China's Accelerated Decarbonization

Economic benefits

December 1, 2020

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BloombergNEF

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+36%

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53%

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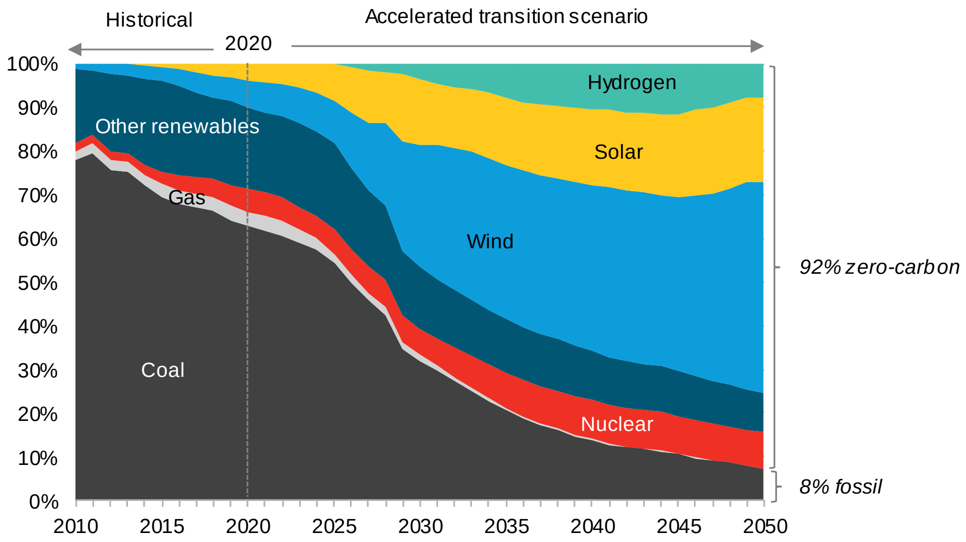
China's recent pledge to achieve carbon neutrality before 2060 has surprised the world. As the world's largest carbon emitter and energy consumer, China's yet-unknown pathway to carbon neutrality is certain to disrupt the globe's energy economy. This white paper examines how accelerated electrification of final energy use in sectors such as industry and road vehicles, coupled with accelerated deployment of renewables, can prepare China to reach its goal.

- China is the world's largest carbon emitter, accounting for 28% of global emissions in 2018. China's path toward carbon neutrality will be no small feat as its energy demand and emissions are still rising. Around 90% of China's emissions come from electricity and heat production, industry, and transport. China can reach peak emissions sooner and increase the speed of reductions thereafter by accelerating decarbonization of the electricity system and electrifying more of the energy demand from road transport and industry.
- This White Paper uses the New Energy Outlook (NEO), BNEF's annual long-term scenario analysis on the future of the energy economy, to consider two scenarios for China: 1) Economic Transition Scenario (ETS), an economics-led scenario that employs a combination of near-term market analysis, least-cost modeling, consumer uptake and trend-based analysis to describe the deployment and diffusion of commercially available technologies; 2) Accelerated Transition Scenario (ATS): building upon the ETS results, post-2023 this scenario considers a higher rate of direct electrification in road transport, buildings and industry, combined with increased uptake of zero-emission electricity supply.

Figure 1: China's electricity generation mix under BNEF's accelerated transition scenario



Source: BloombergNEF

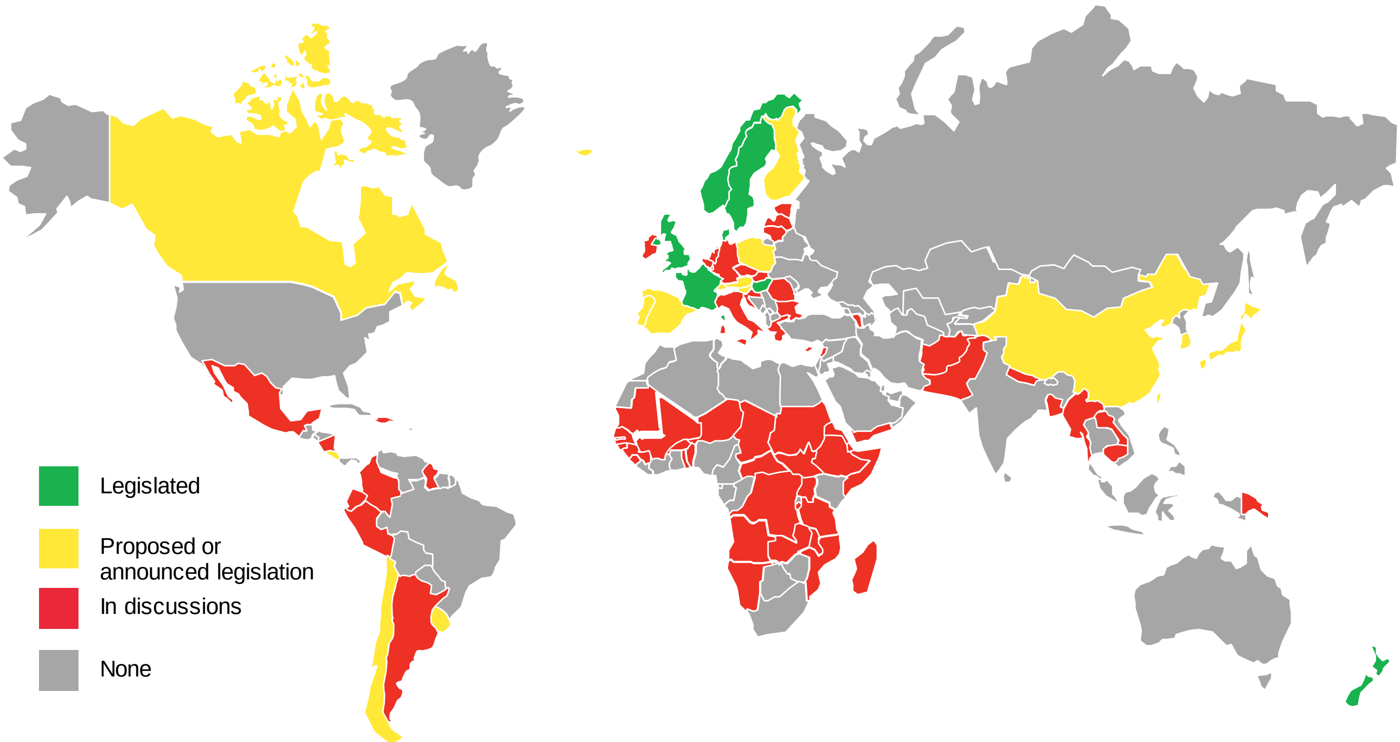
- In the ETS, power demand rises by 55% from 2019 to 2044, reaching 11,287TWh, then declines gradually to 10,788TWh by 2050. In the ATS, due to higher direct electrification of transport, industry and buildings, power demand in 2050 is 36% higher than the ETS, reaching 14,855TWh. Under ATS, electricity demand does not reach a peak prior to 2050. Under ATS, more than 90% of the electricity supply comes from zero-carbon sources dominated by solar and wind, with hydrogen-fueled gas turbines providing balancing needs.
- In the ETS scenario, power sector emissions peak in 2026 and then come down by an average 133 million tons of CO_2 equivalent ($MtCO_2e$) a year until 2050. In the ATS scenario, the peak year is pulled earlier to 2024, and the reduction speed gets faster, at 150 million tons per year, despite electricity in this case contributing 53% of final energy consumption in 2050, around 10 percentage points higher than in the ETS. This makes it much easier for China to reach its carbon neutrality goal by 2060.
- The accelerated transition scenario requires $7.9 trillion worth of investment in electricity generation capacity over the next 30 years, more than double the $3.3 trillion needed under ETS. While China's solar and wind industry are already well-established, a larger market is of course beneficial to their continued growth. More importantly, under ATS, China has the opportunity to use its own domestic market – as it did effectively with solar, battery and EV manufacturing – to achieve global leadership in new technology areas such as hydrogen-fueled gas turbines.

Section 2. Introduction

2.1. China’s carbon neutrality goal

Chinese President Xi Jinping’s September 2020 pledge to “have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060” has ignited strong reactions both at home and abroad. Domestically, policy makers are starting to align broader economic and energy transition priorities as they design the policy blueprint for the next five years and beyond. Globally, China’s climate pledge, followed by similar pledges from Japan and South Korea, has tipped the scale in for bold national climate actions in the run-up to the COP26 in 2021 (Figure 2).

Figure 2: Countries with carbon neutrality targets as of November 2020



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

China is the world’s largest carbon emitter, accounting for 28% of global emissions in 2018. China’s path toward carbon neutrality will be no small feat as its energy demand and emissions are still rising. Understanding the country’s options and the tradeoffs is essential for China to develop a transition pathway that delivers on climate and economic priorities. This white paper uses scenarios developed for BloombergNEF’s New Energy Outlook (NEO 2020) to examine how far China may get in reducing emissions from its electricity system by 2050.

China faces more challenges in reaching its carbon neutrality goal compared to its neighbors Japan and South Korea (Table 1) because its energy demand is growing faster and its emissions intensity is higher. However, China has the advantage of its larger size for renewable energy deployment. And the shared climate goals of China, Japan and Korea provide a unique opportunity for increased collaboration.

Table 1: Comparison of China, Japan and Korea on economy decarbonization readiness

	Factor	China	Japan	South Korea
Energy economy	CO2 emissions per unit of GDP, IEA (2018 values)	0.7 (kg CO2 / $)	0.2 (kg CO2 / $)	0.4 (kg CO2 / $)
	Final energy demand growth, 2009-18, IEA	+35%	-20%	+23%
Electricity	Zero-emissions share of electricity supply, BNEF (2019 values)	33%	29%	34%
	Solar and wind share of electricity supply, BNEF (2019 values)	9%	10%	3%
Road vehicles	Zero tailpipe emission vehicles share of car fleet, BNEF (2019 values)	1.05%	0.25%	0.46%
BNEF view	Technical challenges to achieving net-zero goal	Highest	Lowest	Medium
	Corporate readiness for committing to net-zero goal	Lower	Medium	Lower
	Likelihood of socio-political opposition to net-zero goal	Lowest	Medium	Highest

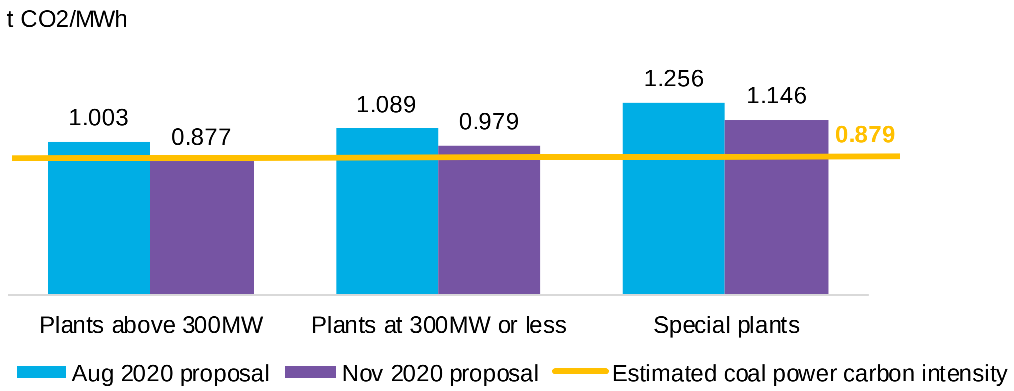
Source: BloombergNEF, International Energy Agency. Note: the colors show relative ranking of the three countries for each ranking, with green marking best, yellow marking middle, and red marking worst among the three.

2.2. China's economic goals

China's leadership wants the country to become a 'moderately developed economy' by 2035, and a 'modern strong nation' by 2050. Though intentionally vague, economists interpret the 2035 goal as a doubling of GDP per capita from 2019, to $20,000-25,000, and a much bigger middle class, with average annual GDP growth of 4-6% in 2021-35. The 2050 goal is to triple the size of the economy from 2019, with a GDP growth rate sliding to 2-4% in 2036-50 (Figure 4).

Recent rising geopolitical tensions and the Covid-19 pandemic have led China's leaders to focus on domestic stability and growth in the short term, and less on the energy transition required to meet China's 2060 goal of carbon neutrality. Current policy language on green development is largely similar to previous rhetoric, with keywords such as 'high quality growth,' 'sustainable development,' 'conventional pollutants reduction' and 'beautiful China' featuring prominently. Their continued presence confirms that environmental protection and low-carbon development remain a policy priority. But more steps need to be taken to turn these policy guidelines into implementation and deliver meaningful impact on achieving carbon neutrality by 2060. For example, China's initial proposal for expanding its carbon-market pilots nationally, released in September, included very generous carbon allowances, thus affecting very few power plants. The second draft, released on November 20, reduced the carbon allowances by about 10%, showing a promising first step in China's climate campaign (Figure 3).

Figure 3: Coal power allowance allocations by plant size and type



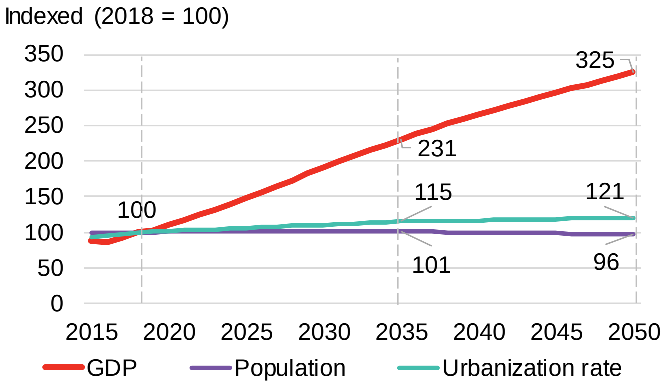
Source: Ministry of Ecology and Environment, China Electricity Council, BloombergNEF. Note: Special plants in the national ETS proposal include circulating fluidized bed (CFB) boilers, and plants burning coal water slurry and coal refuse. These allowances include power consumption by the plants themselves. The national coal power carbon intensity in 2019 is estimated by BNEF, based on the national thermal power carbon intensity and gas power's total generation and carbon intensity.

The struggle between the speed and quality of economic growth has long been a theme in China's development agenda. To make China both wealthier and greener requires the country to seek new growth engines and move away from the traditional energy-intensive drivers such as heavy industries, infrastructure investment, and real estate. China's rapidly aging population also reduces the potential for continued contribution to GDP growth from labor expansion.

China's economy is already shifting gradually away from polluting heavy industry. Domestic consumer spending has increased its share of GDP, surpassing investment and exports to become the biggest growth driver since 2014. As a result, the production growth rate of heavy industry – cement, chemicals and metals – is expected to slow (Figure 5).

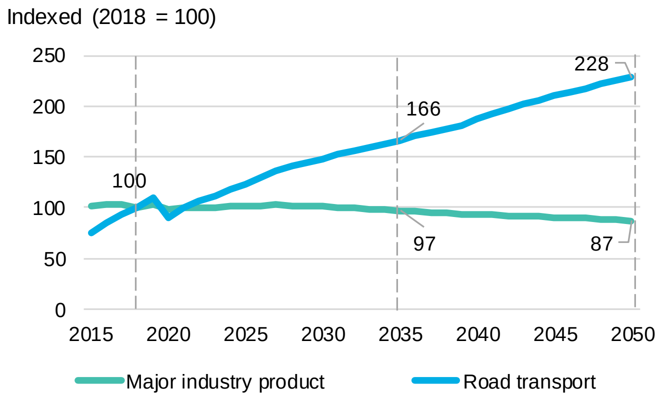
The service sector (referred to as tertiary sector in China's economic statistics) has recorded the highest growth rate compared to the primary (agriculture) and secondary (industry and manufacturing) sectors, and accounted for 54% of national GDP in 2019. Yet manufacturing will still remain an important source of growth and employment in the coming decades. The focus, however, will shift to higher value-added products and segments that depend on technology and innovation, rather than energy and labor. Clean technology manufacturing is a policy priority for China. The country is already the largest manufacturer of solar cells, lithium-ion batteries and electric vehicles.

Figure 4: Growth expectation for GDP, population, energy demand, and urbanization rate



Source: World Bank, China State Information Centre, BloombergNEF.

Figure 5: Expected demand for major industry products and road transport.

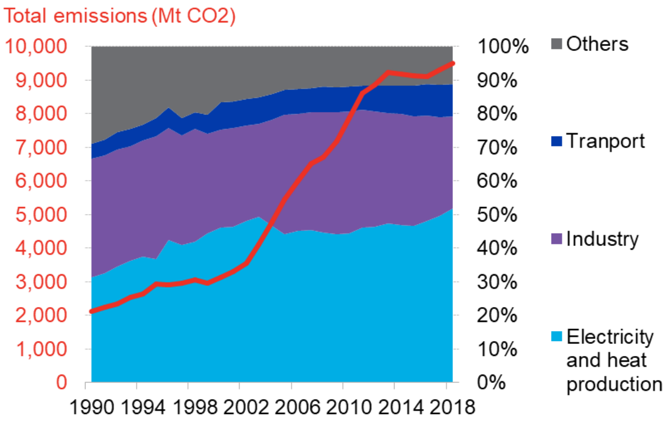


Source: BloombergNEF. Note: major industry product includes steel, cement, and aluminum. The units are kilotons for industrial products, and vehicle-kilometers for road transport.

2.3. The case for accelerated decarbonization of power

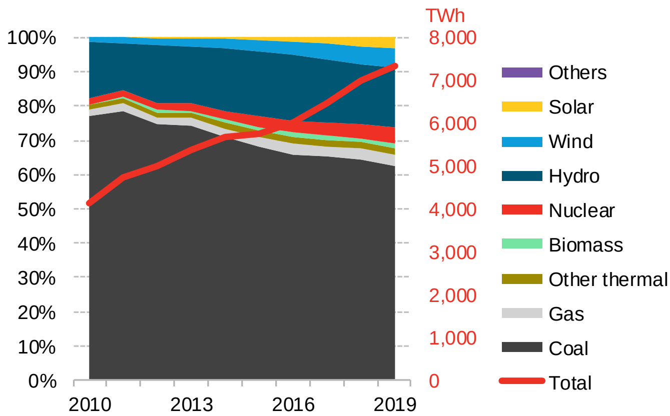
BNEF expects China is on track to reach peak emissions before 2030 from all the major emitting sectors, without any new policy changes. Around 90% of China's emissions (Figure 6) come from electricity and heat production, industry, and transport. Industry emissions peaked in 2012 and have been on the decline due to increased material recycling, improved energy efficiency and coal-to-gas switching. Emissions from electricity and heat production as well as the transport sectors have yet to peak. China can shorten the time to reach peak emissions as well as increase the speed of emissions reductions thereafter by accelerating decarbonization of the electricity system and electrifying more of the demand for energy from road transport and industry.

Figure 6: China's historical carbon emissions by sector



Source: IEA, BloombergNEF. Note: the data is for mainland China.

Figure 7: China electricity generation historical mix, 2010-19



Source: China Electricity Council, BloombergNEF

Section 3. Scenarios and results

3.1. Accelerated and economic transition scenario

This White Paper considers two scenarios that describe changes in China's power sector out to 2050.

- The **Economic Transition Scenario (ETS)** is BNEF's core economics-led scenario as previously published in the New Energy Outlook (NEO). It employs a combination of near-term market analysis, least-cost modeling, consumer uptake and trend-based analysis to describe the deployment and diffusion of commercially available technologies. Most importantly, it does not assume medium- or long-term policy targets are met and removes existing policy incentives once they have run their course.
- The **Accelerated Transition Scenario (ATS)** builds upon the ETS results, to describe a higher rate of direct electrification in road transport, buildings and industry, and greater uptake of zero-emission electricity supply that results in 92% zero-carbon power by 2050.

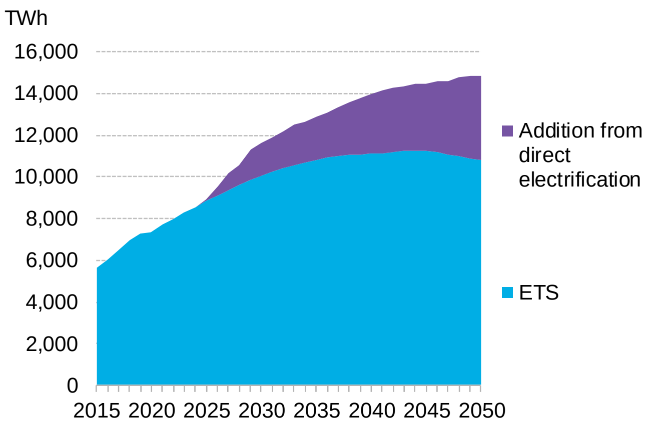
By comparing the two scenarios, we explore major questions of China's potential pathways:

- How much investment is needed, and in what technologies, to deliver the emissions reductions in the power sector consistent with China's decarbonization targets
- What scale of transformation and which technology options can deliver the goal
- What China-specific hurdles might slow down the country's decarbonization

3.2. Demand

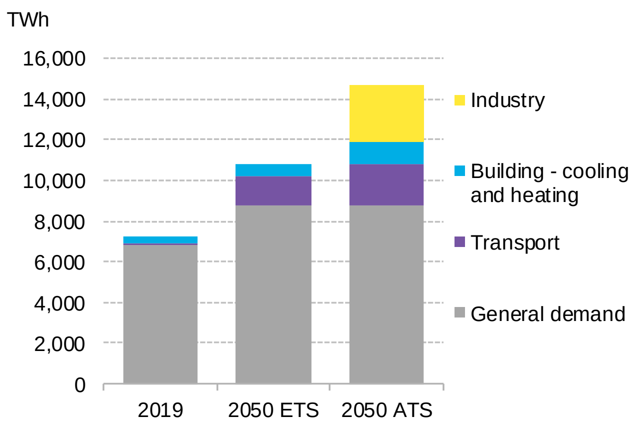
In the Economic Transition Scenario (ETS), power demand rises by 55% from 2019 to 2044, reaching 11,287TWh, then declines gradually to 10,788TWh by 2050. In the Accelerated Transition Scenario (ATS), due to higher direct electrification of transport, industry and buildings, power demand in 2050 is 36% higher than the ETS, reaching 14,855TWh (Figure 8 and Figure 9). Under this scenario, electricity demand in China continues to grow out to 2050, whereas in the ETS demand peaks in 2044, when electricity intensity improvement outpaces economic growth.

Figure 8: Power demand in the ATS



Source: BloombergNEF

Figure 9: Power demand distribution in the ETS vs the ATS



Source: BloombergNEF

Road transport

In the Economic Transition Scenario, annual electricity demand from electric vehicles increases 16-fold relative 2019, to reach 1,385TWh in 2050. Under the Accelerated Transition Scenario, electricity demand from EV charging in 2050 is 42% higher than ETS, reaching 1,968TWh in 2050, when EV charging accounts for 17% of total power demand.

China is already leading the world on electrification of road vehicles. By 2050, under ETS (Table 2), China's fleet of two-wheelers, cars, light commercial vehicles and buses are already mostly electrified. Under the Accelerated Transition Scenario, we assume the remainder of road vehicles are almost all electrified, with select segments such as long-haul heavy-duty commercial vehicles relying on hydrogen.

Table 2: Electrification rate of China's road vehicle fleet in 2050 under the ETS

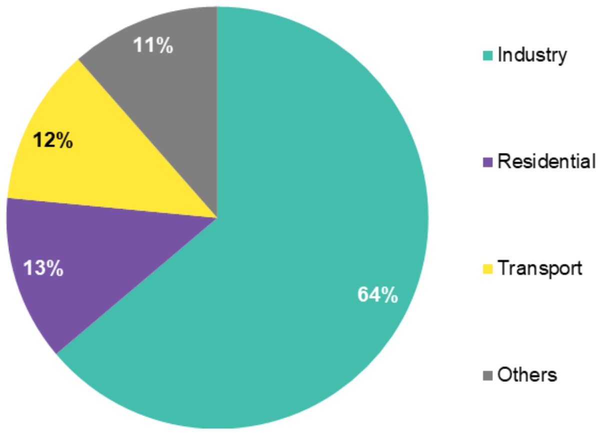
Sub-sector	Electrification rate
Two-wheeler	100%
Bus	78%
Private car	77%
Light commercial	66%
Medium commercial	48%
Heavy commercial	22%

Source: BloombergNEF

Industry

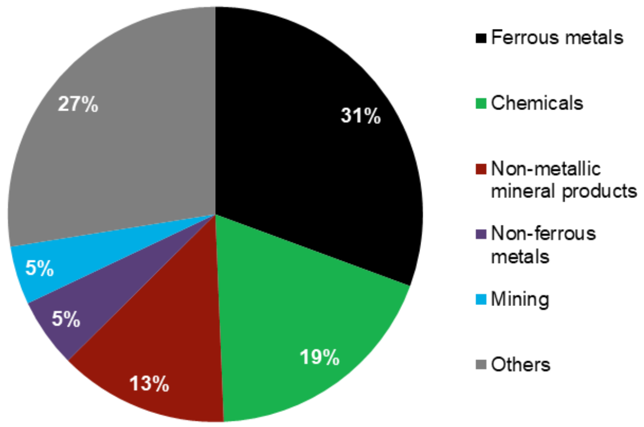
Industry accounts for 64% of China's final energy demand (Figure 10). China's industrial carbon emissions have been declining since 2012, but industrial sectors still accounted for over a quarter of total emissions, or 2.6 gigatons of CO2 equivalent, in 2018. The manufacturing of steel, non-ferrous metals like aluminum and copper, chemicals and cement are the biggest emitters, accounting for 90% of industrial energy consumption. The 14% decline of carbon emissions from industrials from 2012 to 2018 was primarily driven by increased efficiency and, to a lesser extent, coal-to-gas switching. Efficiency improvements made a significant contribution to the decline in total emissions, with energy intensity dropping by 6-11% for key industrial products like steel and cement from 2010-17. Primary aluminum energy intensity dropped from 75GJ/ton to almost 65 GJ/ton on average, similarly primary steel energy intensity declined from 15GJ/t to 12GJ/t. Despite very limited coal-to-gas switching in the metals sector – which accounts for 58% of industrial energy consumption – industrial coal consumption peaked in 2011, thanks to increased natural gas usage by other industrial applications. Increased recycled material usage also helped. The government has set strict targets for increased recycling. Recycled aluminum needs to make up 27% of aluminum supply in 2025 and 30% by 2030, up from about 20% currently. By 2030, scrap steel recovery increases to 250-320 million metric tons, or about 29% of production, up from 15% today. We have accounted for these changes under the Economic Transition Scenario.

Figure 10: China's final energy consumption by sector, 2017



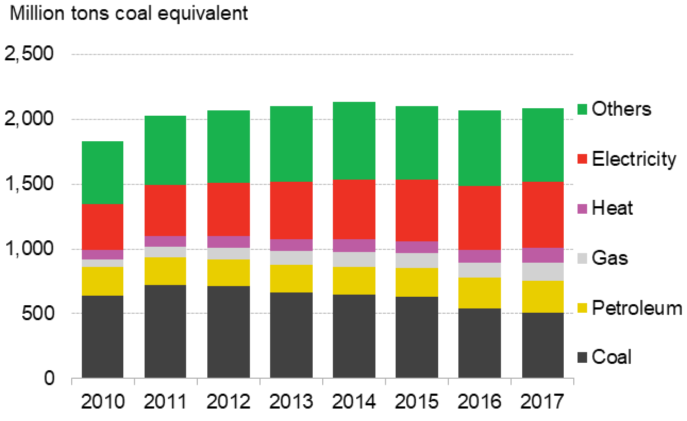
Source: China Energy Statistical Yearbook

Figure 11: China's industrial sector final energy consumption by subsector, 2017



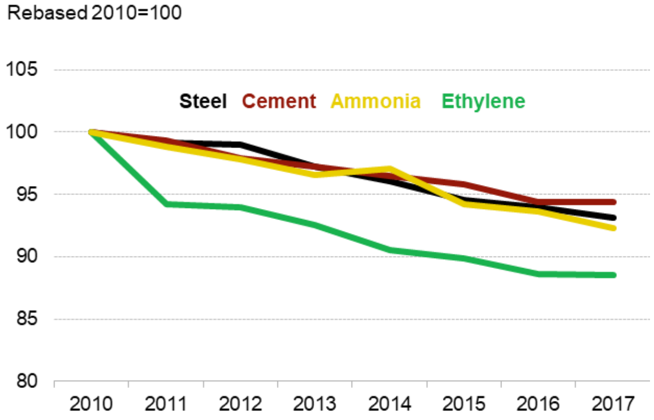
Source: China Energy Statistical Yearbook

Figure 12: Industry energy consumption by fuel type in China



Source: China Energy Statistical Yearbook, BloombergNEF

Figure 13: Energy intensity of key materials production in China



Source: Industry associations, China Energy Statistical Yearbook, BloombergNEF

Under the Accelerated Transition Scenario, additional electricity demand from industrial electrification reaches 2,806TWh, or 24% of total demand in 2050. In the same scenario, steel and aluminum production reach over 50% recycling rates.

Building

Electricity now supplies about 20% of building final energy consumption in China, mainly supported by home appliances and air conditioners. Electric HVAC systems have faster uptake in warmer southern China, as district heating is widely available in northern China.

In the Economic Transition Scenario, AC's penetration continues to grow, but electric heat pumps play a minimal role throughout our model period due to lack of cost-competitiveness. In the ATS, we assume heating currently provided by direct fossil-fuel use gets displaced by heat pumps and direct electric heaters, further adding to electricity demand.

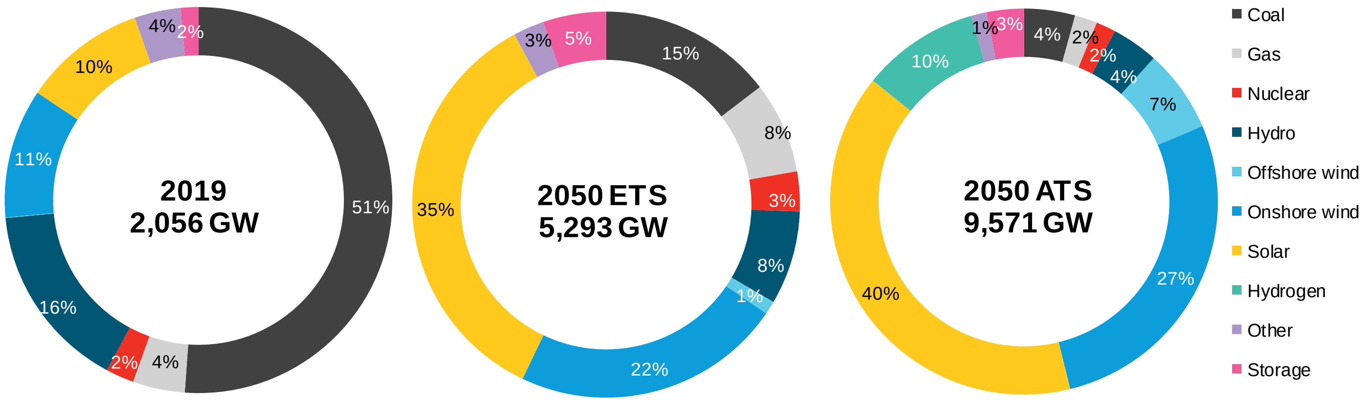
3.3. Power supply

Power generation capacity grows 2.5 times from 2019 to 2050 in the Economic Transition Scenario, rising from 2,056GW to 5,293GW. To meet the additional 36% of demand in Accelerated Transition Scenario, the power system needs to be expanded 1.8 times from the ETS and reaches 9,571GW (Figure 9), as we have prioritized zero-emission sources such as solar and wind, which have lower capacity factors.

Wind and solar account for 58% of total capacity in the ETS and 74% in the ATS in 2050. Total wind capacity grows nearly threefold from the ETS (1,253GW) to the ATS (3,680GW), while solar increases by a smaller 2.3 times (from 1,856GW to 4,226GW) despite having the lowest levelized cost of electricity in most parts of the country. The difference between wind and solar growth has to do with generation- and demand-profile matching, for which wind overall is better suited as it can generate during all 24 hours. In the ATS scenario, electrification in industrial activities tends to increase around-the-clock electricity demand, creating more opportunities for wind as a result.

Cumulative offshore wind installation in 2050 in the ATS (740GW) is almost 13 times that of the ETS (59GW). Most of the incremental power demand comes from the developed regions in the coastal and central part of the country. Currently, inter-regional transmission lines have played an important role in China's power system, as they connect these areas to energy-rich inland regions. In the ATS, we do not assume additional inter-regional transmission capacity is built, meaning that the high-demand areas need to be more self-sufficient in power supply. This results in much higher offshore wind build in the ATS due to the limited land availability for onshore wind.

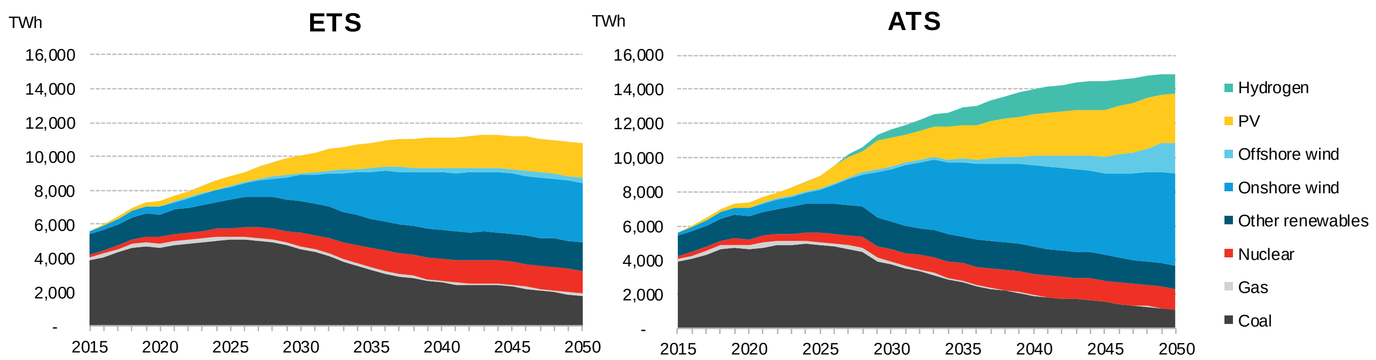
Figure 14: Installed capacity comparison



Source: BloombergNEF. Note: storage include batteries and pumped hydro stations.

Wind and PV contribute about 10% of total generation today, and this increases to 54% in the ETS and 66% in the ATS in 2050, pushing the zero-carbon generation to 82% and 92%. China remains dependent on fossil generation for 18% of all power demand in the ETS in 2050 (Figure 15). With higher generation penetration from wind and PV, this number further decreases to 8%. The remaining fossil generation mainly comes from coal in both scenarios. Gas generation contributes only 1% of total generation in the ETS in 2050 due to its very low capacity factor. In the ATS, natural gas demand from the power sector becomes negligible as hydrogen-fueled turbines replace the balancing role played by natural gas-fueled turbines.

Figure 15: Power generation comparison



Source: BloombergNEF. Note: other renewables include hydro, biomass, and solar thermal.

Section 4. Paving the way for an accelerated transition

4.1. Enabling market dynamics to deepen renewable penetration

In the Accelerated Transition Scenario, China's wind and PV generation reaches 10,882TWh, or 66% of total generation, by 2050. This is 17 times larger than what wind and PV produce today. This scale-up would require the right price signals to attract more and diverse investors, and new market designs to increase the efficiency of transition policies

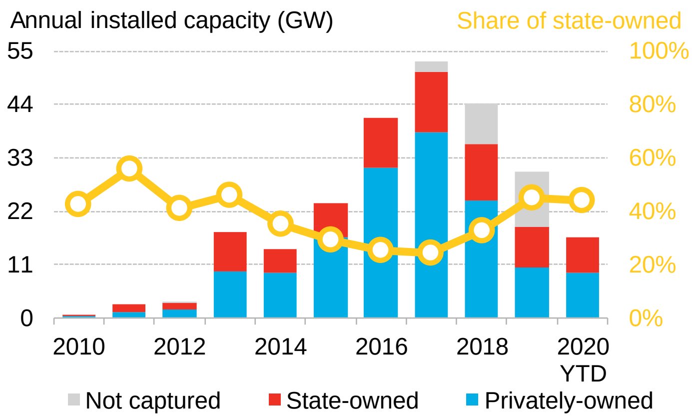
Revenue predictability is key for renewables' upscale

China's top leaders have expressed a strong desire to have markets play 'decisive roles' in allocating economic resources since 2013, in a bid to reduce government responsibilities to medium- and long-term goal setting rather than the near-term operations of the power system, and increase economic efficiency as a result. An ongoing power-market reform that started in 2015 aims to uproot the legacy planned dispatch system, replacing it with liberalized markets for power purchase agreements, spot power trading, ancillary services and more. New types of market-oriented tools, such as renewable portfolio standards, renewable energy auctions and national carbon markets, have also been put in place to provide new drivers for decarbonization and to help price discovery.

The shift to more market-based mechanisms has brought uncertainties to renewable energy revenue structures. The expansion of liberalized power markets has partially overruled the legacy feed-in premium (FiP) scheme that offers fixed-revenue for most existing wind and solar assets. Deregulated trading for their output – at price discounts – now spans across 19 of China's 31 provinces. The lack of revenue clarity also exists in more recent schemes for new projects, like renewables auctions and 'subsidy-free' pilots, raising questions on how investment decisions can be made to scale deployment.

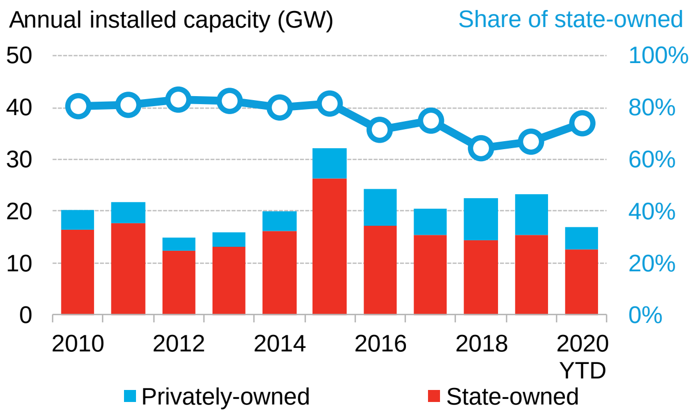
These revenue risks are particularly discouraging for private company investment decisions. State-owned companies may be mobilized purely by government mandate and enjoy low financing costs to cushion risks. China will need both state firms and private investors to help with an accelerated renewable buildout, especially on solar investments. Private companies have accounted for more than half of annual solar installations every year since 2012. That role peaked in 2017, when private companies played the dominant role in pushing new installations to a record high of 53GW, building 78% of new projects (Figure 16). Policy changes introducing more uncertainties have forced a reversal of this trend in recent years. The role of state-owned companies is considerably more important in the wind sector, however, the impact of policy uncertainty on private-sector activity in the sector is similar over 2018-2020 (Figure 17).

Figure 16: China annual new solar installations, state-owned versus privately owned asset owners



Source: BloombergNEF. Notes: share based on BloombergNEF project database (web). 'Not captured' shows gaps between BNEF data and official reporting. Capacity is AC. Data as of November 15, 2020.

Figure 17: China annual new wind installations, state-owned versus privately owned asset owners



Source: BloombergNEF. Notes: share based on BloombergNEF project database (web). Installation does not necessarily mean grid connection. Include both onshore and offshore wind. Data as of November 15, 2020.

Revenue streams for renewables have begun to diversify in recent years, with emerging markets for green certificates and carbon credits being touted by policy makers as possible ways to improve project economics. The former offers a new revenue stream to generators when power retail and consuming entities purchase certificates to meet their renewable portfolio standard mandates. The latter gives a competitive advantage to lower-carbon generators in the wholesale market. Meanwhile, obligations on deregulated power sales, power output forecast and primary frequency regulation have also risen. Regulators need to make sure that the combination of revenue flows and obligations provides the financial certainty needed for investors.

Better market design to highlight the value of power

While market liberalization will play a major role in reducing the cost of renewables deployment for the government and help their integration in the power system, auctions will probably still be needed, at least in the near to medium term, to allow policy makers to manage the speed of transition to deliver the scale of renewables installations for net-zero.

Furthermore, new types of auctions emerging in other markets have transitioned to focus on the value of power rather than the costs, and attracted cost-competitive technology mixtures that can offset the fluctuating nature of wind and solar generation:

- In neighboring India, 'round-the-clock' renewables auctions yielded wind, solar and battery portfolios that can deliver at least 70% capacity utilization factors every month of the year, at a competitive $47.65/MWh on a 25-year levelized basis.
- Massachusetts in the U.S. is creating a market for clean energy to provide peaking services, with a goal of having clean resources meet 46.5% of each utility's and retailer's peak by 2050.
- Moving beyond power, the Netherlands is introducing its new SDE++ scheme to allow hydrogen and carbon capture and storage projects to compete with wind and solar, based on a price per ton of avoided CO_2 emissions rather than a price per kWh of generated electricity.

China has lagged behind in using innovative solutions to optimize the procurement of renewables from a financial and system-integration perspective. Current renewable energy auctions are technology-specific, yet agnostic regarding the time of power delivery. This is mainly because the country's overarching governance structure separates development of wind and solar, and is focused on capacity rather than generation. Different officials are in charge of managing wind or solar development, and installation targets and grid-hosting capacity quotas are separate for the two technologies. Eliminating these siloes, and using a more technology-agnostic, systemwide planning approach, should be an important policy innovation to consider on the path toward decarbonization.

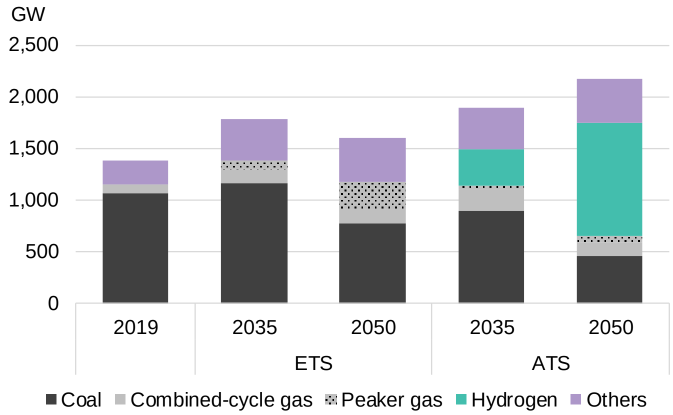
4.2. Reducing emissions in dispatchable generation remains challenging

The need for dispatchable generation

Zero-carbon dispatchable solutions will be crucial for any power system that aims to achieve aggressive decarbonization. Wind and PV can deliver cheap generation and account for over half of total generation, but they are not available round-the-clock. Storage such as batteries and pumped hydro can make renewables more dispatchable, but only to a limited extent. In regions with higher seasonal variance in demand load and renewables resources, dispatchable generation capacities are essential for longer periods of low renewables.

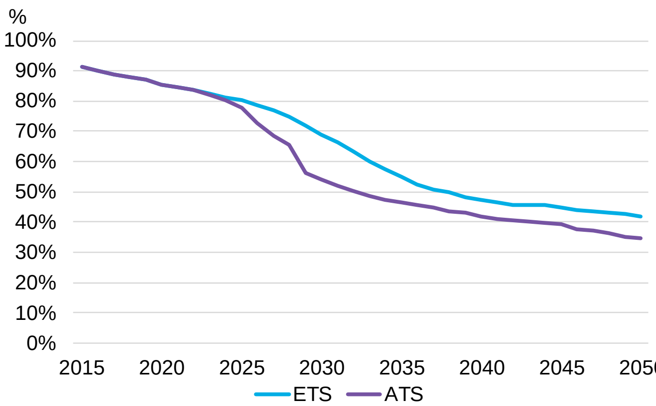
In both scenarios, China relies on dispatchable sources of power generation for around 40% (Figure 19). In the Accelerated Transition Scenario, that is equivalent to 2,176GW of capacity (Figure 18).

Figure 18: Cumulative installation of dispatchable capacity



Source: BloombergNEF. Note: others include nuclear, biomass and reservoir-based hydro.

Figure 19: The share of dispatchable generation in total generation



Source: BloombergNEF. Note: dispatchable generation include fossils, nuclear, biomass, reservoir-based hydro, and clean hydrogen.

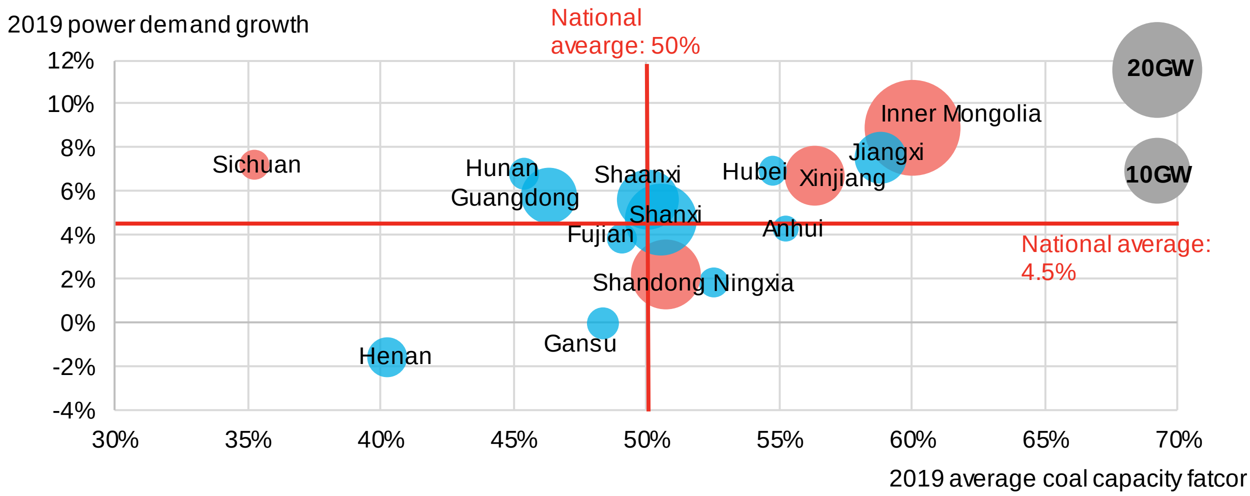
Currently, the majority of China's dispatchable capacity is delivered by coal, which benefits from large domestic resources and low costs. Coal power has played and will continue to play a more flexible role in the system to integrate renewables, resulting in lower capacity factors and more frequent ramping or even shut down. Future dispatchable capacity will play an even more flexible role in the system than coal does today due to higher renewables penetration. Finding locally sourced, zero-carbon, and more flexible dispatchable capacity to replace coal could be the most challenging task of China’s net-zero transition plans in the power sector.

- **Gas** has lower carbon intensity than coal, but the government is concerned about higher costs for end-users and dependence on imports. We expect these concerns will still exist even under the carbon-neutrality target, limiting the role of gas in China’s energy transition.
- BNEF expects China to build 60-70GW more **hydro** in the next decade, mostly in the southern regions. However, new additions could slow down significantly after 2030 as sites become scarce and projects face tightening environmental assessment.
- **Nuclear** also offers a reliable and carbon-free alternative to coal, without taking as much land as a combination of wind, PV and battery does. More importantly, nuclear in China is unlikely to face political and social opposition as it does in other countries. However, it has obvious limitations such as site availability, costs, and inflexibility.
- **Interconnection** could also be helpful as it connects regions with better zero-carbon natural resources that can help reduce fossil generation in other regions. By connecting different regions, interconnectors also allow more efficient use of generating capacity to meet both peak and round-the-clock demand, so regions can maintain a smaller power system to meet the same demand. But in the China context, cutting the share of coal power in interconnection transmission mix will be crucial for emissions reduction.

Enhancing fleet efficiency to reduce demand for coal power

China’s coal fleet faces a dichotomy. General oversupply from the current 1,070GW of commissioned capacity has led to a capacity factor decline from 60% to 50% in the past decade. At the same time, inland provinces such as Inner Mongolia, Jiangxi, and Xinjiang, still need firm capacity to meet fast-rising power demand, and have no nuclear or limited hydropower to rely on (Figure 20).

Figure 20: Top 15 provinces with the largest coal power pipeline under construction, by 1H 2020



Source: "Global Coal Plant Tracker," Global Energy Monitor, July 2020. BloombergNEF. Note: provinces at the export end of inter-regional transmission lines are marked in red.

Policy should therefore have a differentiated approach for the current pipeline of 100GW of capacity under construction and 51GW more approved. Starting from 2014, the authority to approve new power plants has been delegated to local officials, who tend to prioritize short-term economic benefits over the longer-run problems of power-market overcapacity, let alone lifetime carbon footprint. Since then, new coal approvals have increased significantly, particularly in provinces with large coal industries. The national government should realign new coal investments to its new climate pledge, and control additions in areas with high coal-power overcapacity.

Even for regions in need of new firm power, there is still room for efficiency gains so less new capacity will be needed. The pipeline of proposals for inter-regional transmission includes many projects, mostly located in northern China, aimed at balancing the blend of wind and solar in power transfers. The current target for ultra-high voltage transmission lines is to have 30-40% renewables in the generation mix, but more accurate forecasting, energy storage or enhanced demand-side management at the destination should increase the share to at least 50-60%, and reduce the need for coal power.

Increasingly peaky demand profiles – the top 5% of power demand lasts less than 100 hours per year in most provinces – and the rising share of renewables mean that new coal capacity built to meet demand peaks will be dispatched less and therefore have more difficulty recouping investments. We expect the fleet-wide capacity factor for coal power drops to 25-30% by 2050 in both the ETS and the ATS. Demand-side flexibility, such as demand response, higher volatilities in time-of-use retail power prices, and digital technologies such as flexible EV charging and vehicle-to-grid, will become more economical in shaving peak demand. Some are already feasible today in provinces with the right market mechanism, such as Jiangsu and Shandong.

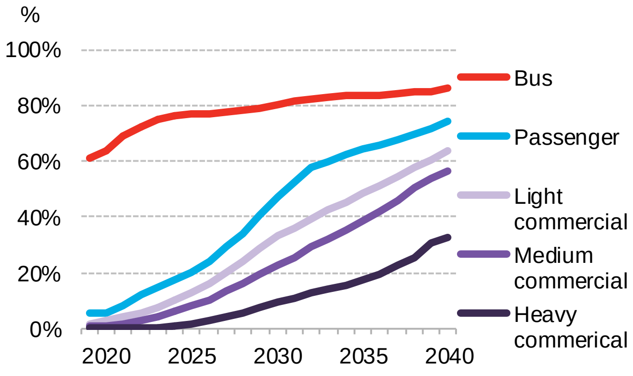
Around 25% of China's operating coal fleet and 26% of its pipeline are combined heating and power (CHP), providing industrial or district heating. Cost-competitive alternatives are limited today, especially for district heating. Coal-to-gas switching has been implemented widely in the industrial sector. It has also been adopted for district heating in wealthier cities like Beijing, with both the end-users and local government bearing the cost. Expanding it to less-developed regions could be challenging due to concerns over higher end-user costs, more gas imports and emissions. Zero-carbon solutions such as wind power direct heating, geothermal and inland nuclear reactors may be pushed further. But to reach scale, the right pricing mechanism has to be in place.

Deepening market deregulation will further help highlight system inefficiencies and pinpoint the places where early retirement should be allowed. By the end of 2019, some 56% of China's coal generation is transacted in competitive power markets at prices lower than regulated rates. Deregulation enables plants with higher efficiencies and lower costs to generate more, effectively bringing down the average cost and emissions. Smaller plants see declining generation due to a lack of cost competitiveness to peers and to cheaper renewables. The upcoming national carbon market will further this effect and make a stronger case for early retirements. More coal power should be pushed into markets, except those associated with heat supply.

4.3. Key drivers for transport electrification

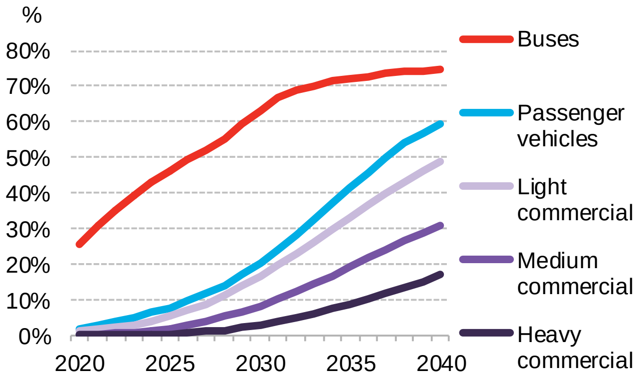
The electrification of road transport is already well under way in China, driven by strong policy support. As the economics and performance of electric vehicles (EVs) continue to improve, under ETS we expect EVs – including battery electric and plug-in hybrid vehicles – to represent 59% of passenger cars on the road in China by 2040 (Figure 21). To get to the ATS level of 100% of electrification of road vehicles (excluding segments such as long-haul commercial vehicles), all vehicle sales would have to reach 100% by 2040 at the latest, considering the road lifetime of vehicles. This will require accelerating the adoption of EVs by private consumers, as well as commercial and public users. China can learn from its successes with increasing the rapid electrification of buses and two-wheelers via a combination of incentives and regulatory mandates. While such measures are also in force for other segments, they need to be strengthened more particularly for the commercial-vehicle segment. China will also need to consider stronger measures to support modal shifts to limit the overall growth of the vehicle fleet.

Figure 21: China EV share of annual vehicle sales by segment under ETS



Source: BNEF

Figure 22: China EV share of vehicle fleet by segment under ETS



Source: BNEF

Needs for accelerated deployment of charging infrastructures

The electrification of road vehicles will need the support of charging infrastructure. Under ETS, passenger vehicles need 96 million home chargers and over 3.3 million public chargers by 2040 (Figure 23). Electric buses and commercial vehicles would also need over 1.1 million chargers by 2040 under ETS (Figure 24). ATS does not require significantly higher cumulative deployments, but it needs faster deployment of the charging infrastructure, as well as higher utilization rates for public chargers.

Figure 23: China's need for cumulative public charging infrastructure for passenger vehicles and vans under ETS

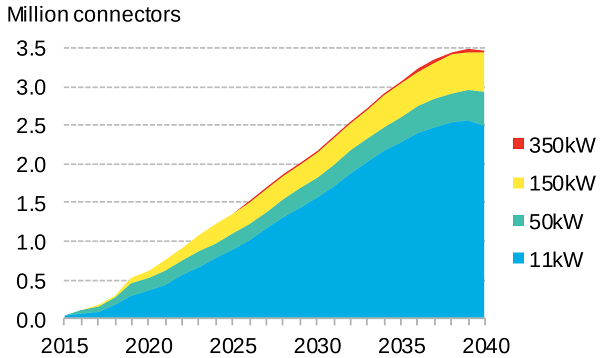
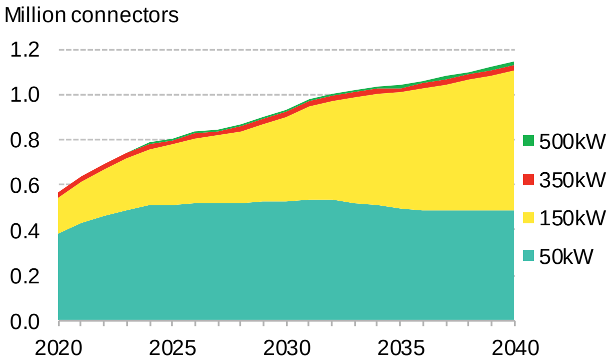


Figure 24: China's need for cumulative electric commercial truck and bus charging infrastructure under ETS



Source: BloombergNEF

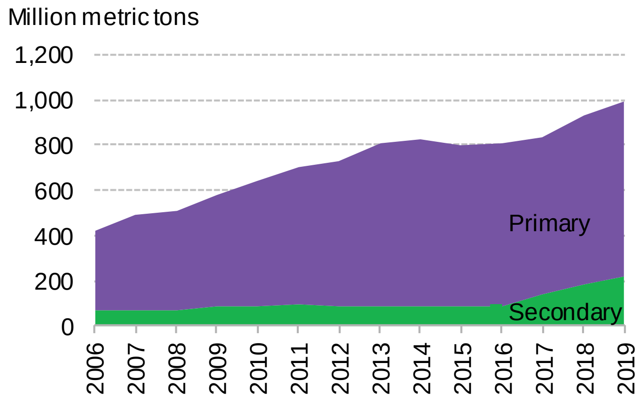
4.4. Recycling's role in industry decarbonization

Industry is the second-largest carbon-emitting sector in China, and its share of total emissions is expected to grow as the power and transportation sectors undergo deeper and faster decarbonization. Industrial emissions are hard to abate because the production processes are complex and hard to electrify. For China, most of the industrial assets are relatively new and could continue to operate for decades, which makes it even harder and more costly to replace fossil fuels.

Efficiency, electrification, carbon capture, hydrogen and the circular economy of recycling and reuse are major strategies for industrial deep decarbonization. Among them, efficiency improvement and materials recycling play critical roles in the near term, thanks to their readiness for deployment. China's industry has focused more on improving energy efficiency and has secured tremendous achievements, shown by the declining energy intensity of basic materials. In the next decades, we expect material recycling to drive the industrial emissions reduction before hydrogen and carbon-capture technologies are economically available for large-scale deployment.

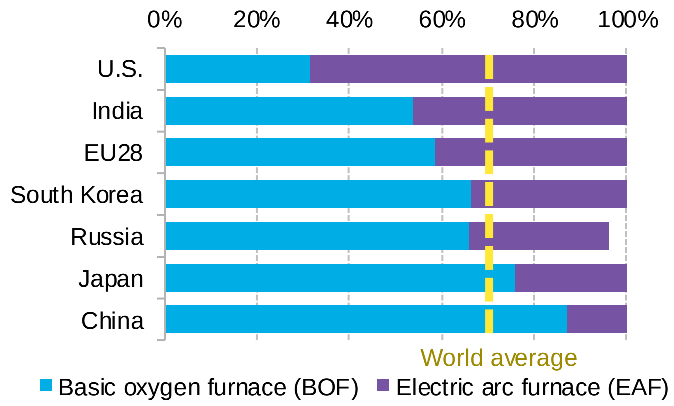
China still lags behind many other countries in materials recycling rates and recycled-material consumption rates, which are major indicators for a country's circular economy development. Steel from end-of-life vehicles is recycled at almost 100% in developed countries such as the U.S. and Japan, while it just recently passed 60% in China. Furthermore, while recycled content (secondary steel) accounts for more than two-thirds of steel production in the U.S., China's share just hit 22% in 2019 after a more than twofold increase in the past five years (Figure 25).

Figure 25: China's steel production from primary and secondary sources



Source: China Association of Metal Scrap Utilization, BloombergNEF

Figure 26: Comparison of steel furnace types, 2018



Source: Bureau of International Recycling, BloombergNEF

Steel production alone accounts for 15% of carbon emissions in China. Recycling can reduce the carbon emission by more than half compared to production from iron ore. In the ETS, annual scrap-steel supply reaches 320 million metric tons in China, which is about 29% of the total production. The secondary supply extends further to 65% by 2050, much higher than the world average of 45%. In ATS, we assume China's share of secondary production grows by about 10%, which is in line with the global trend.

We believe there are two major hurdles to recycling more steel. One is China's relatively low steel stock accumulation, which limits the availability of scrap steel. China may have to import scrap to make up the gap. With more countries boosting domestic recycling, international scrap-steel prices may surge, adding to recycling costs. Another hurdle is China's extremely low share of electric arc furnaces (EAFs) in steel production (Figure 26). The traditional basic oxygen furnace (BOF) process, which relies heavily on coal input, can accommodate only up to 30% of scrap steel. Most steel scrap needs to go through the EAF, which uses electricity for heating and emits much less than BOF. To reach 50% recycled content, China needs to retire BOF assets and invest extensively in EAF facilities.

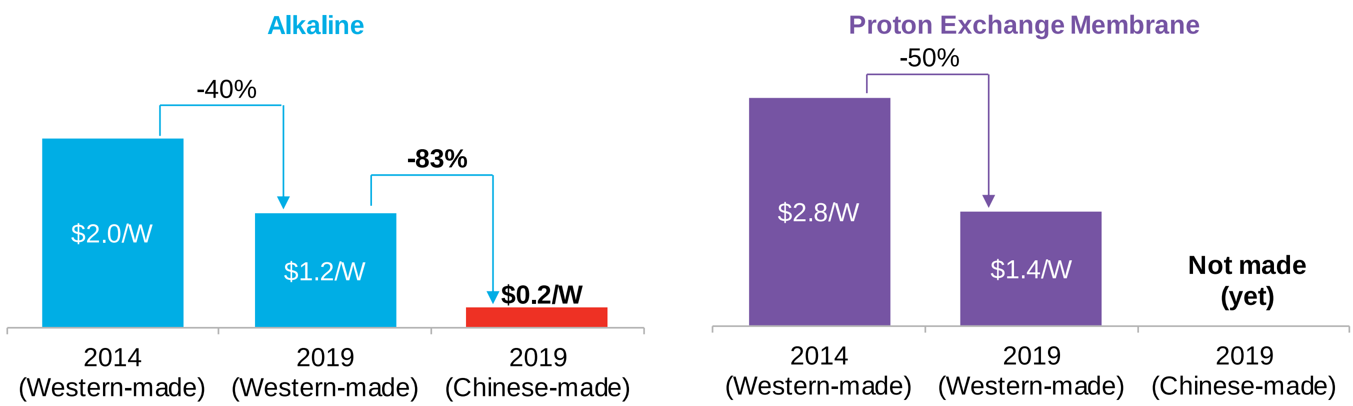
China has developed supportive national policy to boost domestic materials recycling. The government banned most scrap-material imports in 2018, hoping to push the recycling industry to adopt domestic scrap. Shanghai became the first city to enforce mandatory municipal-waste sorting, and a similar scheme will spread into 46 cities in the next few years. Recently, an amendment of Law on the Prevention and Control of Environmental Pollution by Solid Waste has provided more details on waste producers' responsibility and strengthened industrial solid-waste management. These policies help solve the problems from the supply and demand side of material recycling. However, further scale-up of domestic recycling requires defining more market standards and providing higher tax incentives to the recycling business.

4.5. Hydrogen

Hydrogen has become a hot topic in the energy sector. Many leading companies are forming hydrogen business units, projects are being planned, and countries are devising national strategies to be at the forefront of the fledgling industry.

Interest has surged because hydrogen offers a promising route to cut emissions in some of the most fossil-fuel-dependent sectors of the economy, such as steelmaking, heavy-duty vehicles, international shipping and the production of cement. Hydrogen can be produced and consumed without releasing carbon dioxide or other greenhouse gases, and can therefore be used as a clean fuel for industries that cannot be easily or economically electrified.

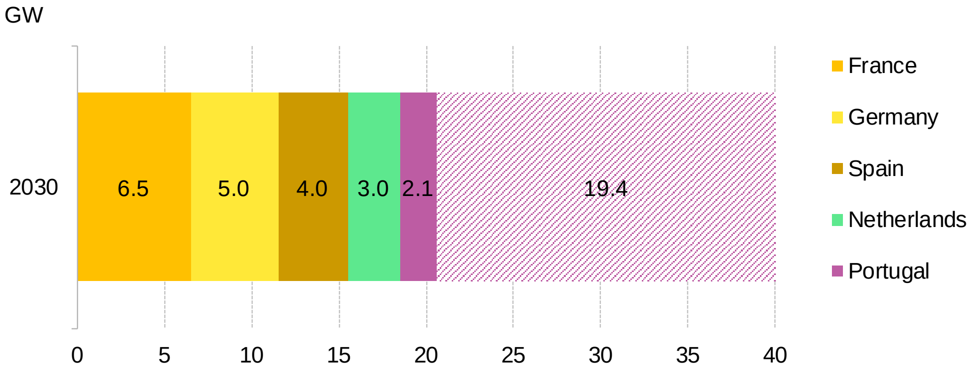
Figure 27: Benchmark system capex based on large-scale electrolyzers, 2014 and 2019



Source: BloombergNEF. Chinese manuf.: Jingli, Peric, Mainland Hydrogen. Western manuf.: NEL, Hydrogenics, McPhy, ITM Power, Teledyne, Areva H2Gen, Siemens.

Hydrogen is the simplest and most abundant element in the universe. However, on Earth, it is mostly nonexistent in its free form, and must be produced from other substances. Currently, over 99% of it is produced from fossil fuels for use in the chemicals industry, and this is a major source of pollution. But hydrogen can also be produced cleanly by splitting water using renewable electricity in a device called an electrolyzer. This equipment is expensive, but costs have fallen by 40% in the last five years and could fall further if the industry scales up. China already has the lowest cost of electrolyzers. However, China is starting to fall behind European countries that have been announcing aggressive plans for electrolyzer deployment as part of their stimulus measures following the Covid-19 pandemic.

Figure 28: EU and member-state electrolyzer deployment targets for 2030



Source: BloombergNEF, European Commission, national hydrogen strategies.

We estimate that as much as 34% of global greenhouse gas emissions from fossil fuels and industry could be abated using hydrogen. If the industry is scaled up, we estimate that hydrogen could be produced from renewable energy for $0.80 to $1.60/kg in most parts of the world before 2050. This is equivalent to gas priced at $6-12/MMBtu, and would make hydrogen competitive with current natural gas prices in China.

This could unlock low-cost emissions reductions in many sectors. For instance, a carbon price of $50/tCO2 would be enough to switch from coal to clean hydrogen in steelmaking by 2050, $60/tCO2 to use hydrogen for heat in cement production, $78/tCO2 for making chemicals like ammonia, and $145/tCO2 to power ships with clean fuel, if hydrogen costs reach $1/kg. Heavy trucks could also be cheaper to run on hydrogen than diesel by 2031, although batteries remain a cheaper solution for cars, buses and light trucks.

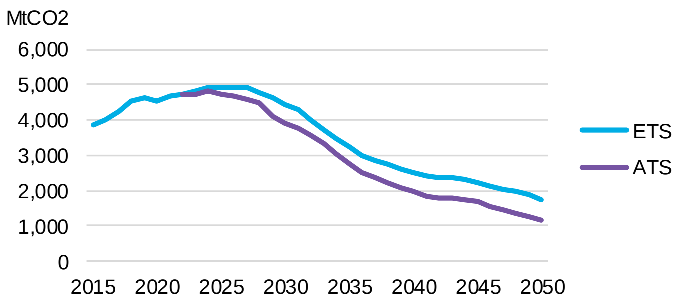
China has already become the largest fuel-cell bus and commercial vehicle market in the world. China needs to consider policies supporting the use of hydrogen for sectors that are hard to decarbonize, such as steel and cement. To lead in development of hydrogen technology, China needs to also reconsider existing rules that limit the safe use of hydrogen.

Section 5. Opportunities

5.1. Emission reduction

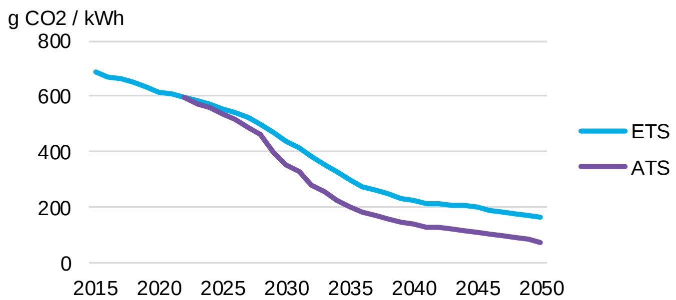
In the Economic Transition Scenario, power-sector emissions peak in 2026 and then come down by an average 133 million tons of CO2 equivalent (MtCO2e) until 2050. In the Accelerated Transition Scenario, the peak year is pulled earlier to 2024, and reduces faster at 150 million tons per year, even though electricity contributes 53% of final energy consumption in 2050, versus 42% in the ETS. This makes it much easier for China to reach its carbon-neutrality goal by 2060.

Figure 29: Power-sector emissions



Source: BloombergNEF

Figure 30: Power-sector emissions intensity

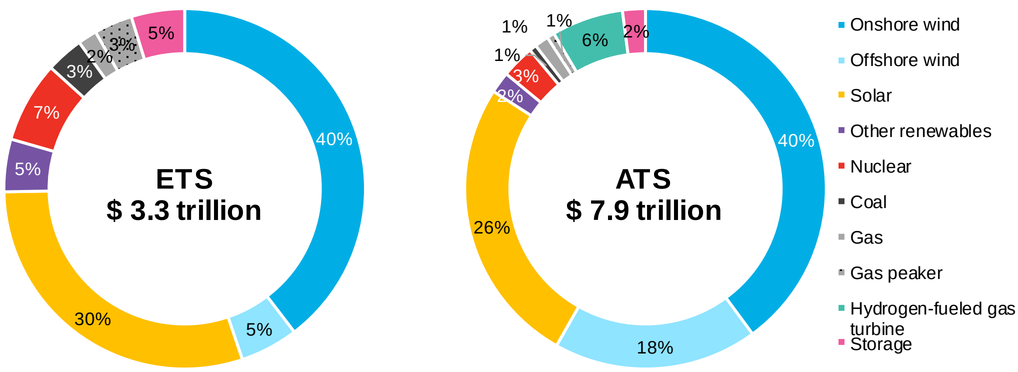


Source: BloombergNEF

5.2. Electricity

Around $3.3 trillion of investment in new power capacity to 2050 is needed under the ETS, an average of $106 billion per year. About $2.4 trillion, or 75%, goes to renewables. Under the ATS, $7.9 trillion is needed in the same timeframe, with 84%, or $6.4 trillion, going to wind and PV, and 6%, or $508 billion, going to hydrogen-fueled gas turbines. While China's solar and wind industry are already well-established, a larger market is of course beneficial to their continued growth. More importantly, under ATS, China has the opportunity to utilize its own domestic market – as it did effectively with solar, battery and EV manufacturing – to achieve global leadership in new technology areas such as hydrogen-fueled gas turbines.

Figure 31: Cumulative investment in new capacity, 2020-50

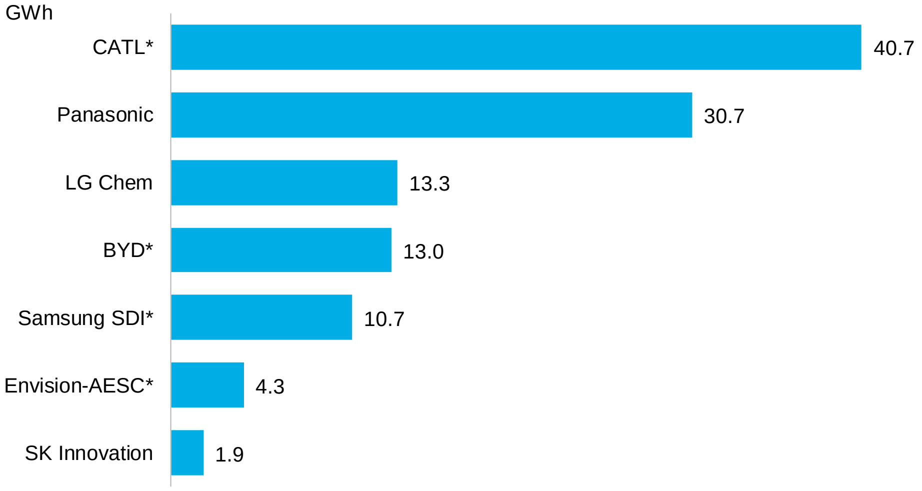


Source: BloombergNEF. Note: storage includes pumped hydro and battery.

5.3. Electric vehicles, battery manufacturing and chargers

China's lead in EVs has already enabled its battery manufacturers, such as CATL and BYD, to emerge as major global suppliers (Figure 32). Accelerated EV adoption domestically will enable China's automakers to similarly lead global automakers in EVs.

Figure 32: Lithium ion-battery shipments in 2019

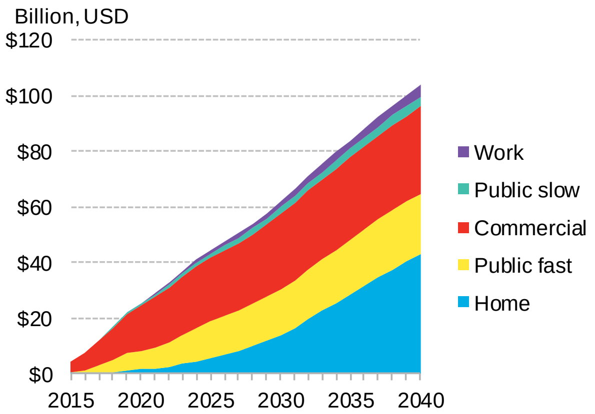


*Source: BloombergNEF, company statements and annual reports. Note: * indicates that there is at least one number between EV and storage shipments that comes from a company statement and annual report.*

Charging infrastructure

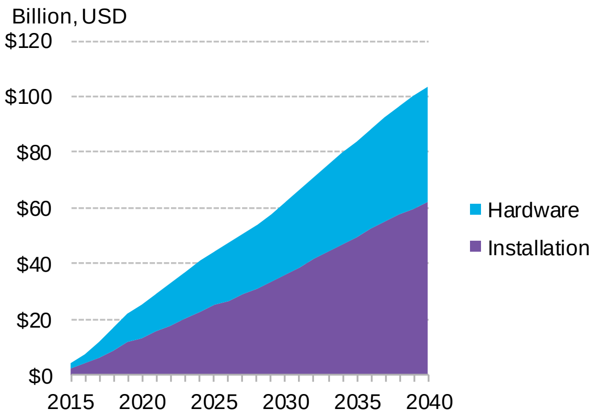
By 2040, China will need a cumulative investment of $104 billion in all types of charging hardware and installation (Figure 33). Around 60% of the cumulative investment will be spent on installation costs by 2040, with the remainder going to charging hardware (Figure 34). This provides a significant market opportunity for China's charger manufacturers and infrastructure operators.

Figure 33: China cumulative charging infrastructure investment by charging type



Source: BNEF

Figure 34: China cumulative charging infrastructure investment by charging type by cost category

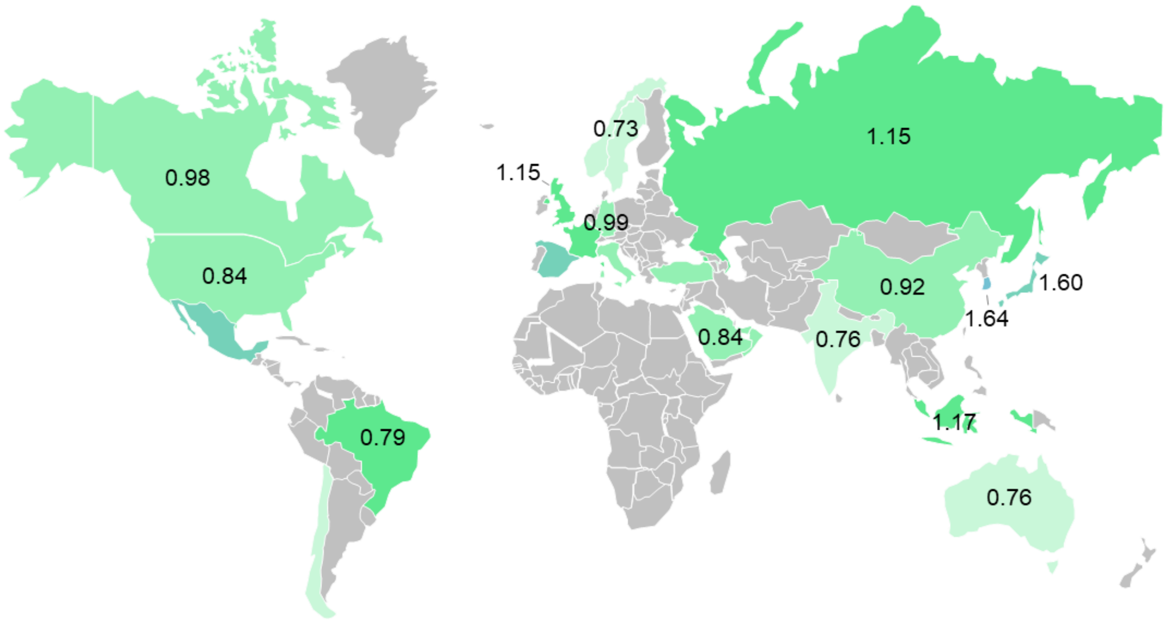


Source: BNEF

5.4. Hydrogen

The creation of a clean hydrogen industry would also present massive investment opportunities for China. Globally, over $11 trillion of spending on production, storage and transport infrastructure would be required for hydrogen to meet around a quarter of global energy needs in 2050. Annual global sales of hydrogen would be $700 billion, with billions more also spent on end-use equipment. China's renewable resources also position the country as one of the largest potential producers of lower-cost green hydrogen.

Figure 35: Levelized cost of hydrogen production from renewables, 2050 ($/kg)



Source: BloombergNEF.

About us

Contact details

Client enquiries:

- Bloomberg Terminal: press <Help> key twice
- Email: support.bnef@bloomberg.net

Yvonne Liu	Associate, China Research
Jonathan Luan	Associate, China Research
Leiliang Zheng	Associate, Advanced Materials
Siyi Mi	Analyst, Electrified Transport
Jinghong Lyu	Analyst, Intelligent Mobility
Nannan Kou	Head, China Research
Dario Traum	Head, EMEA Energy Transition
Ali Izadi	Head, APAC Research

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