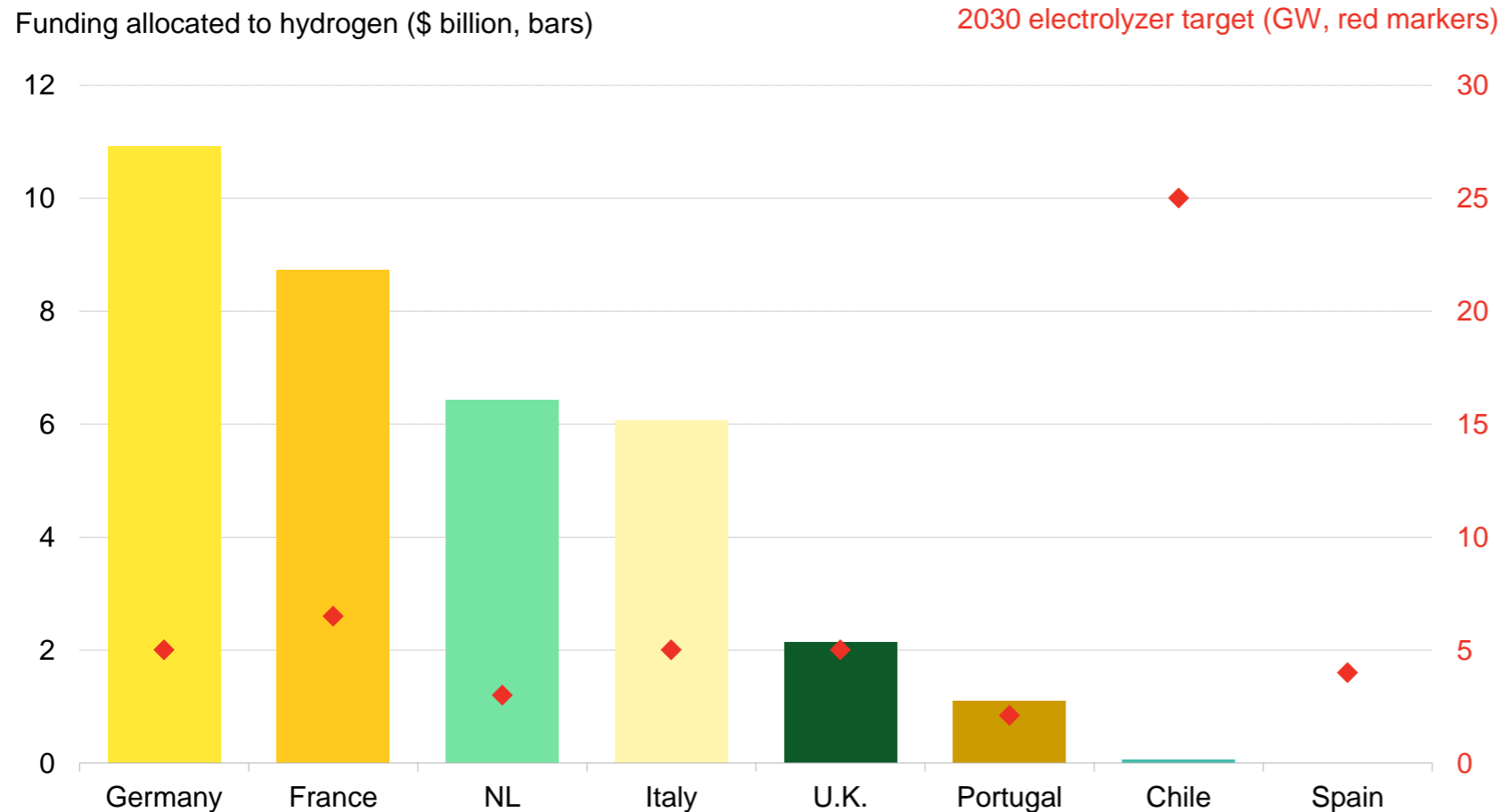
Even if less than a half of what the EU and Chile promise ends up commissioned, the capex of alkaline electrolyzers in Europe should fall from \$1,200/kW in 2019 to \$115/kW by 2030.

Source: BloombergNEF. Note: EU hydrogen strategy target shows electrolyzer target for EU member states only, excludes targets for trading partners. U.K. target includes hydrogen from fossil fuels + CCS.

Funding to meet national hydrogen strategies lags behind ambitions



2030 funding allocated to hydrogen versus electrolyzer targets



Germany and France have made the largest funding commitments to hydrogen

Combined, the two countries have allocated nearly \$20 billion in funding to hydrogen.

Other EU states plan to rely more strongly on EU funding

Italy promises 5 billion euros (\$6 billion) through public resources, but it is unclear how much will come from the national government versus EU funds. Spain and Poland are likely to draw heavily on EU support.

Chile plans to attract private investment to fund its electrolyzer target

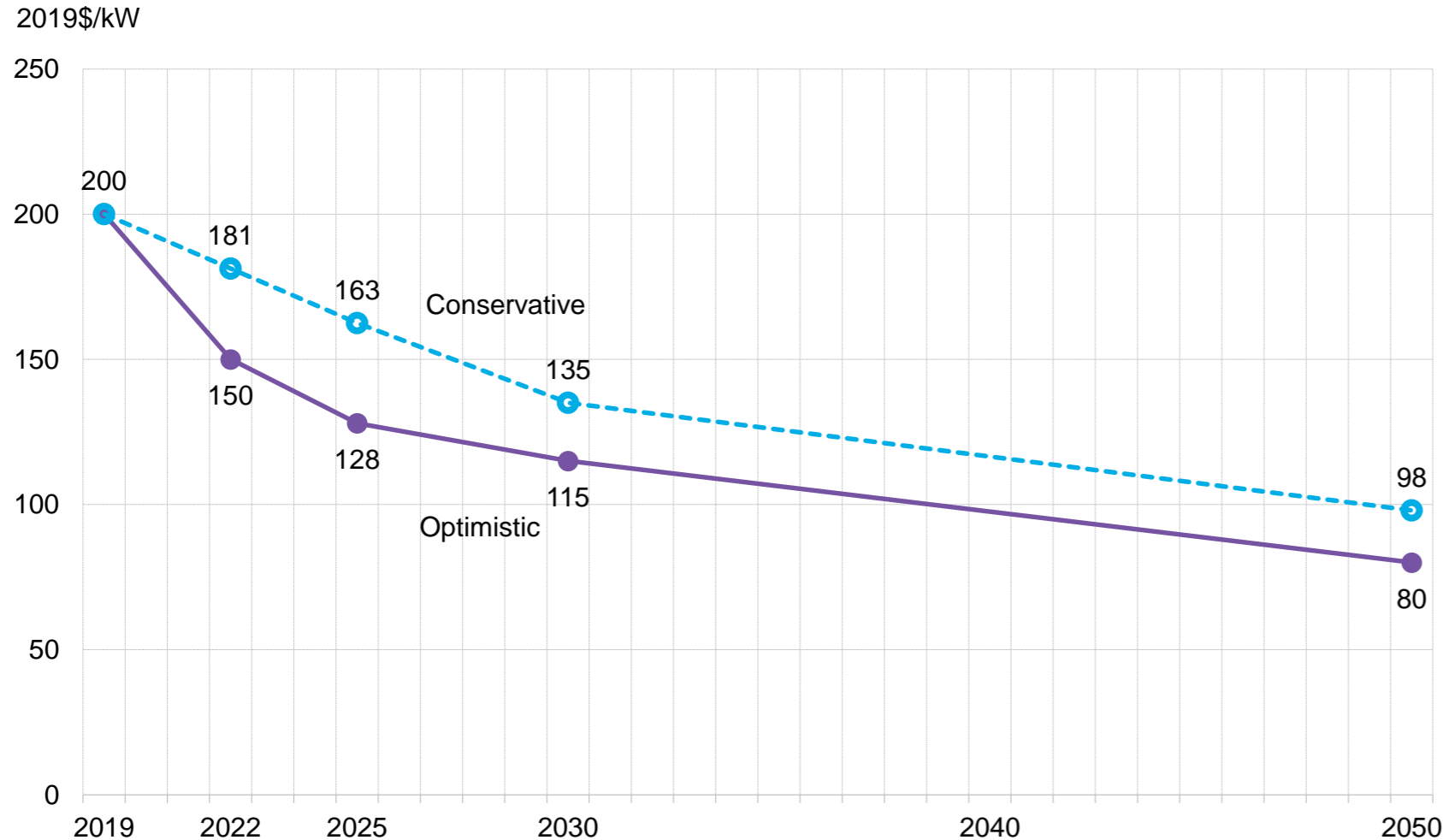
Its plan targets regulatory changes in order to incentivize hydrogen production.

Source: BloombergNEF. Note: EU hydrogen strategy target shows electrolyzer target for EU member states only, excludes targets for trading partners. U.K. target includes hydrogen from fossil fuels + CCS.

Electrolyzer costs could fall below \$100 per kilowatt



System capex projection of large-scale, Chinese-made alkaline electrolysis projects



Electrolyzers made by Chinese manufacturers are already up to 83% cheaper than western-made models

Reasons include cheaper raw materials and labor, higher factory utilization rates and lower spending on R&D and marketing.

Western electrolyzer costs will have to converge with Chinese costs, one way or another

We expect western and Chinese costs to largely converge by 2030. This could happen in two ways – western manufacturers lowering their costs, or Chinese manufacturers expanding to western countries. We are starting to see signs of both.

Chinese electrolyzers can fall by another 74% by 2030 if deployment follows our optimistic trajectory

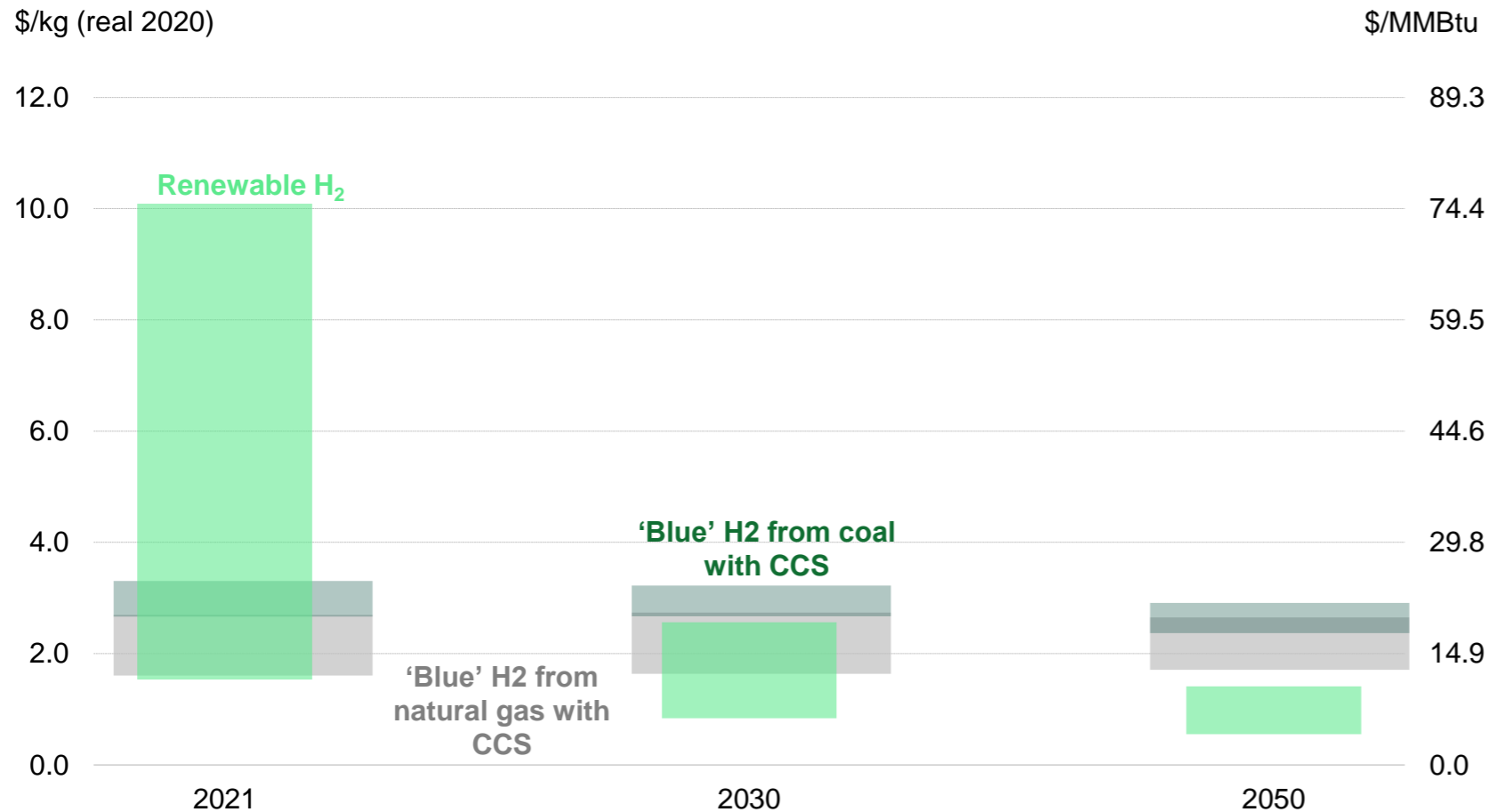
This is now highly likely given the targets set by the European Union and Chile and the pipeline of projects that have already been announced.

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

Renewable hydrogen is currently expensive, but costs are coming down



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



Blue' hydrogen from natural gas or coal with carbon capture and storage (CCS) is currently cheaper to produce than 'green' renewable H₂, but projects are rare

This relationship should reverse by 2030, when renewable H₂ could be cheaper than H₂ from natural gas or coal with CCS in all countries modeled, assuming alkaline electrolyzers are used.

Currently, CCS adds \$0.64/kg to the cost of hydrogen from natural gas and \$1.14/kg to the cost of hydrogen from coal

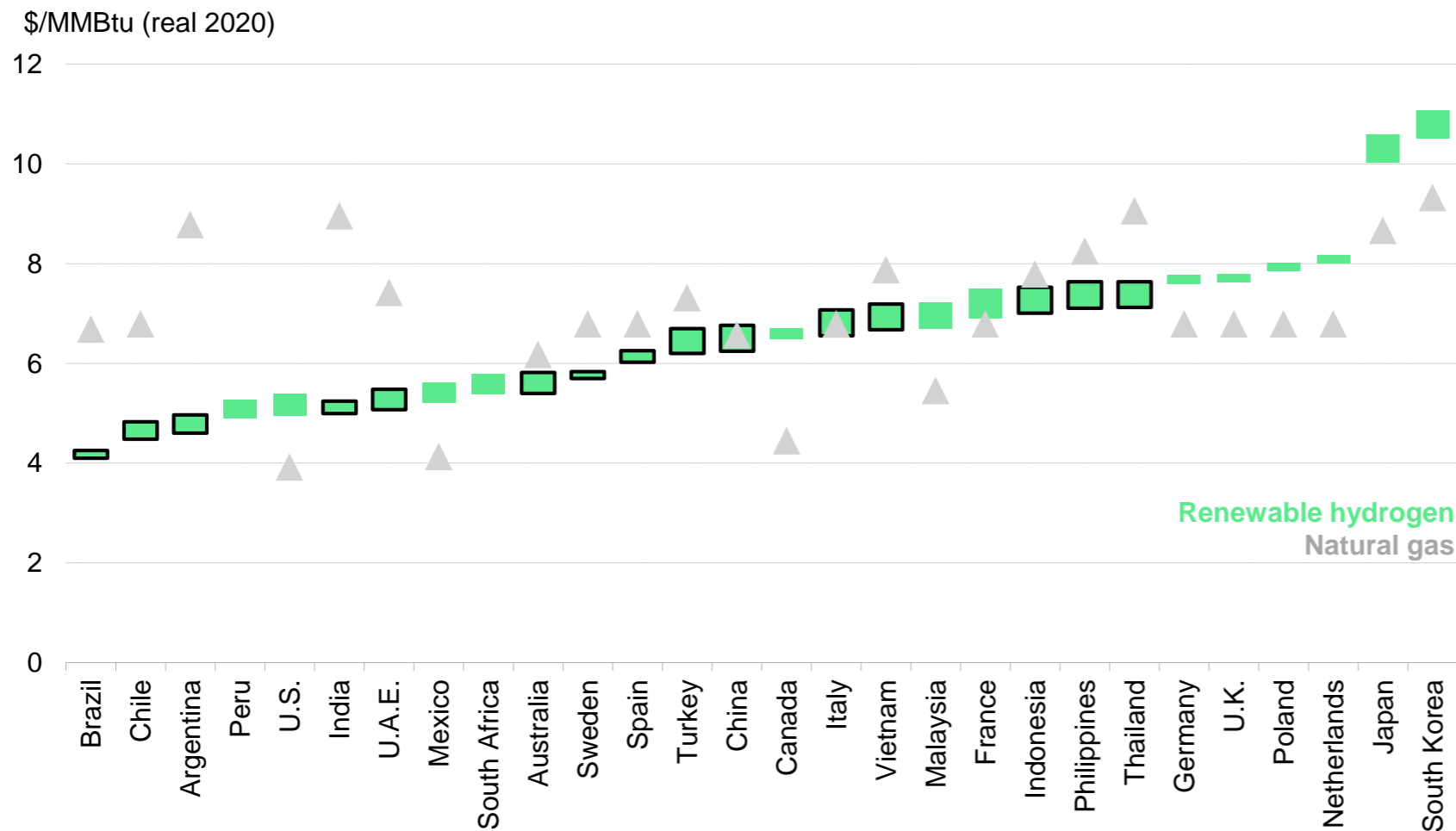
These costs could fall to \$0.53/kg for gas and \$0.85/kg for coal by 2050 if CCS technologies mature.

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.

Renewable hydrogen could be less costly than natural gas in many locations in 2050



Renewable H₂ versus natural gas, 2050



15 countries could make renewable H₂ at a cost lower than the local natural gas price by 2050.

They are Brazil, Chile, Argentina, India, U.A.E., Australia, Sweden, Spain, Turkey, China, Italy, Vietnam, Indonesia, Philippines and Thailand.

These locations are largely places with higher-than-average expected gas prices in 2050

The exceptions are Japan and South Korea – which have high gas prices, and also high renewable production costs – and Australia, which has mid-range gas prices but comparatively cheaper renewable H₂.

Production costs for renewable H₂ could range from \$4.10/MMBtu in Brazil to \$11.07/MMBtu in South Korea by 2050

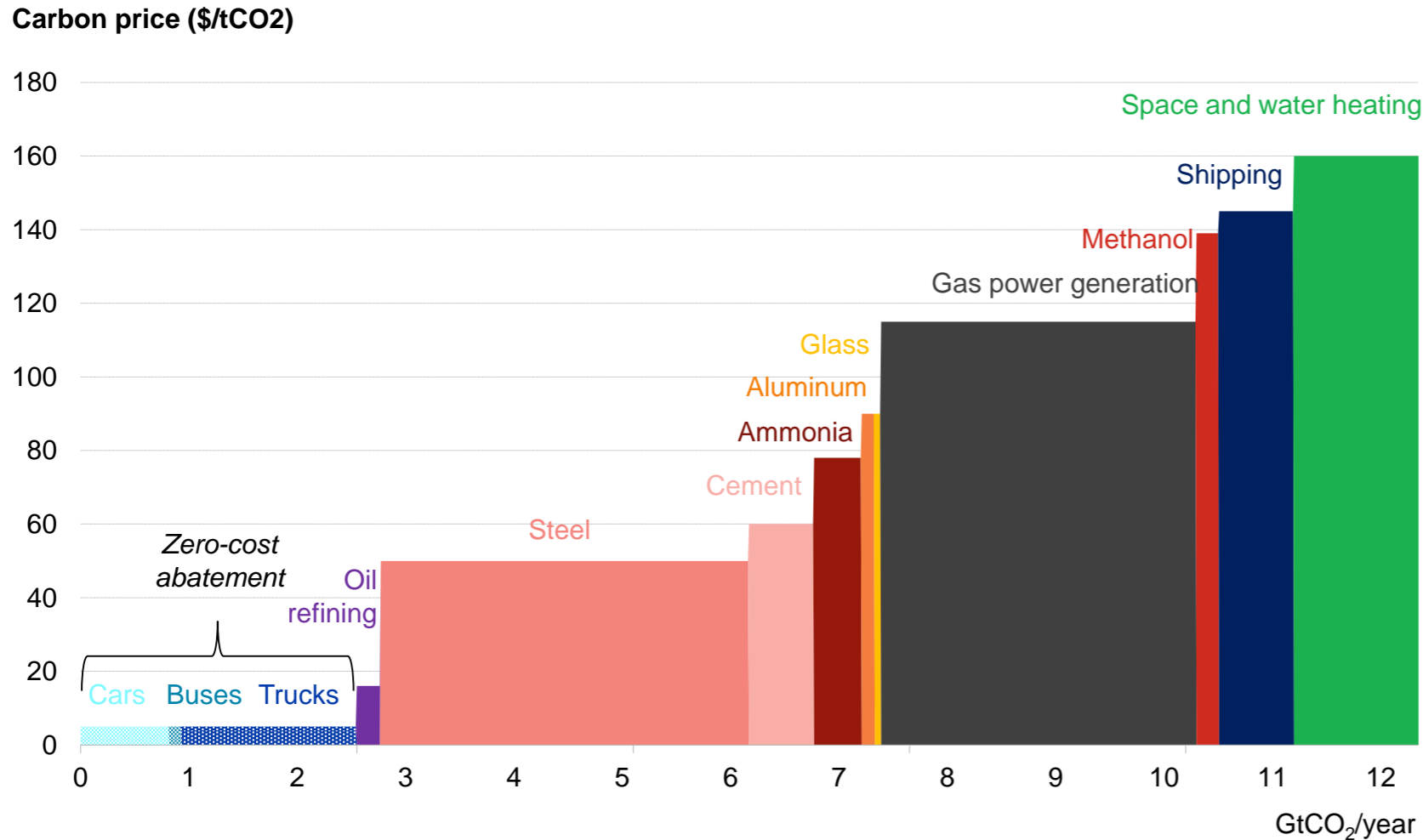
Natural gas prices, in comparison, could be as low as \$3.92/MMBtu in the U.S. and as high as \$9.32/MMBtu in South Korea.

Source: BloombergNEF. Assumes our optimistic electrolyzer cost scenario. The LCOH₂ range reflects a diversity of electrolyzer type, alkaline (low) to PEM (high). The electricity powering the electrolyzer is either PV or onshore wind, whichever is cheaper. The natural gas prices include transportation costs, the H₂ costs do not.

Up to 34% of global emissions could be abated using hydrogen – 20% for less than \$100/tCO₂



Marginal abatement cost curve from using \$1/kg hydrogen for emission reductions in 2050



Hydrogen will need carbon pricing to take off

Almost all industries BNEF has analyzed would require a carbon price for hydrogen to outcompete the cheapest fossil fuel alternative

Carbon prices may not need to be high for hydrogen to be competitive

Hydrogen at \$1/kg (\$7.44/MMBtu) could abate a fifth of global emissions by 2050 with carbon prices less than \$100/tCO₂. We expect such carbon prices to emerge in the EU by 2030.

How hydrogen competes against other zero-carbon alternatives will be key

Other technologies could outcompete hydrogen. While we expect no carbon price may be needed for hydrogen vehicles to outcompete internal combustion engines, battery electric vehicles are likely to be even cheaper, limiting the scope for hydrogen adoption in road transport.

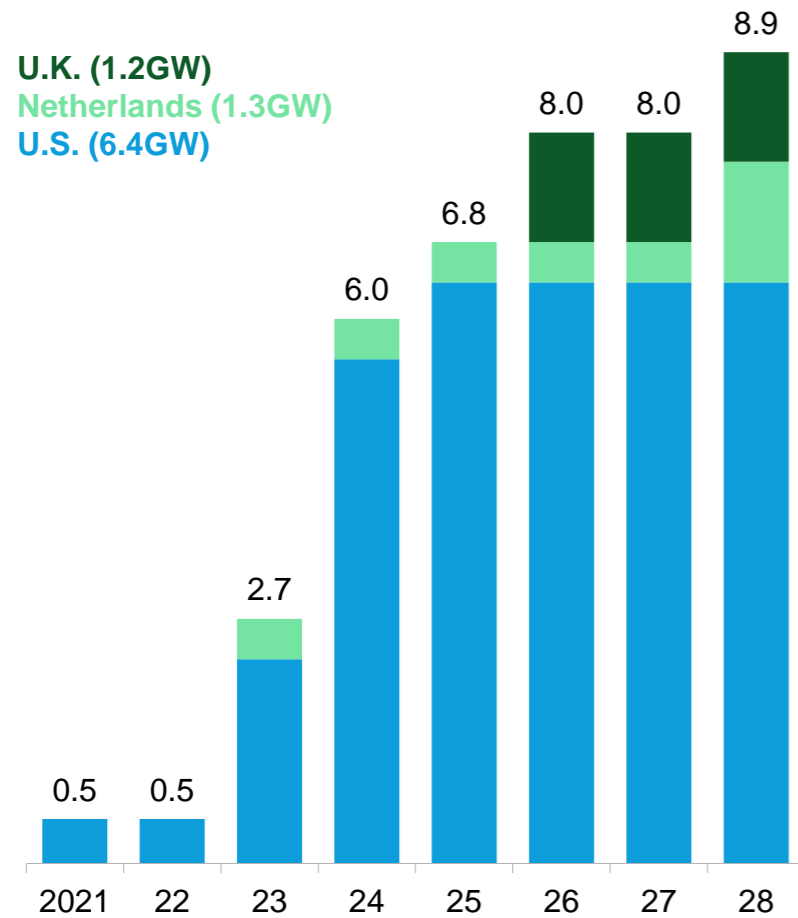
Source: BloombergNEF. Note: sectoral emissions based on 2018 figures. Renewable hydrogen delivered at \$1/kg to large users, \$4/kg to road vehicles. Aluminum emissions for alumina production and aluminum recycling. Cement emissions for process heat. Refinery emissions from hydrogen production. Road transport and heating emissions are for the segment that is unlikely to be met by electrification only, assumed to be 50% of space and water heating, 25% of light-duty, 50% of medium-duty trucks, 30% of buses and 75% of heavy-duty trucks.

Turbine manufacturers have begun work on hydrogen-ready power generation technology

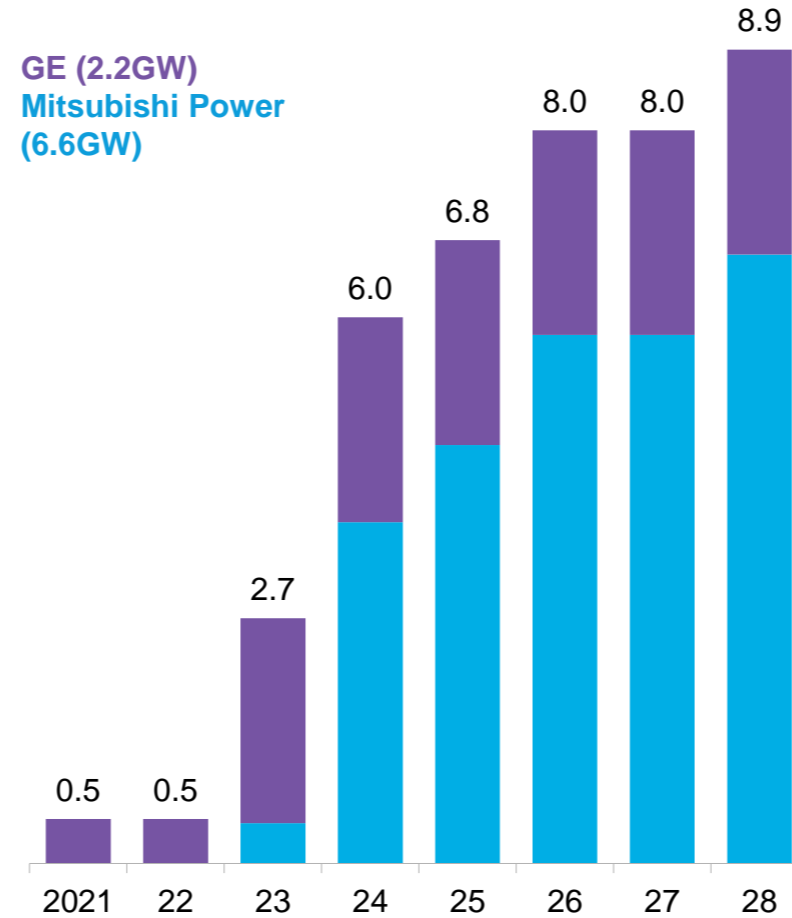


Cumulative announced capacity of H₂-ready power projects by country and manufacturer

Capacity (GW)



Capacity (GW)



Hydrogen could be a key tool in managing such variable renewable energy

Hydrogen can also compete with batteries, whose costs rise quickly with longer-duration storage applications.

Turbine manufacturers have already produced units of up to 50MW that can run on high blends of H₂ at petrochemical sites

The next challenge will be to demonstrate the feasibility of larger-capacity turbine models.

Recent announcements suggest some 8.9GW of hydrogen-ready gas turbines could be operating worldwide by 2028

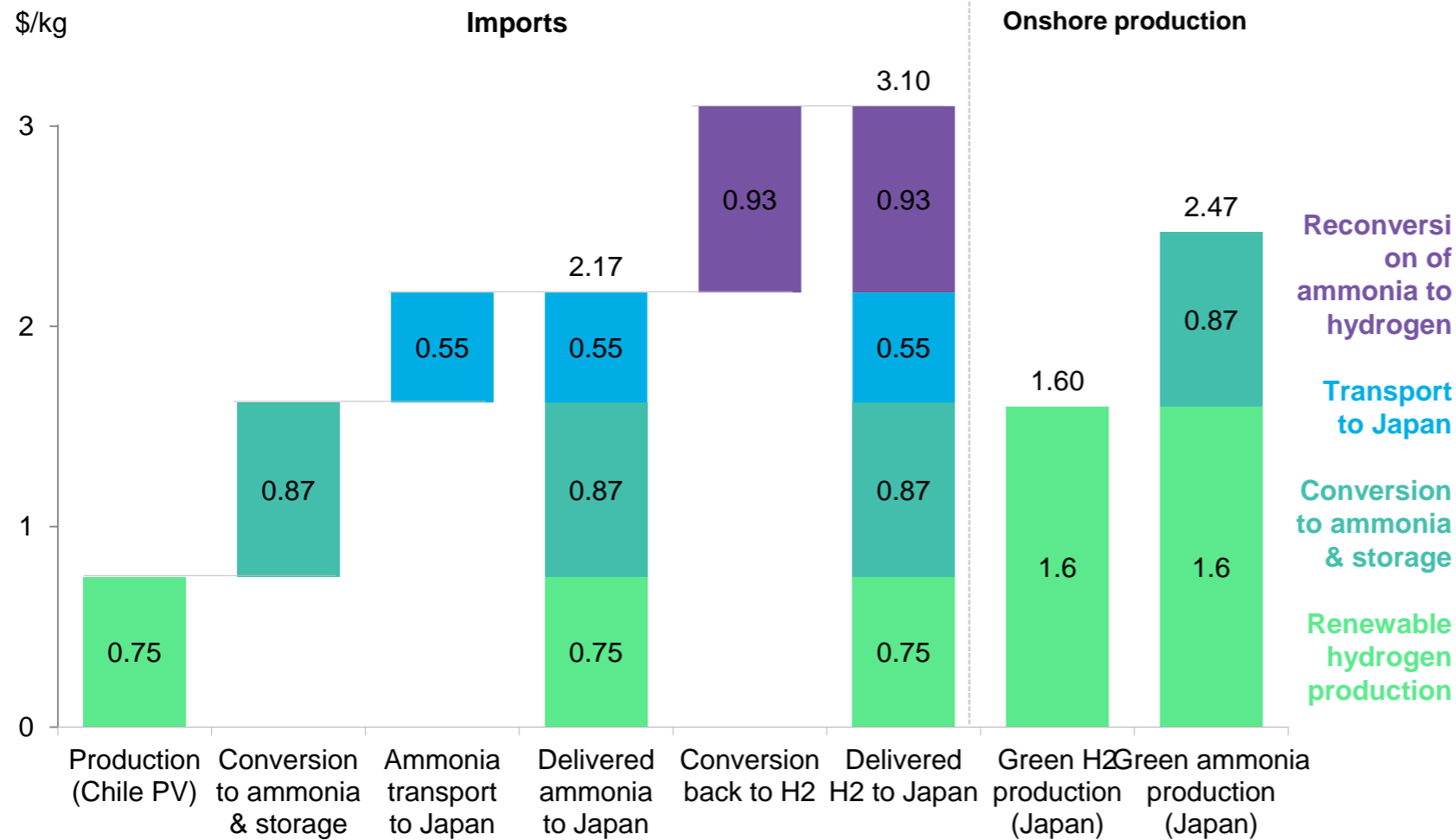
Some of these projects could be commissioned as early as 2021.

Source: BloombergNEF

Seaborne H₂ unlikely to be competitive with local H₂, but ammonia could be a seaborne alternative



Landed cost of H₂ in Japan: seaborne imports from Chile versus onshore production, 2050



BloombergNEF research has identified ammonia as the cheapest method of moving hydrogen by ship, both today and in the future

Ammonia's natural advantage is that a market for shipping it already exists, which means no new technology needs to be developed.

Other methods of hydrogen shipping, would require substantial research and development to become feasible

These include liquid organic hydrogen carriers (LOHC) and liquefied hydrogen (LH₂).

Ammonia's main disadvantage is its toxicity

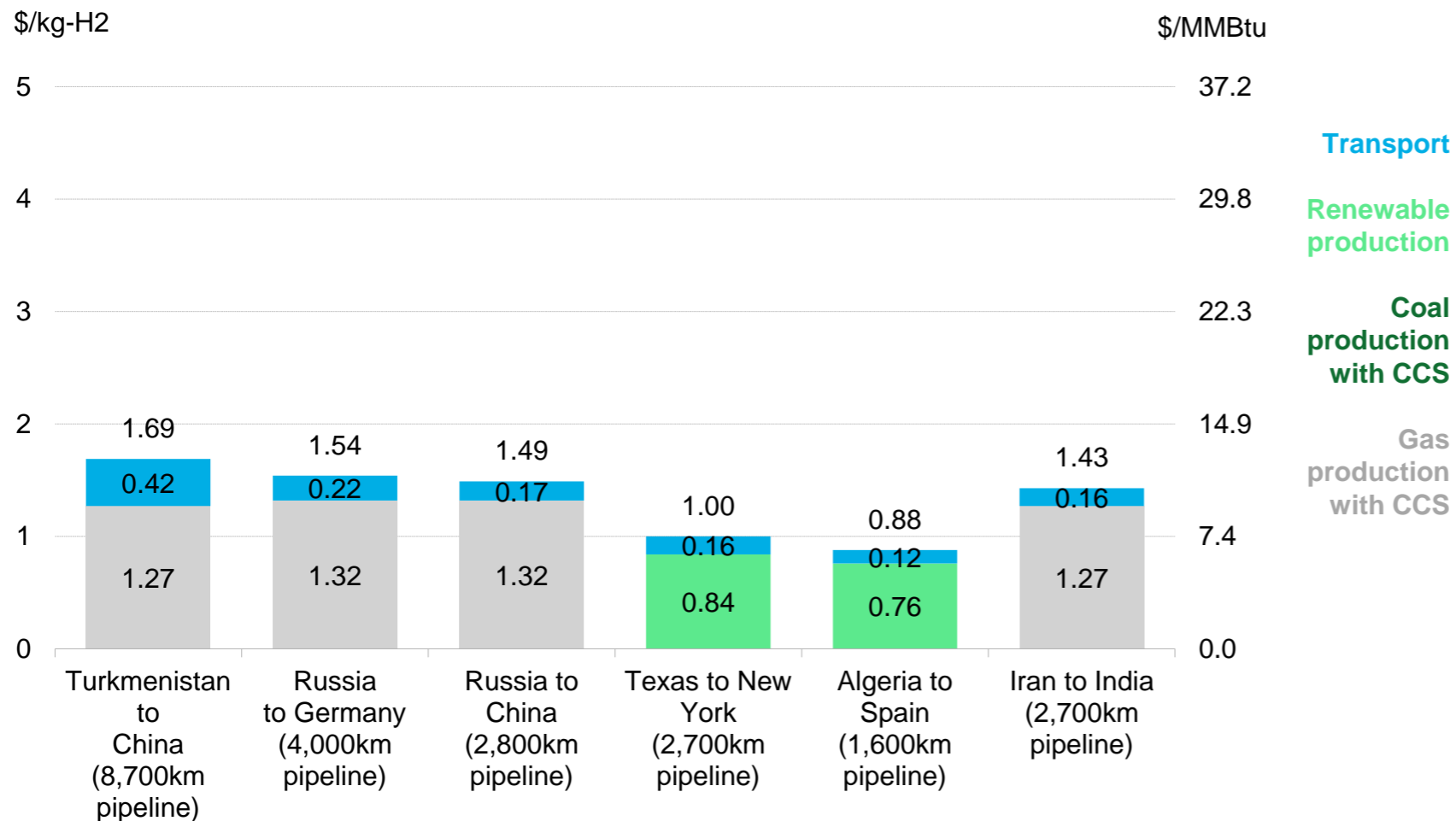
Shipping hydrogen using ammonia as a carrier will require handling with extreme care.

Source: BloombergNEF

Long-distance pipeline hydrogen imports could be as inexpensive as natural gas



Cost of production and long-distance hydrogen transport via high-capacity pipeline, 2050



Pipelines could transport hydrogen a lot cheaper than ships

Large and well-utilized hydrogen pipelines could transport hydrogen for costs that approach those of piping natural gas

Large pipelines could enable long-distance hydrogen supply chains to emerge

If such pipelines are built, they could enable the transport of hydrogen from regions with cheap production costs to more expensive locations, such as from northern Africa to Europe.

Existing natural gas infrastructure could be repurposed for hydrogen

Operators of gas pipelines facing the prospect of a net-zero future are considering the prospects for converting their pipelines to carry hydrogen. Doing so could make hydrogen transport even cheaper.

Source: BloombergNEF. Note: compression and storage costs included in transport. Assumes 6,600t/day pipeline.



Introduction: Energy Transition in 2020

3



Power sector: renewables, integration, storage, grids

8



Transport: electrification, heavy-duty transport

22



Industry: Decarbonizing hard-to-abate sectors, hydrogen

30



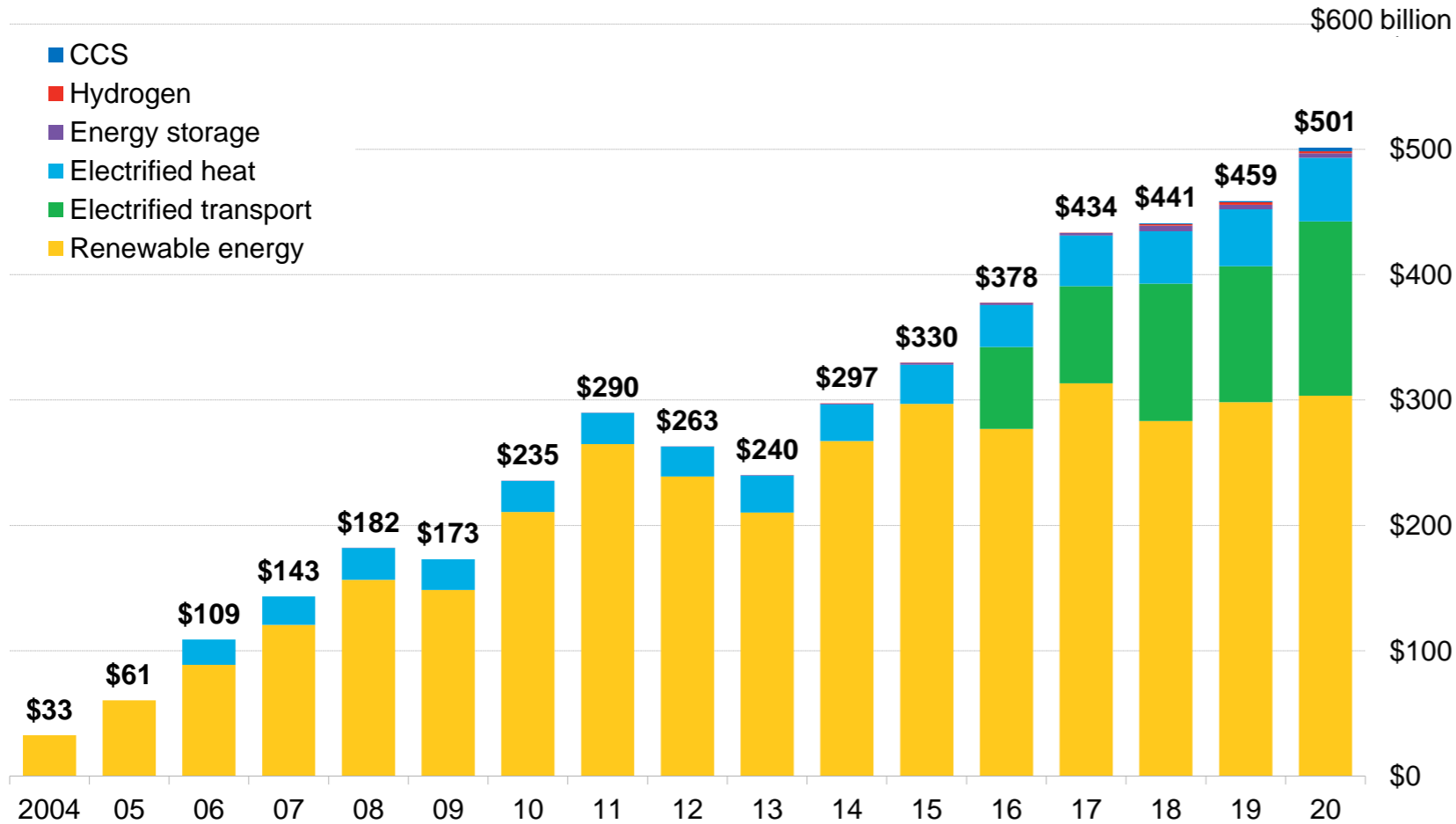
Finance: Asset investment, green bonds, ESG

50

Energy transition investment reached a half a trillion dollars in 2020



Global energy transition investment



Global investment in the energy transition reached half a trillion dollars in 2020

Energy transition investment includes renewable energy, electrified transport, electrified heat, energy storage, hydrogen, and carbon capture and storage.

Renewable energy investment has been flat since 2015, at around \$300 billion per year

However, with equipment costs falling, the amount of capacity built has increased more than 13 times since 2004

Electrification of transport and heat received almost \$200 billion in 2020

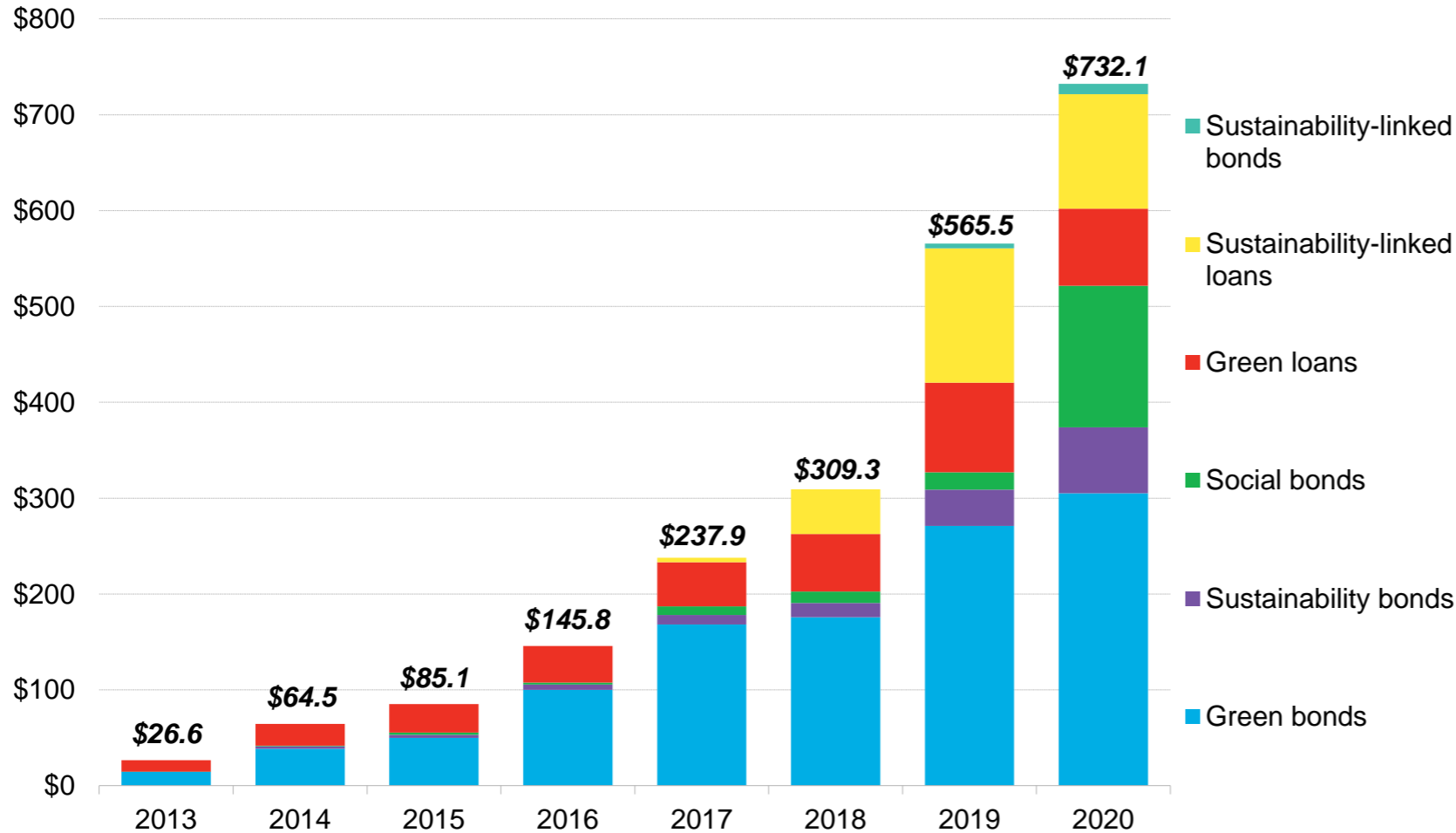
Electrified transport received \$139 billion in 2020, and electrified heat \$50 billion.

Source: BloombergNEF

Companies and institutions raised \$732 billion of sustainable debt in 2020



Sustainable debt issued by instrument type (\$ billion nominal)



Companies and governments raised \$732 billion in sustainable debt in 2020

That is more than \$160 billion above 2019's issuance, an increase of 29% year on year.

As the market grows, it is expanding in scope

Sustainable debt in the early part of the decade was almost entirely activity-based green bonds, specific to assets or projects.

Today, sustainable debt includes activity- and behavior-based instruments

Behavior-based debt includes goals such as reductions in emissions intensity, reducing waste from operations, and improving workforce diversity and safety.

Social bonds had a record year, issuing almost \$150 billion

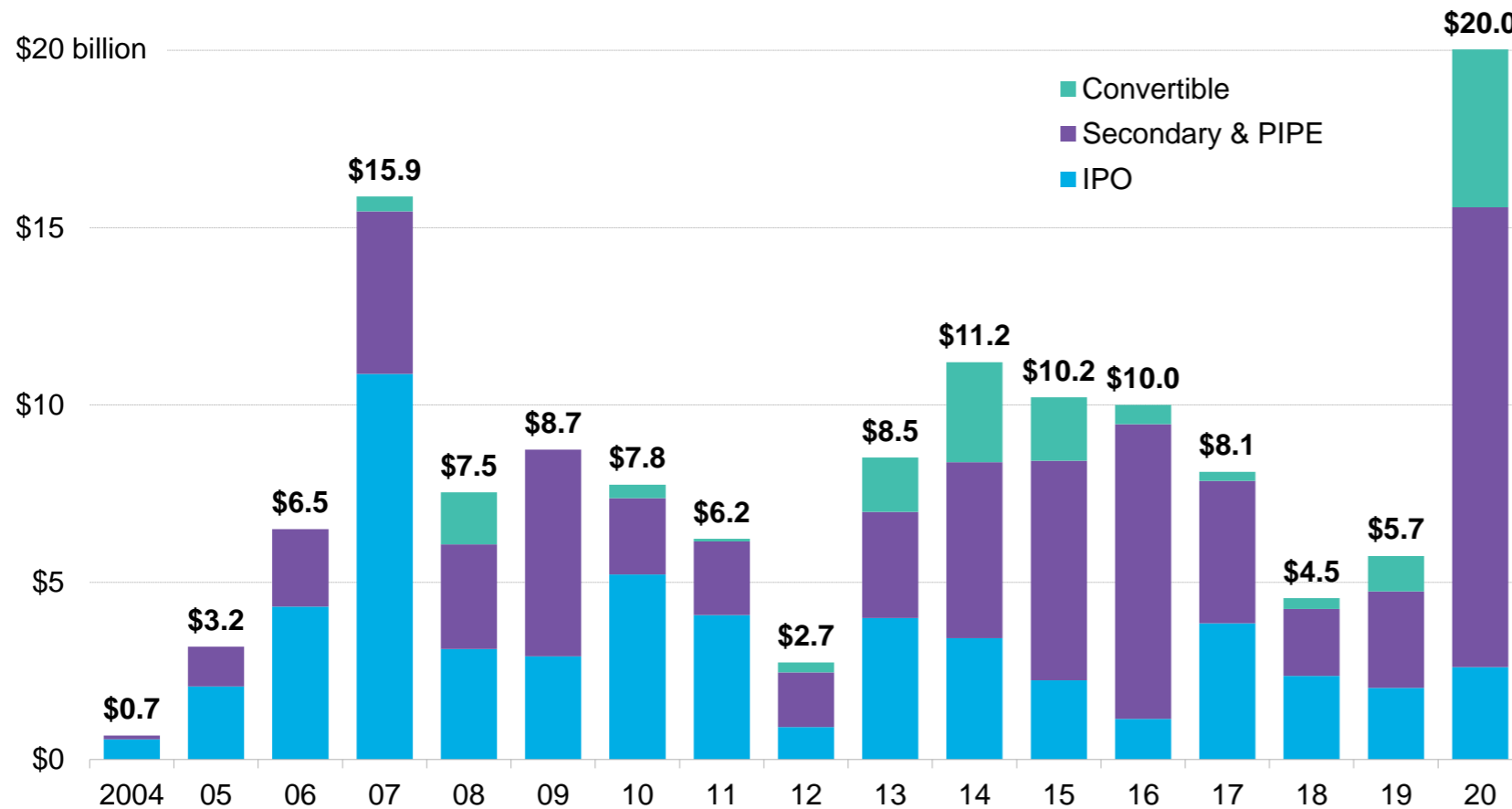
Sustainability bonds, green bonds, and sustainability-linked bonds also hit new records.

Source: BloombergNEF

Renewable energy and storage companies raised a record \$20 billion in public markets in 2020



Renewable energy and energy storage capital raising activity



2020 was a record year in public markets for renewable energy and storage companies

Companies raised \$20 billion via initial public offerings, secondary offerings, private placements, and convertible issuances.

IPOs were the least significant new source of funds; secondaries the most significant

Even without IPO funding, 2020's secondary and convertible funds raised would have made for a record year.

The biggest single deal was \$2.8 billion

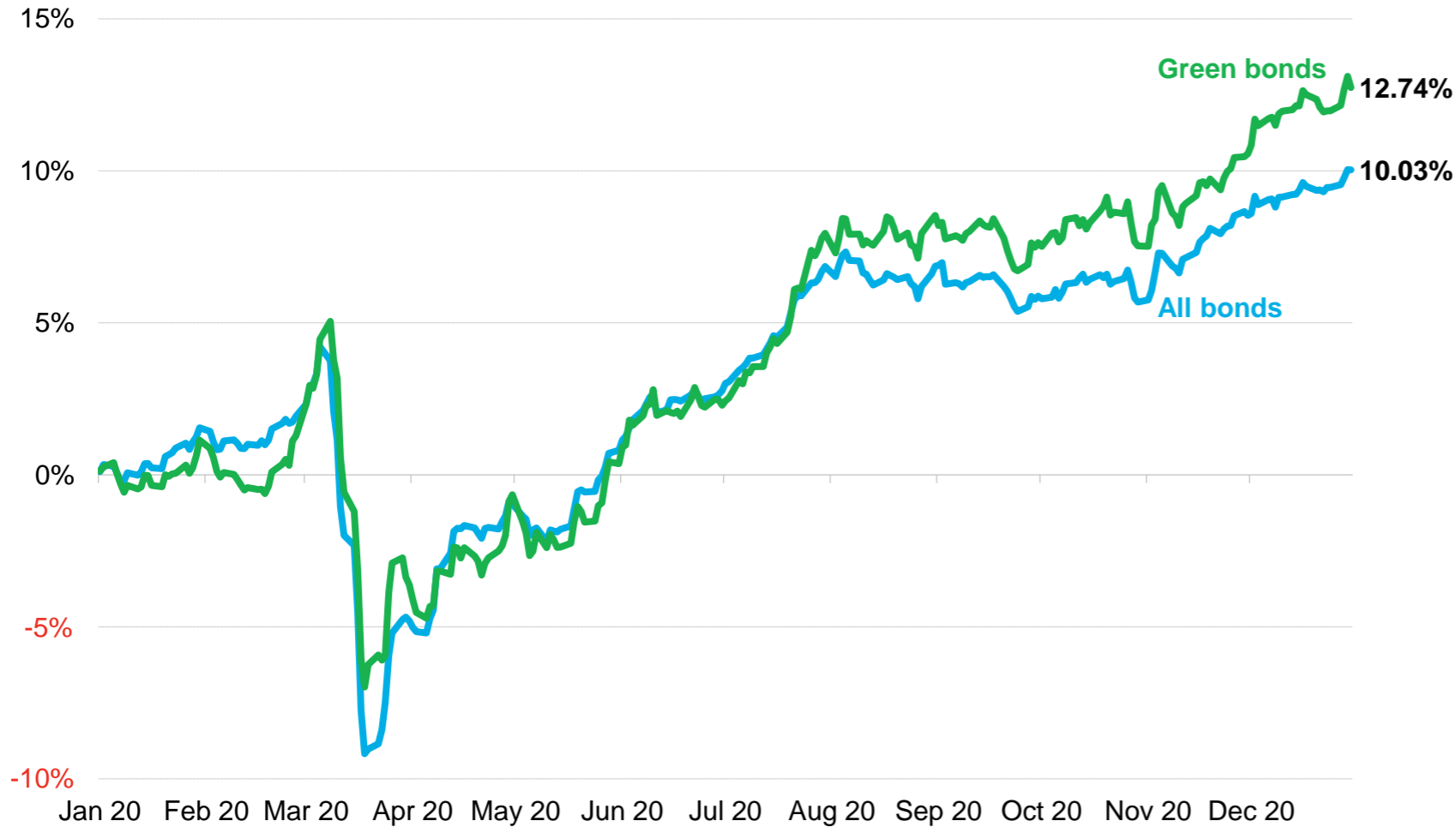
China's Contemporary Amperex Technology (CATL) raised \$2.8 billion. The next largest deals were Plug Power (\$846 million) and JA Solar (\$777 million).

Source: BloombergNEF

Green bonds outperformed global bonds in 2020



Global green bond and all bond performance, 2020



Green bonds outperformed the broader global bond market in 2020

The Bloomberg Barclays MSCI Global Green Bond Index ended the year up 12.74%, while the Bloomberg Barclays Global Aggregate Credit Total Return Index ended the year up 10.03%.

Green bonds declined less in the early days of the Covid-19 pandemic than the broader bond market

Green bonds declined as steeply as the rest of the bond market, but not to the same degree.

Green bonds decoupled from the rest of the bond market in August 2020

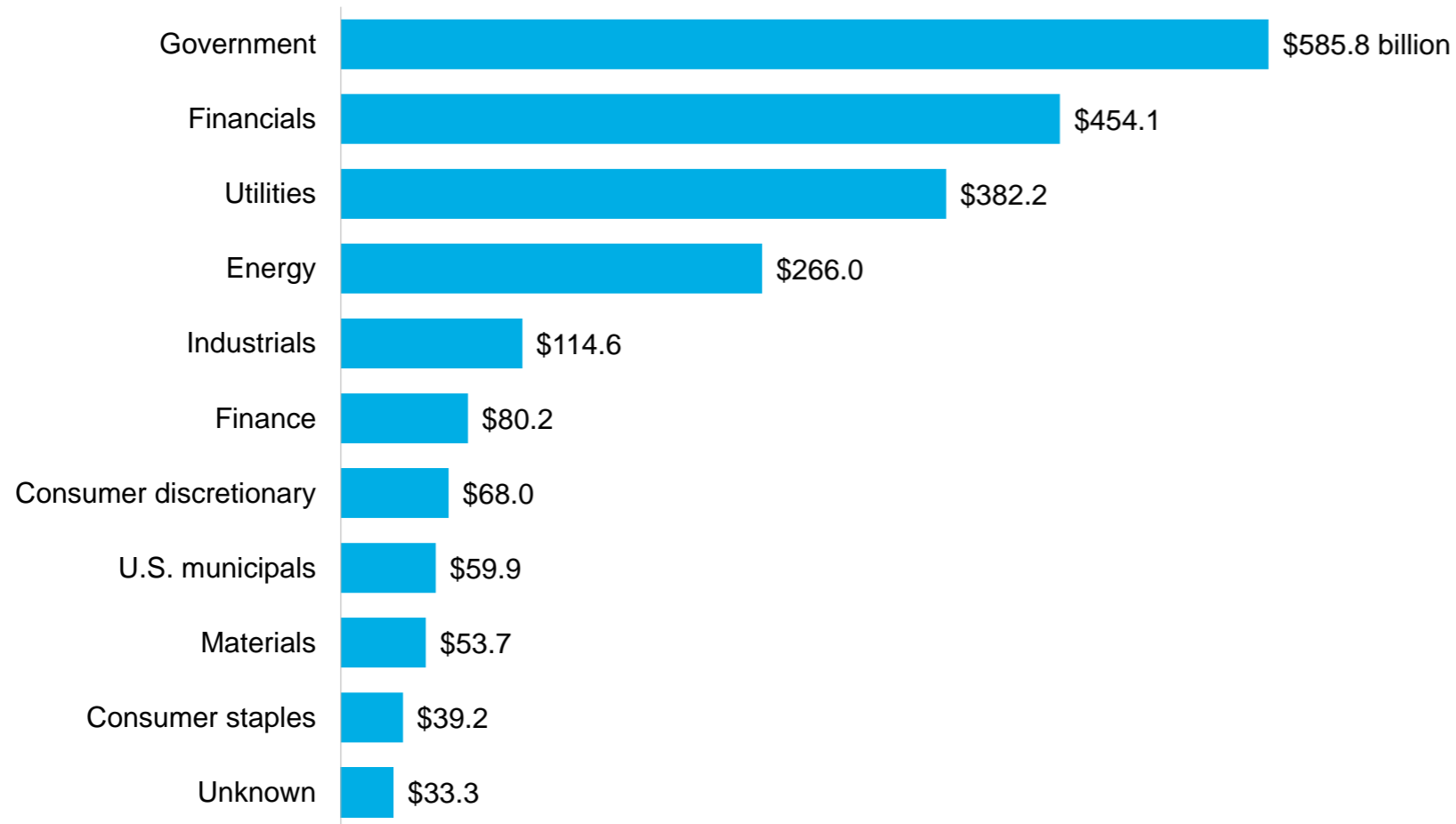
Annual performance was quite closely coupled in mid-summer, with green bonds then pulling away from the rest of the bond market.

Source: Bloomberg

Government agencies, financials, and utilities have issued the bulk of sustainable debt to date



Sustainable debt issued by issuer industry, global, 2012 to 2020



Government agencies, financial institutions, utilities, and energy companies are the largest issuers of sustainable debt

These four sectors have issued more than \$1.6 trillion in sustainable debt since 2012, with government the first sector to issue a half-trillion dollars cumulatively.

Other sectors are much smaller issuers to date

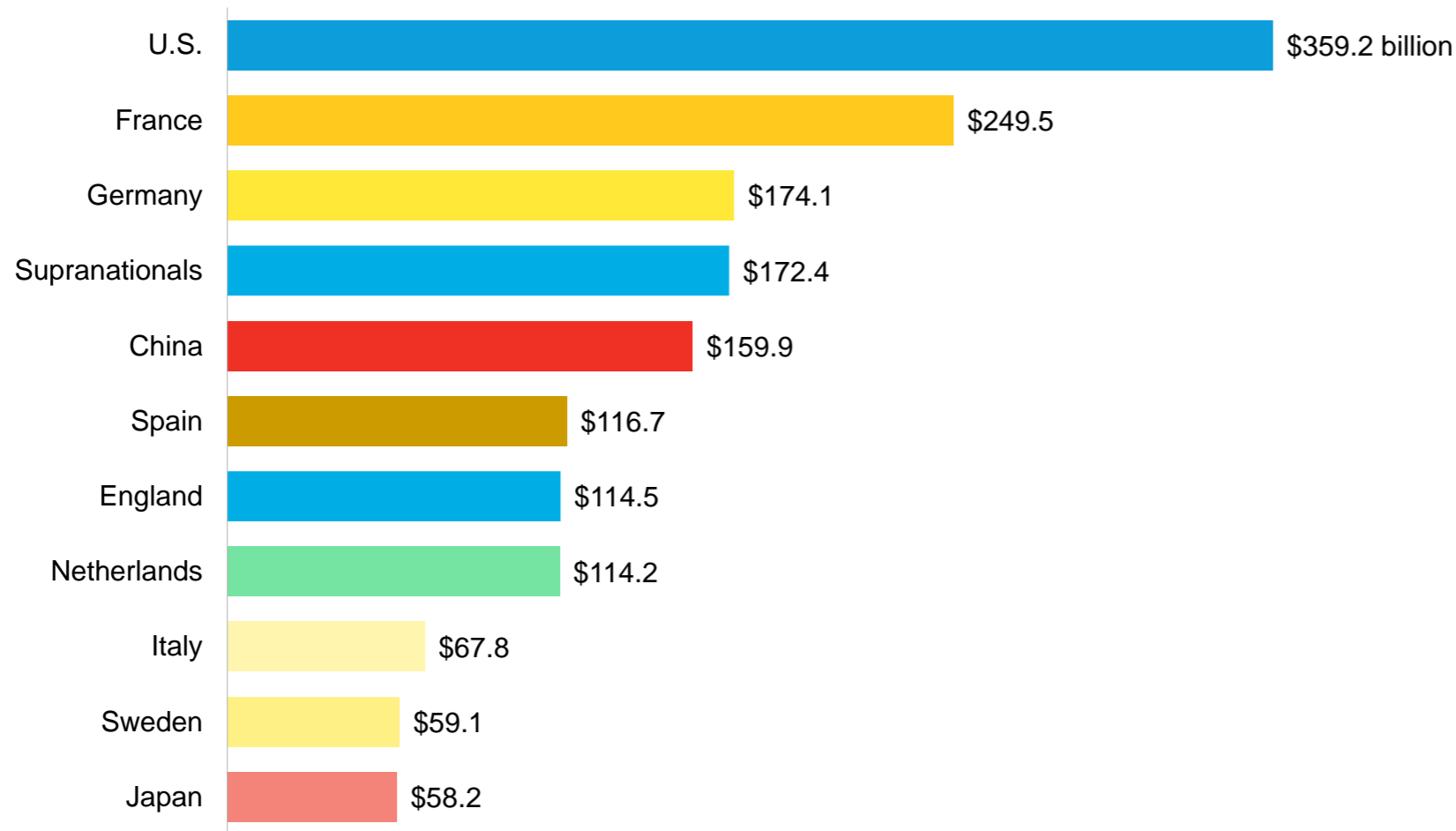
Consumer discretionary, materials, and consumer staples firms have together issued around \$160 billion in sustainable debt. U.S. municipals have issued more sustainable debt than materials companies.

Source: BloombergNEF Sustainable Debt Data Hub [link](#). Note: "Financials" includes banks, insurance, and real estate. "Finance" includes select securitization, namely from the U.S. Federal National Mortgage Association ("Fannie Mae"). "U.S. Municipals" are local governments.

The U.S., France, and Germany are the biggest issuers of sustainable debt



Sustainable debt issued by issuer country, 2012 to 2020



The U.S. has issued the most sustainable debt to date

U.S. issuance of \$359 billion is more than \$100 billion greater than France. The U.S. market is boosted by substantial offerings from municipal bond and asset-backed security issuers.

China, which was the largest issuer in 2016, has slipped in cumulative ranking

China is now fifth in cumulative sustainable debt issuance, and has issued less than supranationals.

Japan is the only other country outside of Europe and the U.S. in the top rankings

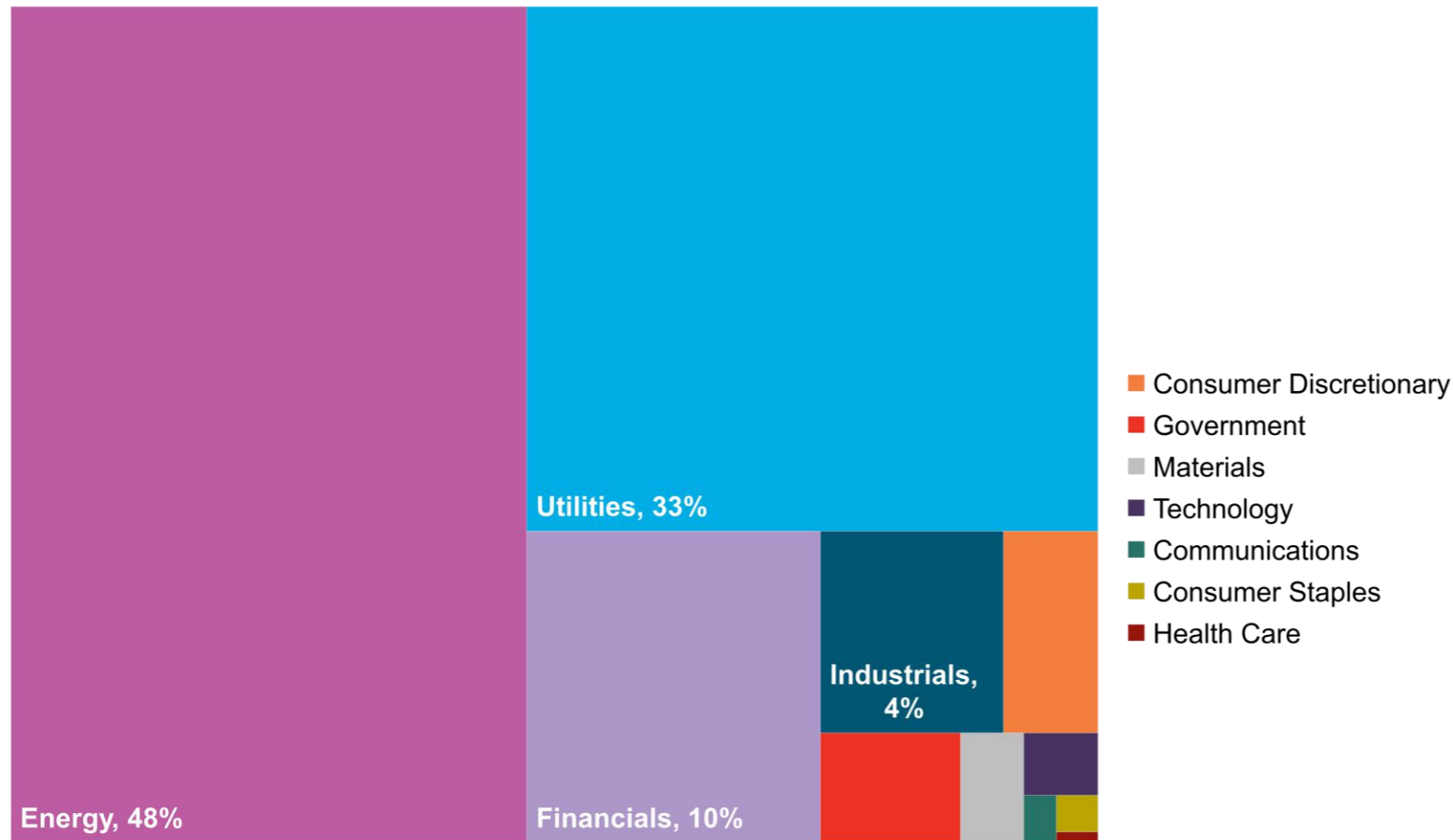
Japan's volume of offerings between 2019 and 2020 grew by about 51%, adding more than \$22 billion.

Source: BloombergNEF Sustainable Debt Data Hub [link](#). Country of risk.

Energy and utilities companies are key issuers of green debt



Green loans by sector



Green loans are dominated by energy and utility issuers

Activity-based debt engages some industries much more than others. Issuers of activity-based debt must have an environmental and/or social project or activity in mind to undertake earmarked debt financing, which limits the pool of potential issuers.

Some \$80 billion in green loans were offered in 2020

Despite volumes between 2019 and 2020 decreasing by 14%, green loans saw hefty volumes offered in 2020.

Utilities are a substantial issuer of green bonds and loans

Utilities are the second most popular sector to issue green loans. Additionally, utilities offered \$40 billion in green bonds in 2020, making them the third most substantial issuing sector of 2020.

Source: BloombergNEF

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