China's Climate Transition:

Outlook 2022

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CREA
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Contents

Executive summary

As the world's largest greenhouse gas emitter, and the main source of emissions growth over the past two decades, China's emissions trajectory is one of the key determinants of the success of global climate efforts. A comparison of China's current emissions targets with the global pathways consistent with Paris Agreement goals shows that it's crucially important for China to not just meet but exceed the targets by 2030. After 2030, extremely rapid emission reductions will be needed.

To measure China's progress, we compiled a suite of climate transition scenarios published by different international organisations and academic institutions and identified a set of indicators that can be compared against historical data and used to measure progress in a much more granular and forward-looking fashion than a simple look at the annual change in emissions would permit. We converted the scenario data into benchmarks for each indicator that allow us to assess whether the country's emissions and energy trend in key sectors aligned with the climate transition scenarios and Paris Agreement.

Our assessment found multiple indicators on track, including clean energy investments, electrification, building sector emissions, and electric vehicle sales. China's clean energy investments, in particular, have continued to grow rapidly and are approaching the scale projected in 1.5-degree scenarios, a remarkable achievement.

The essential gap between China's energy and emissions trends, at least until 2021, was caused by the growth rate of total energy consumption, which is much faster than in the transition pathways. Energy demand increased faster than in the pathways across all key emitting sectors, which is why emissions kept increasing. Resolving this issue requires a combination of increased energy efficiency measures, a shift in the economic growth model, or an even larger scale of clean energy investment than projected in the transition scenarios, together with better-managed energy systems. For non-CO2 greenhouse gases, there are no official quantitative targets or regular emissions reporting that would allow the assessment of trends or progress.

China's emissions and fossil fuel consumption have been falling since the summer of 2021. This has aligned total emissions trends with the transition pathways in the short term. However, even in 2022, two of our key indicators remained off track: investments in coal-based power capacity and investments in coal-based industrial capacity, particularly iron and steel capacity.

We identify important gaps and shortcomings in China's energy and emissions data reporting. The electricity sector has good data availability and reporting frequency but all other sectors are lagging behind to varying degrees. Monitoring and reporting of non-CO2 greenhouse gas emissions are the least developed.

To gain insights into the views and expectations driving China's policymaking, we carried out a survey of 26 Chinese energy sector analysts and experts. The surveyed experts are sceptical about the prospect of carbon emissions peaking before 2025 or having already peaked. Some are even doubtful that the target of peaking before 2030 will be met. Although most of the interviewed experts believed that peaking carbon by 2030 should not be a challenge, China achieving carbon neutrality by 2060 might need a lot of work depending on the level of CO2 emissions at the peak. It appears that Chinese analysts and experts expect a return to the growth pattern that prevailed before mid-2021, when energy consumption and CO2 emissions experienced a sharp turnaround. These expectations go a long way in explaining the mismatch between current falling trends in coal

consumption and emissions, and policies and investment decisions leading to more coal-based capacity being put in place.

China's long-term target of achieving carbon neutrality before 2060, following currently envisioned trajectories, is aligned with the low end of the Paris Agreement goals (limiting global temperature rise to below 2°C) but not the high end (1.5°C). On the other hand, the level of ambition is at least comparable to that of most developed economies (net zero emissions by 2050), a fact frequently and justifiably pointed out by Chinese policymakers. This points to the importance of raising the bar across the key emitting countries, including but not limited to China.

China's success in meeting and exceeding its current climate targets is possibly the single most important factor in the global fight against climate change. The framework laid out in this report is meant as the basis for a regular re-assessment and update of China's progress by CREA.

1 Introduction

The historic heatwaves and droughts of summer 2022 were a stark reminder of the importance of the success of the global climate effort for China. Temperature records were broken across the country and the Yangtze river, one of the world's largest rivers, dried out in places. In the previous summer, severe flooding in Henan forced the evacuation of tens of thousands of people. 300 people died, many of them lost their lives when the metro tunnels of the provincial capital Zhengzhou flooded and trapped passengers inside.

Swiss Re, the world's largest reinsurer, assesses that China is among the countries most affected by the economic and physical impacts of climate change, ranking far above regions such as the EU and North America[1]. At the same time, as the world's largest greenhouse gas emitter, China's own energy and climate policies have a major bearing on the severity of the climate impacts the country will face.

China's greenhouse gas (GHG) emissions more than quadrupled over the course of the past two decades, making China the primary driver of global emissions growth over the period. Emissions growth in 2000-2008 was predominantly driven by an export-driven industrial and investment boom. From 2009 to 2021, emissions growth was driven by two waves of real estate, infrastructure, and industrial expansion. China's high emissions relative to their gross domestic product (GDP) are due to both a coal-heavy energy structure, and an economic structure relying heavily on construction and energy-intensive industry.

China's emissions surged after the onset of COVID-19, due to economic recovery policies aimed at stimulating construction and industrial output, including export industries. Now, the country's emissions are falling. The cool-down is not primarily driven by deliberate climate policies but by economic policies aimed at defusing debt and asset bubble risks in the real estate sector.

China's motivations to act on climate

China has a strong self-interest in climate action, due to pressing environmental challenges at home, as well as the impacts of climate change on food security, water resources, the regional security environment, and other key aspects of national security. Climate action aligns with China's long-term economic and industrial goals, including the ambition to become a technological and market leader in core technologies of the 21st century.

China has also been able to use climate action and diplomacy to meet its global agenda. China wants to be seen as a steady partner and a crucial contributor to solving global environmental issues. Climate policy and diplomacy have allowed China to pursue many foreign policy goals - shaping international rules, portraying China as a responsible stakeholder and provider of important public goods, building a multipolar world, and increasing China's influence and presence in developing and emerging markets.

The impacts of climate change on China include weakened food security, intensified flooding, and other extreme weather events such as cyclones. China's coastline includes low-lying, very densely

[1] Swiss Re Institute. (2021). The economics of climate change. https://www.swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/expertise-publication-economics-of-climate-change.html#chapter-Physical-risks. Scientific publication.

populated areas such as the megacities of the Yangtze River Delta and Tianjin, implying that the costs of sea level rise are massive. The rise in temperatures also facilitates the spread and contagion of malaria and dengue.

According to the China Meteorological Administration, the incidence of torrential rains and extreme heat waves has already increased in China, as has the strength of typhoons landing on the coast[2].

Agriculture is affected among other sectors through increased droughts, floods, and heat waves. Warming has already increased the likelihood of crop failures. Heatwaves in key agricultural regions risk becoming so hot that daytime work in the fields becomes physiologically impossible[3].

Food security is a key priority for China, so the impacts on agriculture are a particularly important reason for the country's decision-makers to pay attention to climate change.

According to public surveys, the Chinese are among the nations the most concerned about climate change. In a European Investment Bank survey, 73% of Chinese respondents considered climate change a major threat to society, and 94% said that climate change has an impact on their everyday lives, both higher percentages than in the EU or the US[4].

However, there are also strong interests that oppose climate action and reduction in fossil fuel use in China, including provinces and state-owned enterprises with a high reliance on coal and coal-related industries.

State-owned enterprises in the coal power and steel sectors continue to invest in coal-based capacity. These sectors are China's two largest emitters of CO2, and there is no sign of investment in coal-based capacity being scaled back yet. A complete shift of new investments into clean capacity is needed to put China on track to peak CO2 emissions and avoid a glut of unneeded power and industrial capacity.

Yet, even against this bleak backdrop, it is nonetheless noteworthy that China has demonstrated its determination to tackle climate change by announcing a CO2 emissions peak before 2030 and carbon neutrality before 2060[5], as well as a series of policies to support these goals.

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[2] China Meteorological Administration, (2021). Blue Book on Climate Change in China 2021. http://www.cma.gov.cn/2011xwzx/2011xqxxw/2011xqxyw/202108/t20210805_582404.html

[3] Kang, S., Eltahir, E.A.B. North China Plain threatened by deadly heatwaves due to climate change and irrigation. Nat Commun 9, 2894 (2018). https://doi.org/10.1038/s41467-018-05252-y

[4] European Investment Bank (EIB). (2020). Climate change more feared by the Chinese than by EU or US citizens. https://www.eib.org/en/infographics/2nd-climate-survey-climate-change-fear-china-eu-us. Research report.

[5] UN News. (2020). 'Enhance solidarity' to fight COVID-19, Chinese President urges, also pledges carbon neutrality by 2060. https://news.un.org/en/story/2020/09/1073052. News article.

China's policies and commitments

When addressing the COP15 gathering on biodiversity held in Kunming, China, from 11 to 15 October 2021, President Xi Jinping of China stated that China would "put in place a '1+N' policy framework for carbon peak and carbon neutrality"[6].

"1" refers to the long-term approach to combating climate change, which is well-documented in *The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy*, issued on 24 October 2021[7]. China aims to gradually increase the share of non-fossil energy consumption to around 20 percent by 2025, around 25 percent by 2030, and over 80 percent by 2060.

"N" refers to solutions to achieve peak carbon emissions by 2030, starting with the *Action Plan for Carbon Dioxide Peaking Before 2030*, issued on 26 October 2021[8].

China officially added the dual carbon goals to its nationally determined contribution (NDC) targets on 28 October 2021[9], just before COP26 in Glasgow.

On 8 November 2021, The People's Bank of China (PBOC), the nation's central bank, said that it had rolled out a supporting tool for carbon reduction as part of efforts to facilitate the country's goal of carbon neutrality[10]. The bank will provide low-cost loans for financial institutions through the carbon-reduction supporting tool and will guide those institutions to provide loans to firms in key carbon-reduction fields on the premise of independent decision-making and risk-taking.

Since then, "N", a series of climate-related policy documents has been successively issued as specific implementation plans for key areas such as energy, industry, construction, and transport, and for key sectors such as coal, electricity, iron and steel, and cement, coupled with supporting measures in terms of science and technology, carbon sinks, finance and taxation, and financial incentives.

At the two-year anniversary of the announcement of the dual carbon goals, on 22 September 2022, China's top planner National Development and Reform Commission (NDRC), stated that China has established its "1+N" climate policy framework, including sectoral and regional plans[11]. The Commission pointed out that China has made stable progress in its climate actions, and is undertaking to:

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[6] Xinhua. (2021). China to release implementation plans to achieve carbon goals: Xi. https://english.mee.gov.cn/News_service/media_news/202110/t20211012_956262.shtml. News announcement.

[7] Central Committee of the Communist Party of China, State Council. (2021). Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy. https://en.ndrc.gov.cn/policies/202110/t20211024_1300725.html. Policy.

[8] State Council. (2021). Action Plan for Carbon Dioxide Peaking. https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html#:~:text=By%202030%2C%20the%20share%20of,carbon%20dioxide%20peaking%20before%202030. Policy.

[9] NDC Registy China (2021) China first NDC (Updated submission) https://unfccc.int/NDCREG.

[10] Xinhua. (2021). China's central bank rolls out new lending tool for carbon reduction. http://www.news.cn/english/2021-11/08/c_1310299035.htm. News article.

[11] People's Daily, 22 Sept. 2022. NDRC: The country's work on the 'two carbon targets' achieved a good start in the past two years. News article. http://finance.people.com.cn/n1/2022/0922/c1004-32531849.html

- Promote renewable energy development. China's total renewable power installation reached over 1100 GW and China has become the world's leader in renewable power installations.
- Promote industrial restructuring and restrict projects with high energy consumption and high pollution. Compared to 2012, China's energy intensity (total energy consumption per unit of GDP) dropped by 26.4% in 2021, and carbon intensity (total carbon emissions per unit of GDP) dropped by 34.4%.
- Promote the transition of construction and transportation sectors. In 2021, China's newly built green buildings reached 2 billion square metres. The retained number of new energy vehicles in China accounted for half of the world's total.

Are these efforts enough for China to achieve its carbon goals? In this report, we reviewed literature published by international organisations and national researchers and identified indicators and benchmarks from China. We compiled the historical data for the indicators and future development projections to assess China's progress. We also conducted an expert survey to evaluate their confidence in China's emission outlook. Chapter 2 presents an overview of China's sources, history, and drivers of China's greenhouse gas emissions. Chapter 3 introduces the different transition pathways consistent with the Paris Agreement goals to limit global warming, which we will use as benchmarks for China's progress. Chapter 4 compares China's progress in different aspects of the climate transition, using indicators and benchmarks developed from the transition pathways. Chapter 5 presents findings from an expert survey that gauges the views and expectations of well-informed and influential individuals in the energy and climate sectors to understand how they interpret current policies and trends, and how they expect China's emissions to develop over this decade. Our findings and conclusions are given in Chapter 6.

2 Understanding China's greenhouse gas emissions

2.1 The meteoric rise of emissions

China is the world's largest greenhouse gas emitter today, and the second-largest historical emitter, after the United States. In 2019, it produced 27% of global greenhouse gas emissions, with around 18% of the world's population and GDP. China's share of global emissions rose to this level from less than 10% in 1990. China was responsible for 60% of the increase in global CO2 emissions from 2010 to 2019 and is the only major emitter to increase emissions after the beginning of the COVID-19 pandemic, due to a rapid and carbon-heavy recovery from the initial lockdowns. The country's high emissions relative to GDP are due to both a coal-heavy energy structure and an energy-intensive economic structure that relies heavily on construction and smokestack industries.

As a result, China's emissions are dominated by energy and industrial processes, in particular the production of steel, cement, and other construction materials.

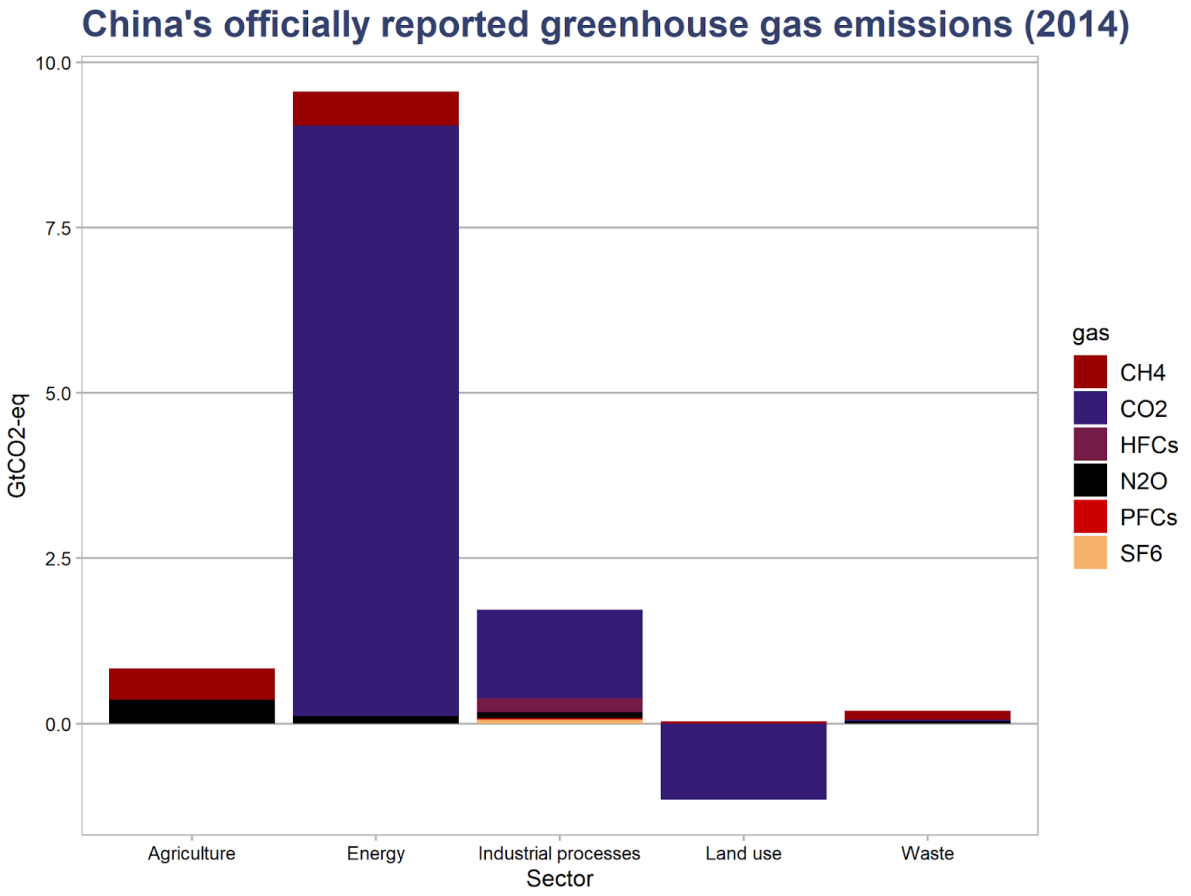

Figure 1 | China's reported greenhouse gas emissions in 2014, the most recent year for which official data is available

China has committed to CO2 emissions and clean energy targets since the Copenhagen climate summit in December 2009. Actions to achieve these targets have made the country the world leader in deploying renewable energy and nuclear power, but have not been sufficient to peak CO2 emissions from fossil energy consumption.

China first committed to peaking CO2 emissions "around 2030", in the Obama-Xi climate declaration in 2014. In 2020, President Xi Jinping pledged that China would target carbon neutrality before 2060 and peak CO2 emissions "before 2030"[12].

The increase in China's emissions in the 2000s was driven by its rapid industrial and economic growth after the export and investment boom started by WTO accession. This boom came to a head with the global financial crisis, and in 2008, leadership responded with an unprecedentedly large infrastructure stimulus programme that drove even faster emissions increases in 2009-2012. This spending was predominantly directed at the most energy-intensive parts of the economy: construction and heavy industry, particularly steel, cement, and other construction-materials industries.

When the effect of the stimulus programme started to wear out in 2013, coal, steel, and cement consumption began to fall. This fall was compounded by the "war on corruption" launched by General Secretary Xi Jinping, curbing local government permits and enthusiasm for construction projects.

The leadership's initial response to the slowdown of the industrial economy was to brand the changes as a part of an "Economic New Normal" in which household consumption, services, and high-value-added industries would become the key drivers of growth. This was also the time when Presidents Xi and Obama announced the "climate deal" between the two countries, including China's CO2 peaking commitment and paving the way for the Paris Agreement, while the air pollution crisis dominated domestic headlines, creating a unique window of opportunity to limit coal consumption at least in the more prosperous coastal areas.

However, falling demand and prices for key commodities and heavy industry products led to major financial distress in state-owned enterprises towards the end of 2015. A new wave of the stimulus was launched in late 2015. This stimulus-driven growth continued in the following years and intensified as the government sought to offset the economic impact of the COVID-19 pandemic with construction supply-side stimulus measures.

China's emissions surged after the onset of COVID-19, due to economic recovery policies aimed at stimulating construction and industrial output, including export industries. Now, the country's emissions are falling. The cool-down is not driven mainly by deliberate climate policies, but the combination of economic policies aimed at tamping down real estate speculation and low-value construction projects, strict COVID-19 control policies, and clean energy expansion.

[12] UN Affairs. (2021). China headed towards carbon neutrality by 2060; President Xi Jinping vows to halt new coal plants abroad https://news.un.org/en/story/2021/09/1100642. News announcement.

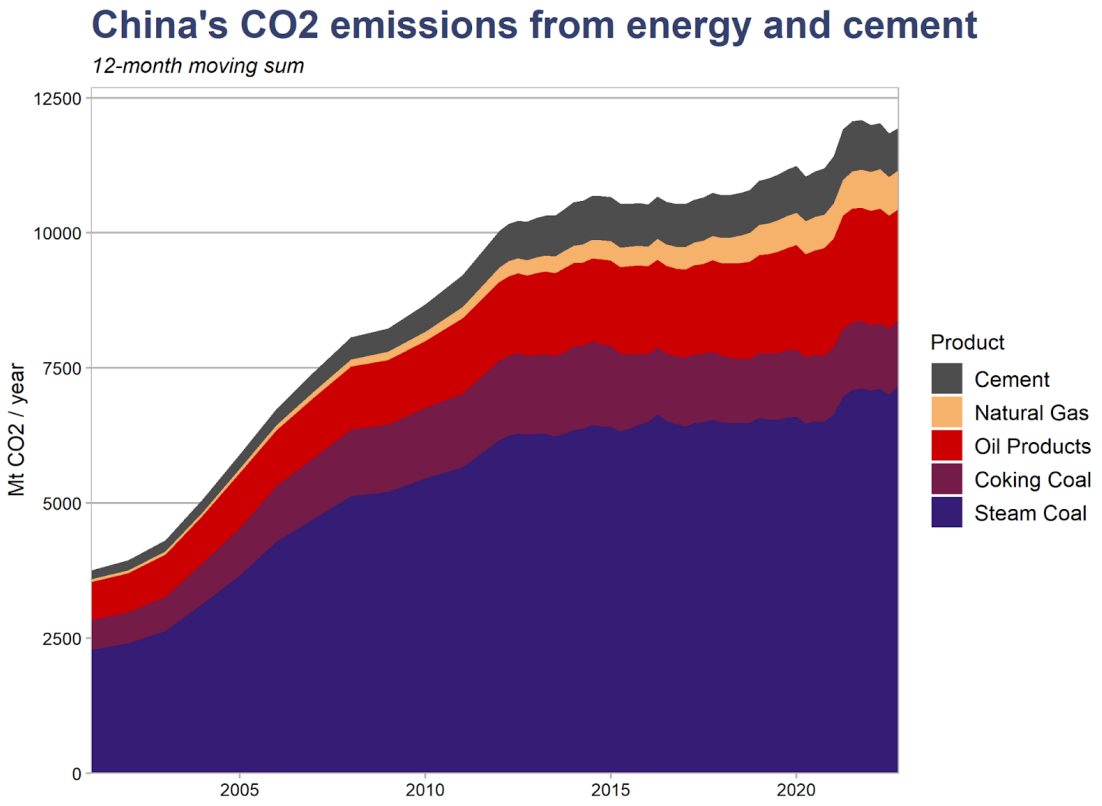

Figure 2 | China's CO2 emissions from energy and cement, 2000 – September 2022

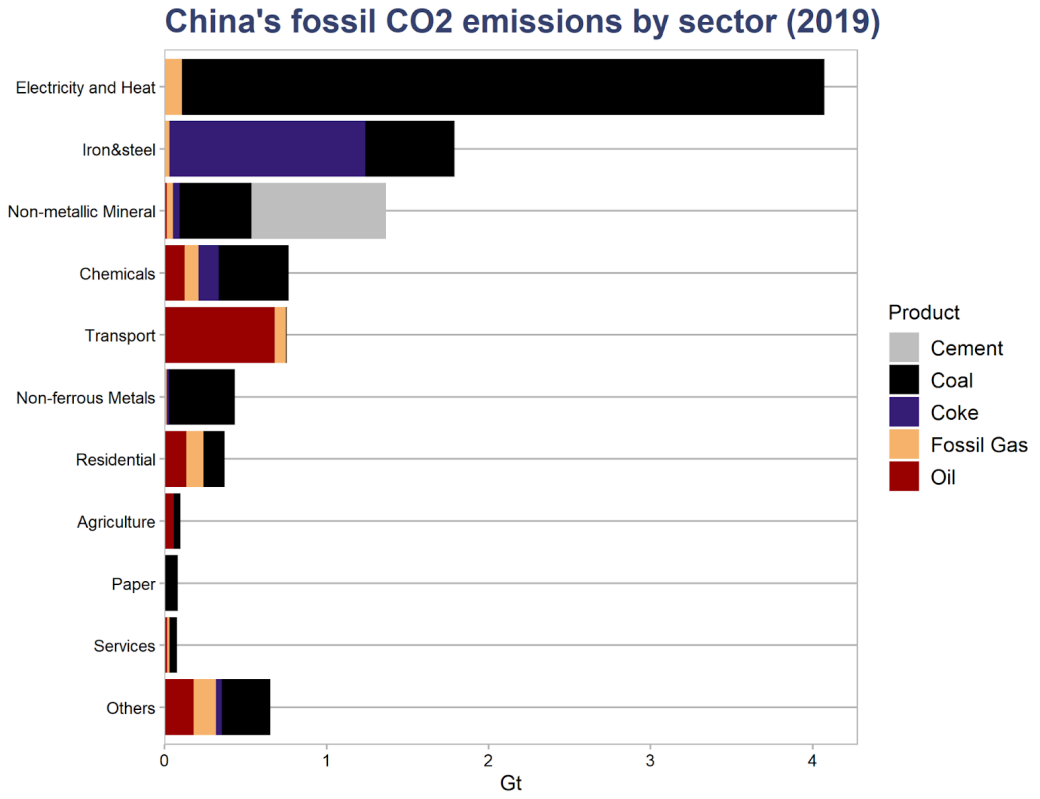

Figure 3 | China's fossil CO2 emissions by sector (2019)

China's CO_2 emissions are heavily dominated by power generation and heavy industry sectors, with iron and steel, non-metallic minerals (cement and glass) and chemicals being the largest industrial emitters. Notably, the entire transport and household sectors rank below these industries in total emissions (Figure 3). When emissions from power generation are allocated to the sectors consuming the power (Figure 4), the non-ferrous metals industry (e.g. aluminium, copper, and nickel) stands out as a major emitter due to the sector's high electricity demand.

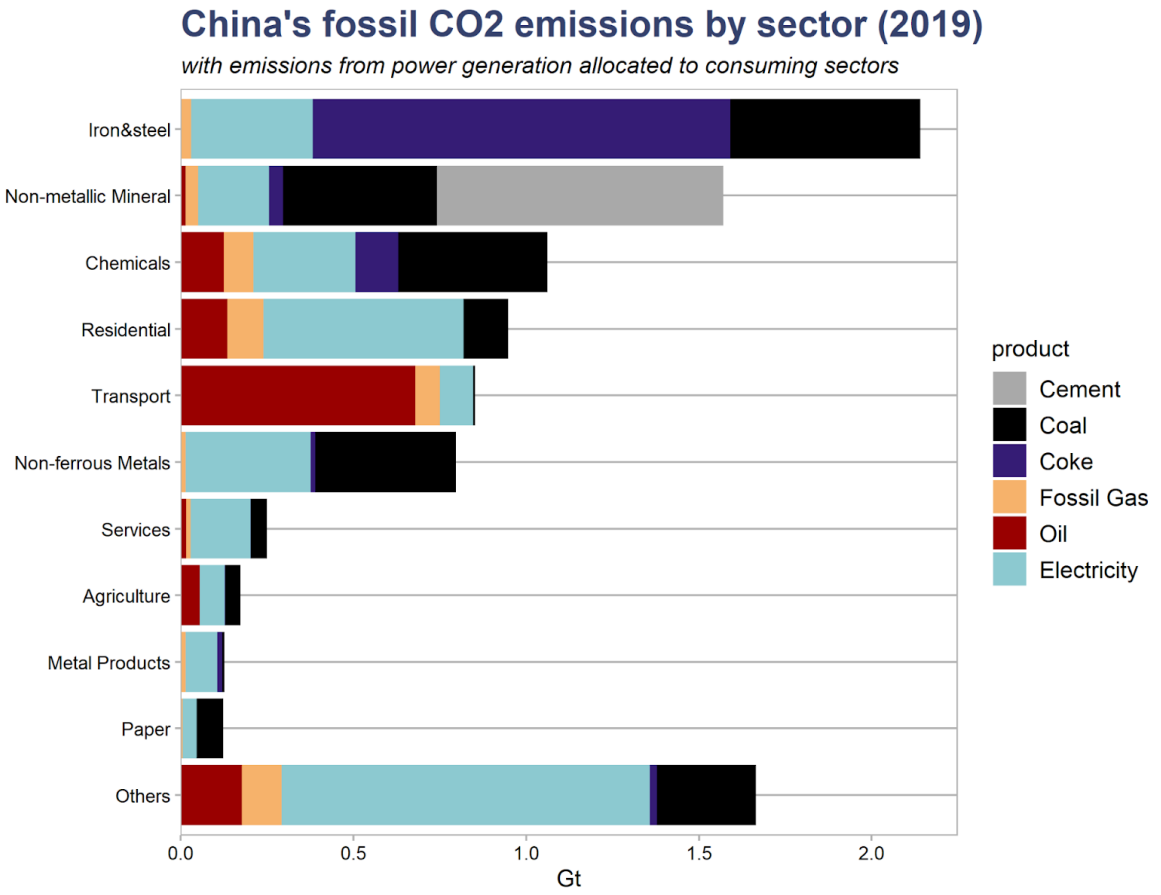

Figure 4 | China's fossil CO_2 emissions by sector; with emissions from power generation allocated to consuming sectors

Satellite-based estimates suggest that China's methane emissions were increasing by approximately 1.5% per year in 2010–2017, with increases across all emitting sectors (coal, oil and gas, rice and livestock farming as well as landfills and wastewater[13]. However, emission inventories based on activity data (e.g. coal production) suggest that emissions growth is likely to have slowed down or halted in 2012–2018 when coal production growth was slow or negative. There is significant uncertainty about emission levels and trends.[14]

[13] Zhang, Y. et al. (2022). Observed changes in China's methane emissions linked to policy drivers https://www.pnas.org/doi/10.1073/pnas.2202742119. Research article.

[14] Liu, G. et al. (2021) Recent slowdown of anthropogenic methane emissions in China driven by stabilized coal production https://pubs.acs.org/doi/pdf/10.1021/acs.estlett.1c00463. Research article.

2.2 China’s emissions in an international context

China's per capita emissions from fossil fuel use within the country's borders overtook the world average around 2005 and those of the EU in 2013.

When emissions are allocated based on where goods are consumed, rather than based on where they are produced, China’s emissions are approximately 15% lower. In other words, China's large export industry does contribute to its high emissions, but less than is generally perceived.

Consumption-based emissions per capita were still higher in the EU than in China in 2019, the last year of data, but have converged since then.

China’s consumption-based emissions are high relative to the level of the GDP because of the energy-intensive structure of the economy. The most energy-intensive commodities — steel, cement, and non-ferrous metals — are predominantly produced for the domestic market. Furthermore, China is also a major importer of emissions-intensive commodities. Emissions embedded in trade peaked around the 2007 global financial crisis, and have been falling since then. In other words, net exports have not contributed at all to China's emissions growth since 2008.

A major focus of China's climate targets has been reducing the CO2 intensity of the economy, i.e. CO2 emissions per unit of GDP. China has made rapid progress in this regard, but from a very high starting point compared to the average of other non-OECD countries, let alone developed economies. In comparison to other emerging economies that have achieved rapid economic growth in the past few decades, China has followed a far more CO2-intensive growth trajectory, due to the high share of coal in the energy mix and the highly energy intensive structure of the economy. The slowdown in CO2 emission growth since 2013 has produced some convergence, but emissions per capita remain more than twice as high as those of most other emerging countries at the same level of GDP per capita.

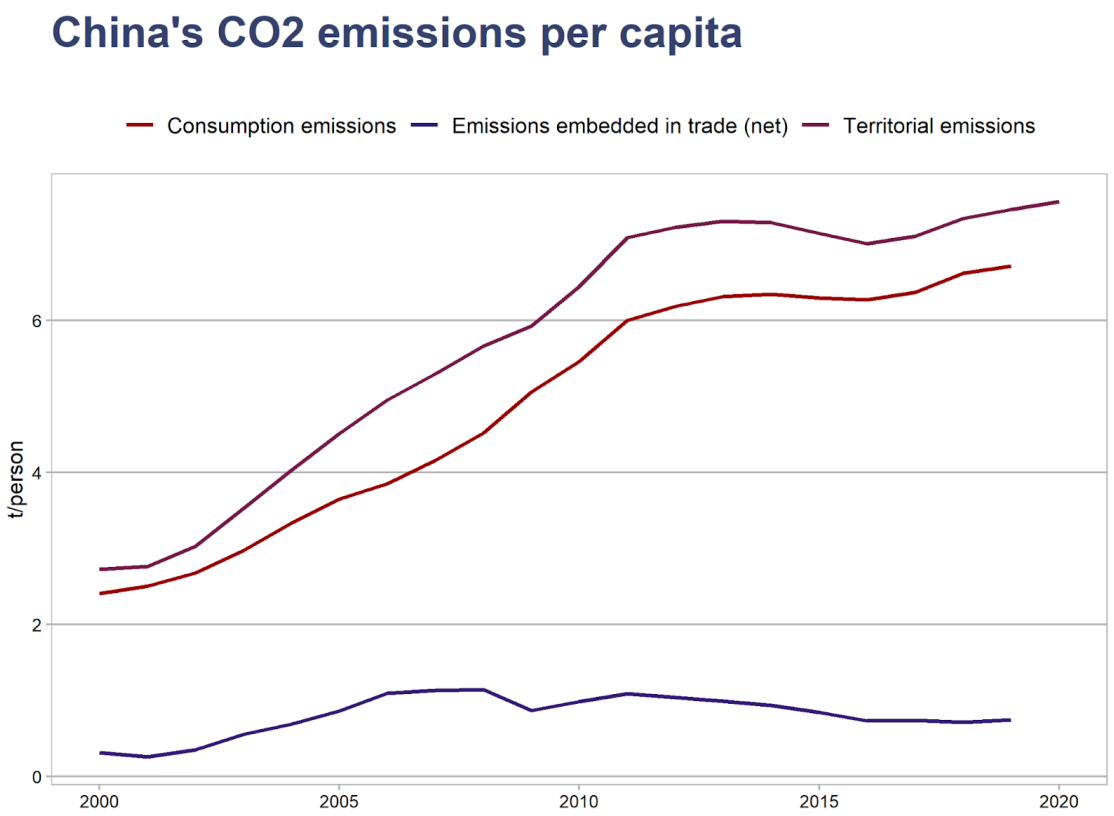

Figure 5 | China's CO2 emissions per capita

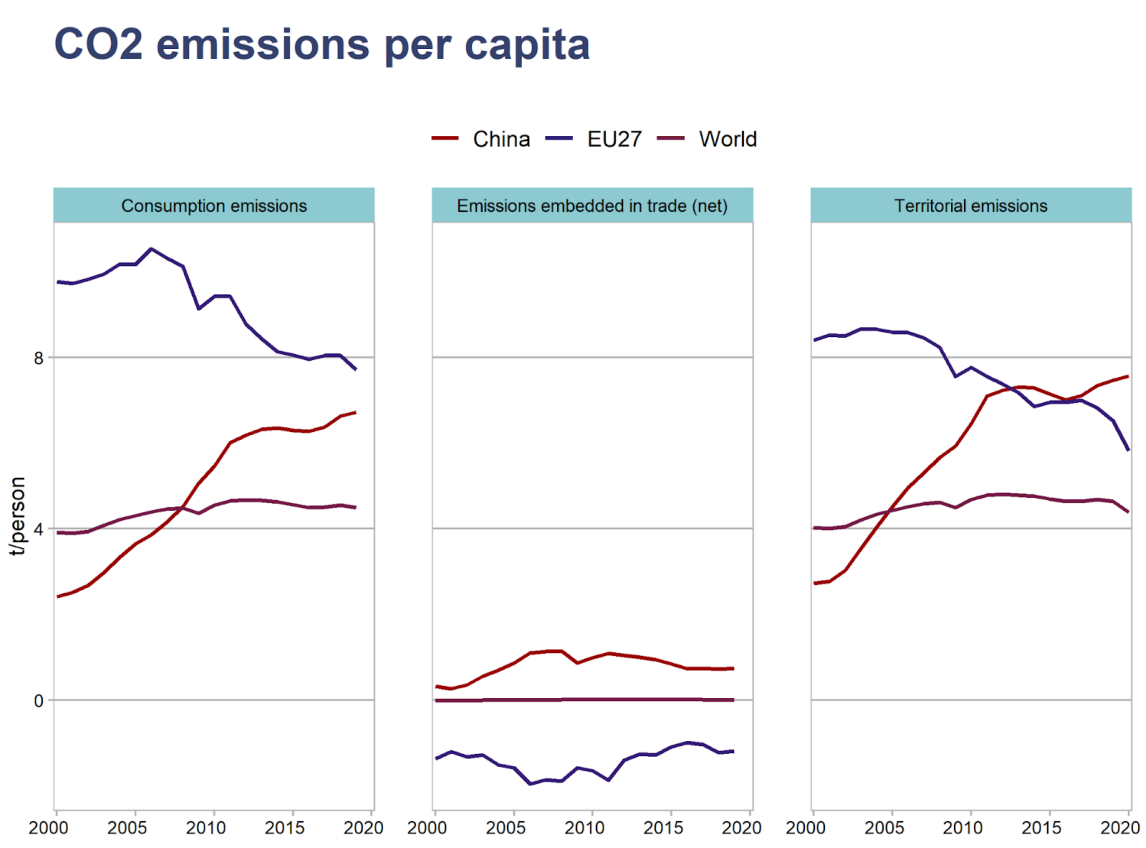

Figure 6 | Comparison of CO2 emissions per capita

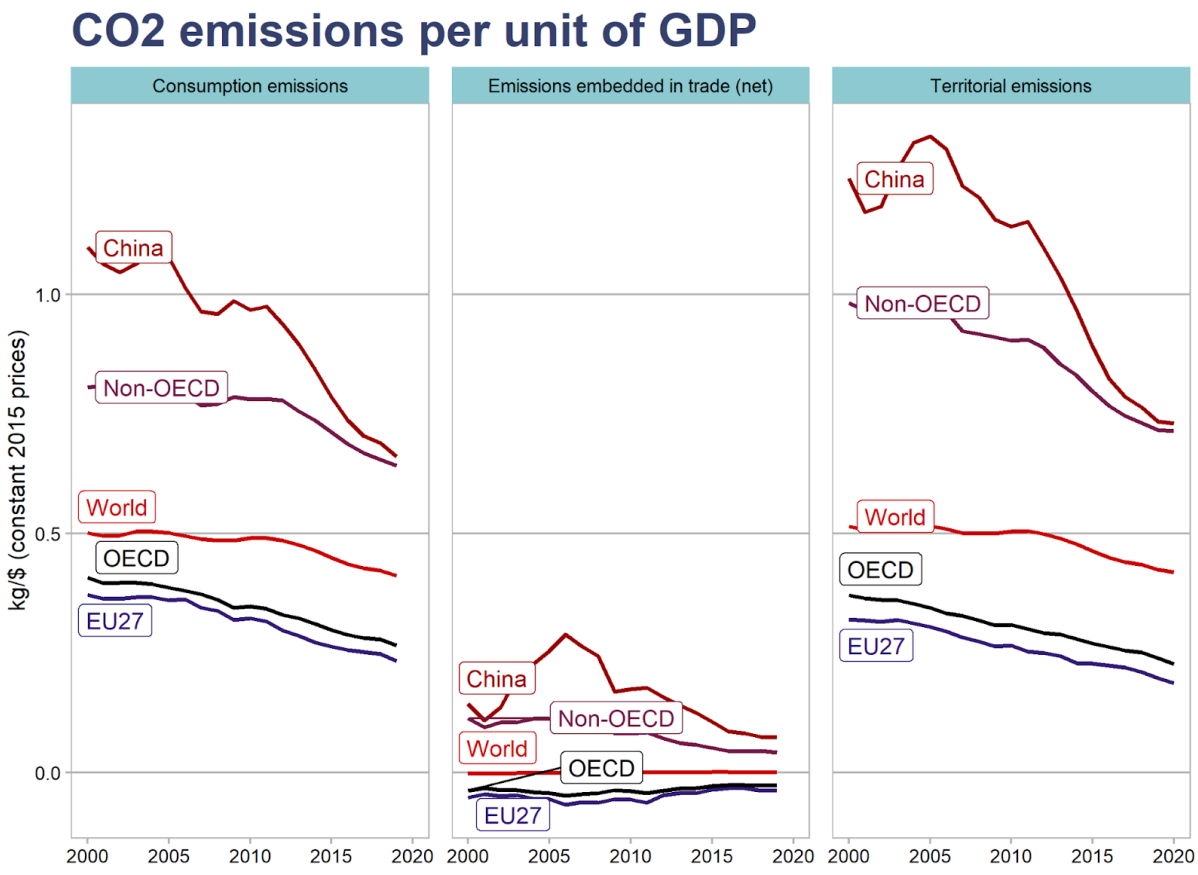

Figure 7 | Comparison of CO2 emissions per unit of GDP

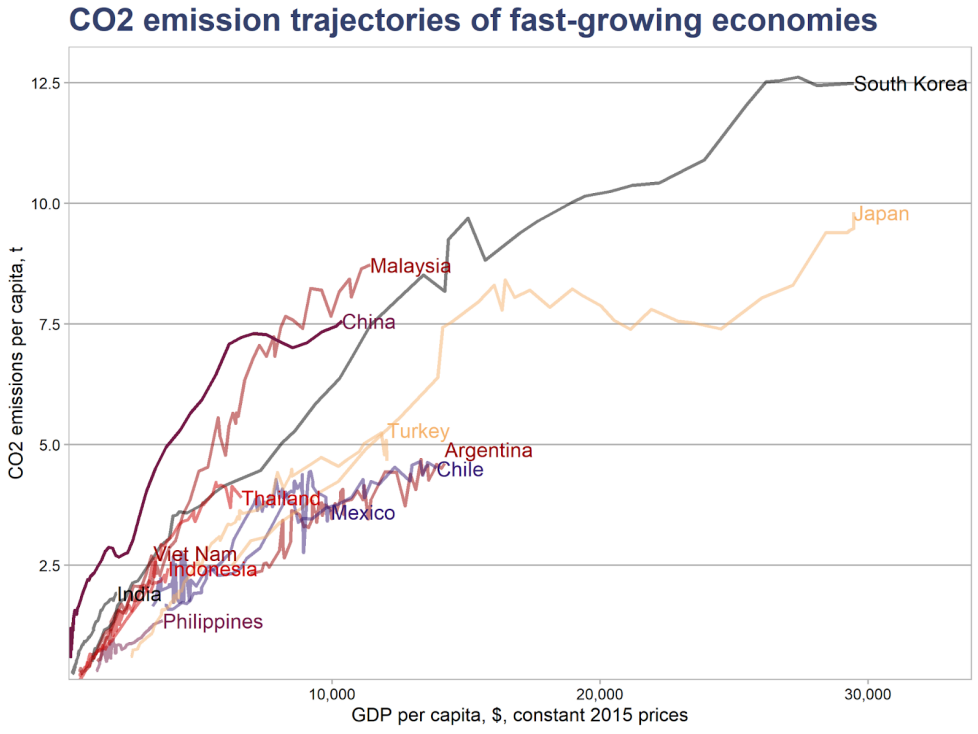

Figure 8 | CO2 emission trajectories of fast-growing economies

3 Pathways to carbon neutrality for China and the world

3.1 Overview

Meeting the goal of the Paris Agreement to limit global warming well below two degrees Celsius (2°C) requires remaking the world's energy systems, industry, agriculture, and land use, among other things. The most effective and cost-efficient ways to do this can be projected using a variety of models that incorporate information about the demand for goods and services, production technologies, and their costs, as well as available resources.

Most importantly, the models provide consistent and physically and economically plausible pathways for meeting the needs of the global economy for energy, goods, services, and commodities while respecting the goals of the Paris Agreement.

To capture the range of pathways and solutions available for China and the world, we have compiled a suite of climate transition scenarios consistent with the Paris Agreement prepared by the following research institutions: Central Banks and Supervisors Network for Greening the Financial System (NGFS); Climate Action Tracker (CAT); International Energy Agency (IEA); Institute of Climate Change and Sustainable Development (ICCSD) of Tsinghua University; School of Environment and Natural Resources; Renmin University (SENR-RMU); Institute of Atmospheric Environment; China Academy of Environmental Planning (CAEP-IAE) and Electric Power Planning and Engineering Institute (EPPEI); and North China Electric Power University (NCEPU) and Peking University (PKU).

These climate transition scenarios can serve as frameworks to support policymakers in evaluating the impacts of different policy approaches on technology choices and their implications for energy and emissions trends.

We have identified a set of indicators, such as installed clean energy capacity or transport oil consumption, that can be compared against historical data and used to measure progress in a much more granular and forward-looking fashion than a simple look at the annual change in emissions would permit. We have converted the scenario data into benchmarks for each indicator that allow us to assess whether that particular indicator is aligned with the climate transition scenarios.

While different proposals and scenarios differ in certain details, there are also clear commonalities. In all of them, the basic formula for decarbonising China’s energy system is to replace much of the fossil fuel used in industry, transport, and households with electricity, and to produce that electricity from clean energy sources. This, in turn, requires an enormous expansion of clean electricity production. The majority of this expansion is delivered by wind and solar. All scenarios project only a modest expansion in gas-fired capacity. Enhancement of forest carbon sequestration and other land carbon sinks is also important across scenarios.

A key underlying assumption for emission scenarios is the assumed or projected rate of economic growth. All pathways included in this report assume an average growth rate of 5.0–5.5% between 2020 and 2030, making them directly comparable in this regard. This rate is slightly lower than the

6–7% growth that China reported in 2015–2019, but faster than the average for 2020–2022, given the current World Bank projection for 2022 of 2.8%[15].

The different scenarios differ a lot more in terms of their projections of total energy demand growth, and the role of nuclear power, carbon capture and storage (CCS), biomass, fossil gas, and coal-fired power. The ICCSD sees a larger share for nuclear power than other scenarios, while the NCEPU and PKU include more thermal power than other scenarios. Some of the pathways, such as those prepared by the CAT, the CAEP and the EPPEI do not consider CCS a technologically mature and cost-effective solution to reduce CO2 emissions in contrast to others, such as the ICCSD, NCEPU, and the SENR, who see CCS applied to fossil emissions as one of the routes to decarbonise the power sector, as well as carbon capture and storage applied to bioenergy as a way to achieve "negative emissions" and offset emissions from other sectors. The international scenarios from the IEA and underlying Intergovernmental Panel on Climate Change (IPCC) work tend to assume that much of the economic potential for energy efficiency can be exploited, resulting in lower overall energy demand. The ICCSD scenarios factor in structural change in the economy and energy efficiency potential, resulting in low projections for total energy demand.

The SENR scenarios see a significant role for fossil gas outside the power sector in the next decade, with gas consumption continuing to grow at the same rate as in the past few years until 2030. The IPCC and IEA scenarios, in contrast, project a sharp slowdown in gas consumption growth already over the 2020s. However, within each scenario family, the scenarios targeting lower global temperature increases have slower growth or more rapid reduction in fossil gas use.

Apart from the ICCSD, most scenarios published in China don't cover other greenhouse gases besides CO2, or give them cursory treatment at most. It hasn't been specified whether the "carbon neutrality" target should be understood to cover all greenhouse gases or only CO2, with official statements being made both ways. Because of the sparsity of data both on emissions and on the viability and costs of mitigation options, estimates of the emission reduction potential vary widely. It's however clear that a target covering all greenhouse gases would require deeper reductions in CO2 emissions, as it won't be plausible to reduce the emissions of the other gases to zero and there are no foreseeable solutions to achieve negative emissions for the other gases whose concentrations in the atmosphere are far lower than those of CO2 (see section 4.2 on Non-CO2 greenhouse gases).

3.2 Global pathways

Vast amounts of research and modelling are conducted by international organisations and universities in developing pathways under different scenarios to achieve carbon net zero emissions. Work by NGFS, CAT, and IEA has been selected for this report. NGFS's delayed action scenarios forecast rapid carbon reductions after 2030, which is similar to China's two-stage development (see section 3.3.1). Data from CAT and IEA are their projections for China.

[15] The World Bank. (Sep 2022). The World Bank In China. https://www.worldbank.org/en/country/china/overview. Financial report.

Table 1 | Overview of the global scenarios included

Institute	Scenario	Source
IEA	Sustainable Development (SDS)	World Energy Outlook 2021 https://www.iea.org/reports/world-energy-outlook-2021
NGFS	Delayed transition	https://www.ngfs.net/ngfs-scenarios-portal/data-resources/
NGFS	Below 2°C	https://www.ngfs.net/ngfs-scenarios-portal/data-resources/
NGFS	Net Zero 2050	https://www.ngfs.net/ngfs-scenarios-portal/data-resources/
CAT	1.5 degrees	https://climateactiontracker.org/countries/china/
CAT	2 degrees	https://climateactiontracker.org/countries/china/

3.2.1 Central Banks and Supervisors Network for Greening the Financial System (NGFS)

The Central Banks and Supervisors Network for Greening the Financial System (NGFS) is a group that contributes to the development of environment and climate risk management in the financial sector. Along with an academic consortium from the Potsdam Institute for Climate Impact Research (PIK), International Institute for Applied Systems Analysis (IIASA), University of Maryland (UMD), Climate Analytics (CA), ETH Zürich (ETHZ), and the National Institute of Economic and Social Research (NIESR), the group has developed a set of global transition pathways for analysing climate risks to the economy and financial system. The pathways are divided into economic sectors and geographic regions and have been generated with three well-established integrated assessment models (IAMs), namely GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. The scenarios were included in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC).

The NGFS provides country-level data for six different transition scenarios based on the IPCC socioeconomic pathways and the latest International Monetary Fund (IMF) economic forecasts. The pathways differ in their level of ambition, resulting in different levels of global warming, and in how orderly the transition is. Delayed action scenarios see a slower start to reducing emissions in the 2020s and consequently require much more rapid emissions reductions after 2030. We use the "Delayed transition" scenario, compatible with the 2°C temperature goal but not with the 1.5°C goal, as the benchmark for China's transition, as this pathway most closely resembles China's carbon neutrality plan. The scenario assumes that global emissions don't fall before 2030, and then requires very rapid reductions right after 2030 to preserve a more than 50% chance of staying below 2°C. The scenario is expected to result in approximately 1.6°C warming by the end of the decade (90% confidence interval: 1.2°C to 2.4°C). China has not made explicit commitments about the rate of emissions reductions in the decades following the peak, other than reaching carbon neutrality by 2060, but the goal of the Paris Agreement requires rapid, front-loaded reductions after 2030.

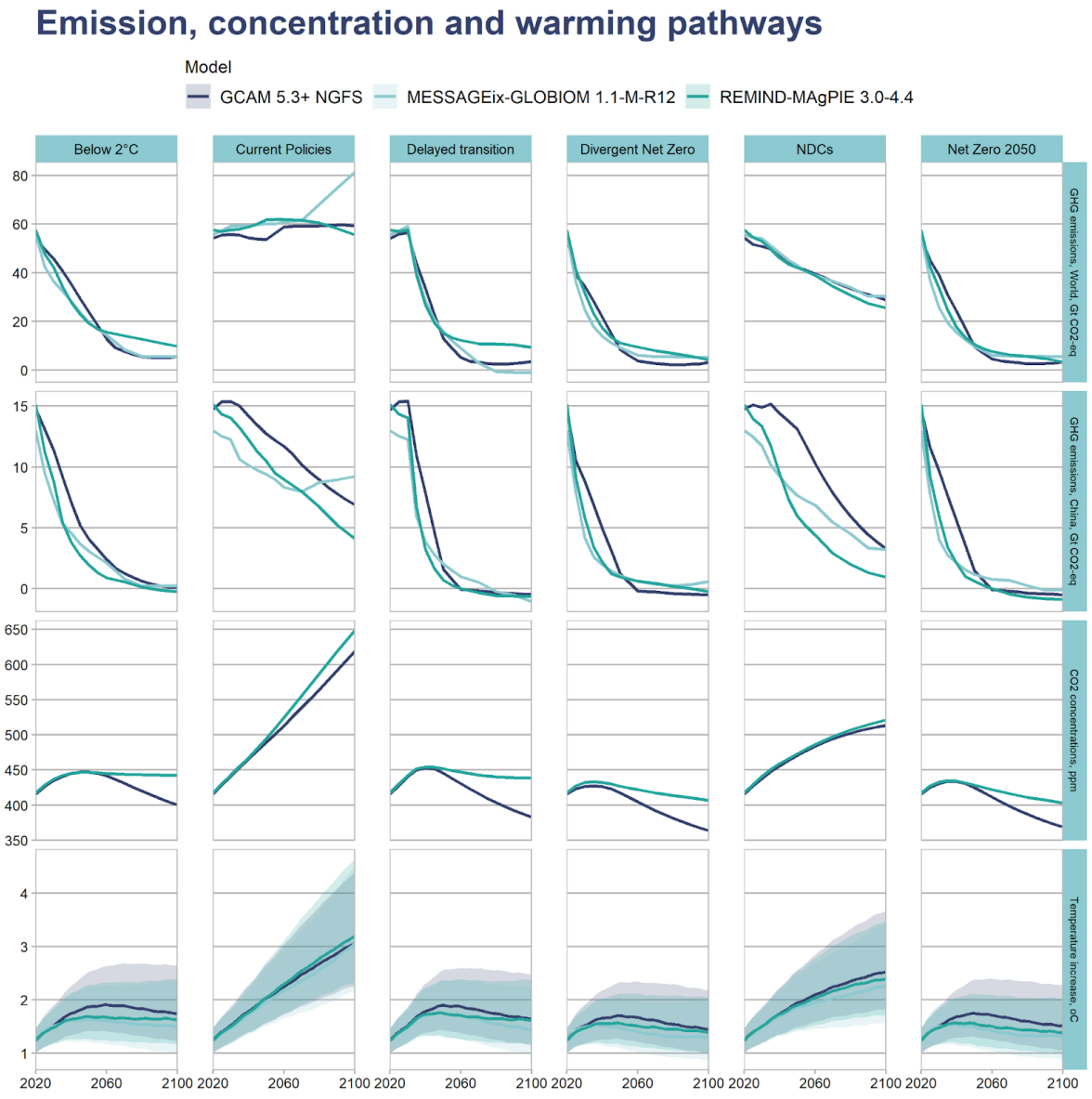

Figure 9 | Emission, concentration, and warming pathways

3.2.2 Climate Action Tracker (CAT)

Using the 1.5°C scenario in the IPCC 2018 special report, *Global Warming of 1.5°C*[16], with the International Energy Agency's 2015 data as the base year, in 2020, the Climate Action Tracker published the report, *Paris Agreement Compatible Sectoral Benchmarks*[17], to define and analyse a series of benchmarks for 2030 and 2050 across four major sectors at the global level: power, transport, industry, and buildings. Seven countries were selected for further analysis: Brazil, China, the EU, India, Indonesia, South Africa, and the USA.

[16] IPCC. (2018). Global Warming of 1.5°C https://www.ipcc.ch/sr15. Special scientific report.
[17] Climate Action Tracker. (2020). Paris Agreement Compatible Sectoral Benchmarks. https://climateactiontracker.org/documents/753/CAT_2020-07-10_ParisAgreementBenchmarks_FullReport.pdf Analytical report.

In October 2021, through the report *State of Climate Action 2021*, CAT updated the indicators for the four major sectors and added the targets for technological carbon removal, land and coastal zone management, agriculture, and climate finance[18]. All CAT indicators and benchmarks are designed to be compatible with limiting global warming to 1.5°C.

3.2.3 International Energy Agency (IEA)

The International Energy Agency (IEA) assessment no doubt has a focus on energy but also covers industry, transport, and building sectors. The power sector is the single largest source of energy-related CO2 emissions today. Decarbonising the energy system is the key to achieving the goal of limiting global warming to 1.5°C. At the same time, decarbonising other sectors through electrification relies on electricity from carbon-free power generation sources. IEA has published a collection of reports examining the technologies and policies needed for countries and regions to achieve net-zero emissions in energy systems.

The IEA's flagship report *World Energy Outlook* (WEO) analyses what would be needed over the period up to 2030 to put the world on a path towards net-zero emissions by 2050[19]. WEO's *Energy Technology Perspectives 2020* maps out the technologies needed to tackle emissions in all parts of the energy sector, including areas where technological progress is still lacking[20]. The *Tracking Clean Energy Progress* (TCEP) reports assess the status of 46 critical energy technologies and sectors and provide recommendations on how they can get on track with net-zero emissions[21]. Up to 2021, individual reports have been produced for the power, industry, transport, buildings, fuel supply, and energy integration sectors.

The *Net Zero by 2050: A Roadmap for the Global Energy Sector* report outlines the essential conditions for the worldwide energy sector to reach net-zero CO2 emissions by 2050 and highlights the key milestones for technologies, infrastructure, investment, and policy[22]. The IEA's net-zero emissions (NZE) by 2050 scenario is consistent with the IPCC 2018 pathway aimed at limiting the long-term average global temperature rise to 1.5 °C without temperature overshoot.

We use the *WEO Sustainable Development Scenario* (SDS) as the benchmark for China, as the net-zero scenario does not include disaggregated projections for China.

3.3 Pathways for China

Translating the international goal of limiting global warming to 1.5°C to emission targets and pathways for individual countries is a complex, and often contentious, challenge. Different countries and researchers emphasise countries' current per capita emissions, level of economic development and per capita income, historical responsibility, and capacity to act, as the key determinants of how large a responsibility the different countries should be assigned. Given China's share of global emissions, almost one quarter, and China's dominant role in the increase of

[18] Climate Action Tracker. (2021). State of Climate Action. https://climateactiontracker.org/publications/state-of-climate-action-2021/. Research report.
[19] IEA. (2021). World Energy Outlook. https://www.iea.org/topics/world-energy-outlook. Research report.
[20] IEA (2020). Energy Technology Perspectives 2020. https://www.iea.org/reports/energy-technology-perspectives-2020. Research report.
[21] IEA. (2021). Tracking Clean Energy Progress. https://www.iea.org/reports/tracking-clean-energy-progress-202. Research report.
[22] IEA. (2021). Net Zero by 2050. https://www.iea.org/reports/net-zero-by-2050. Analytical report.

global emissions, peaking emissions and reaching carbon neutrality are mathematical necessities if the global goals are to be met.

After the announcement of the carbon neutrality target in September 2020, numerous Chinese research institutions have unveiled their proposals or pathways for meeting the target. We've compiled a representative selection of pathways to form the basis for this report, shown in Table 2. The first ones were published soon after the initial announcement by Tsinghua professors He Jiankun and Zhang Xiliang and the team. Their work presumably informed the initial decision to set the carbon neutrality target, and the choice of the target year, while China's climate envoy Xie Zhenhua, who was influential in convincing the leadership to adopt the target, acted as an advisor to the project. As such, these scenarios are the closest thing to an official plan that existed at the time of the announcement. No other Chinese research is as comprehensive as that of the ICCSD and it often tends to focus on one sector. More recent work reflects changes in energy trends and the policy environment since the announcement.

Table 2 | Overview of the included scenarios by Chinese researchers

Institute	Scenario	Source
Institute of Climate Change and Sustainable Development (ICCSD)	1.5 degrees	China's Long-Term Low-Carbon Development Strategies and Pathways https://www.efchina.org/Reports-en/report-lceg-20210711-en
Institute of Climate Change and Sustainable Development (ICCSD)	2 degrees	China's Long-Term Low-Carbon Development Strategies and Pathways https://www.efchina.org/Reports-en/report-lceg-20210711-en
School of Environment and Natural Resources (SENR), Renmin University	1.5 degrees	Wang K (2021) Research on China's carbon emissions pathway under the 1.5°C target http://www.climatechange.cn/CN/10.12006/j.issn.1673-1719.2020.228
School of Environment and Natural Resources (SENR), Renmin University	2 degrees	Wang K (2021) Research on China's carbon emissions pathway under the 1.5°C target http://www.climatechange.cn/CN/10.12006/j.issn.1673-1719.2020.228
North China Electric Power University (NCEPU) and Peking University (PKU)	Accelerated electrification with diverse power mix (shortened to "Accelerated" in the graphs)	Pathways and Policy for Peaking CO2 Emissions in China's Power Sector https://mp.weixin.qq.com/s/AUXybE5neN-jxCah7APZoA
North China Electric Power University (NCEPU) and Peking University (PKU)	Continued electrification led by new energy (shortened to "New Energy" in the graphs)	Pathways and Policy for Peaking CO2 Emissions in China's Power Sector https://mp.weixin.qq.com/s/AUXybE5neN-jxCah7APZoA
Institute of Atmospheric Environment, China Academy of Environmental Planning (CAEP-IAE) and Electric Power Planning and Engineering Institute (EPPEI)	Baseline scenario: high electricity demand, energy mix trend as the 13th five-year plan of China (FYP)	Pathways of carbon emission peak in China's electric power industry http://www.hjkxyj.org.cn/en/article/doi/10.13198/j.issn.1001-6929.2021.11.24
Institute of Atmospheric Environment, China Academy of Environmental Planning (CAEP-IAE) and Electric Power Planning and Engineering Institute (EPPEI)	Low carbon scenario: high electricity demand, maximise RE, lower coal consumption	Pathways of carbon emission peak in China's electric power industry http://www.hjkxyj.org.cn/en/article/doi/10.13198/j.issn.1001-6929.2021.11.24
Institute of Atmospheric Environment, China Academy of Environmental Planning (CAEP-IAE) and Electric Power Planning and Engineering Institute (EPPEI)	Strengthened scenario: low electricity demand, maximise RE, lower coal consumption	Pathways of carbon emission peak in China's electric power industry http://www.hjkxyj.org.cn/en/article/doi/10.13198/j.issn.1001-6929.2021.11.24

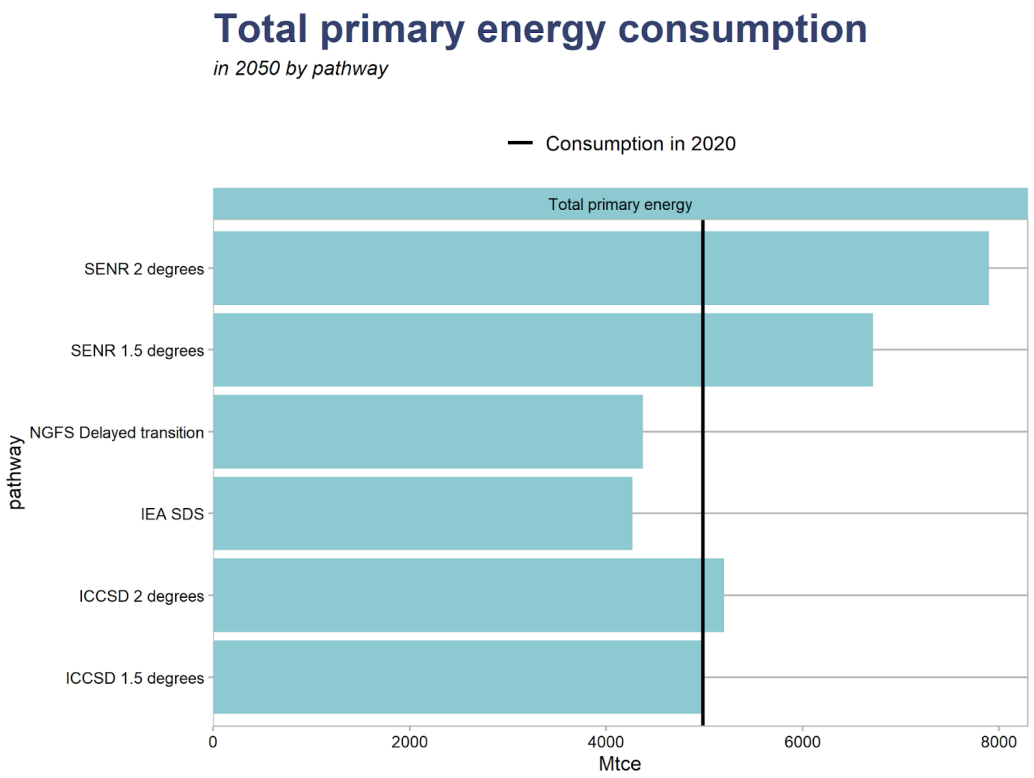

Figure 10 | Total primary energy consumption in 2050 by pathway

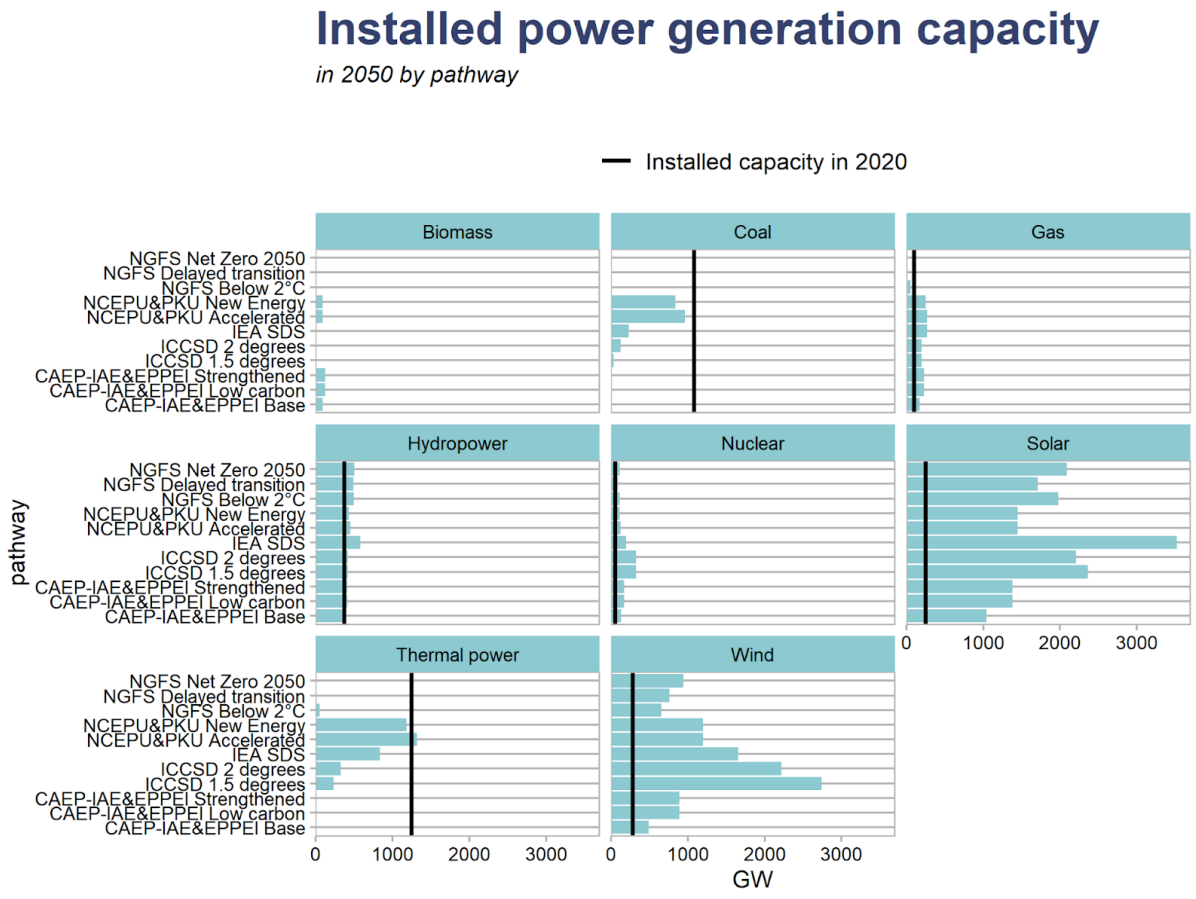

Figure 11 | Installed power generation capacity in 2050 by pathway

3.3.1 Institute of Climate Change and Sustainable Development (ICCSD)

Since the beginning of 2019, the Institute of Climate Change and Sustainable Development (ICCSD) of Tsinghua University has been cooperating with more than ten Chinese research institutes to undertake a research project, *China's Long-Term Low-Carbon Development Strategies and Pathways*, with 18 sub-projects. The results were delivered as a comprehensive report published in 2021[23].

The ICCSD study splits China's long-term low-carbon transition pathway into two stages. The first stage, from 2020 to 2035, will focus on implementing and strengthening the nationally determined contributions (NDCs) to the Paris Agreement of emission reduction in line with the social and economic development goals. The second stage, from 2035 to 2050, will achieve the goal of deep decarbonisation of energy and economy and building a strong modern socialist country while aligning emission reduction pathways with global warming control targets of 2°C and 1.5°C by 2050.

The report analysed emissions reduction pathways, technology support, cost, and prices driven by the long-term decarbonisation goal. The study was based on four scenarios, namely, policy scenario, reinforced policy scenario, 2°C scenario, and 1.5°C scenario. We select 1.5°C scenario and 2°C scenario data for this report which are in line with the Paris Agreement and global net zero goals.

The 2°C scenario is based on the goal of controlling global warming to within 2°C with per capita CO2 emissions not exceeding 1.5 tonnes by 2050 (down from 8.4 tonnes in 2020). The 1.5°C scenario is based on the goals of limiting the global temperature rise to 1.5°C and achieving net-zero CO2 emissions and deep reductions of other GHGs emissions by 2050. Both 1. 5°C and 2°C scenarios are “ideal” scenarios requiring a rapid shift in China’s energy systems and economic development pattern to align with the near-term emission reduction rates. Considering practical, economic, and political challenges in peaking emissions immediately, the ICCSD further introduces “target-oriented” (later peak) variants of the 1.5°C and 2°C scenarios[24], which assume that CO2 emissions only peak late in the decade to allow for the prioritisation of economic growth during this decade and a more gradual shift in the pattern of economic growth (termed “two-stage” development). These pathways envision an enhanced version of China’s current Paris agreement pledges (NDCs) until 2030, accelerating carbon reduction and energy systems transition from 2030, and achieving net zero carbon emissions by 2050.

3.3.2 School of Environment and Natural Resources, Renmin University (SENR-RMU)

According to the deep emission reduction requirements and technical characteristics of the 1.5°C target, Wang Ke et al. at the School of Environment and Natural Resources, Renmin University modified the existing energy system model PECE-LIU2020 by adding hydrogen and bioenergy with carbon capture and storage (BECCS) energy modules. Using the upgraded model, the team studied

[23] ICCSD, (2021). China's Long-Term Low-Carbon Development Strategies and Pathways, Comprehensive Report. https://link.springer.com/book/10.1007/978-981-16-2524-4. Study report.
[24] He, J. et al. (2022). Towards carbon neutrality: A study on China's long-term low-carbon transition pathways and strategies. Environmental Science and Ecotechnology, Vol. 9, 100134. https://www.sciencedirect.com/science/article/pii/S2666498421000582. Scientific article.

China's long-term CO2 emissions reduction requirements, sectoral contributions, and key emission reduction measures under 1.5°C and 2°C scenarios[25].

The concept of 1.5°C and 2°C scenarios align with the IPCC. But the pathways are set based on China's circumstances. Similar to the ICCSD's two-stage transition, under the 2°C scenario, China will take enhanced emission reduction measures based on the existing NDC target, strive to achieve the peak of carbon emissions as soon as possible, and then strengthen policies to accelerate the decline of emissions to meet China's emissions reduction target by 2050. Under the 2°C scenario, already matured and demonstration stage low-carbon technologies, including electric vehicles, wind, and solar, will be developed rapidly. Demonstration of carbon capture, utilisation and storage (CCUS) technology will be accelerated to prepare for deployment after 2030.

Under the 1.5°C scenario, to achieve a more stringent carbon reduction target, China will peak carbon emissions as soon as possible and also accelerate carbon reduction to the 1.5°C targets by 2050. China needs to accelerate technology renovation and innovation, rapidly develop hydrogen and BECCS technologies, improve energy system efficiency and deep decarbonise steel, chemical engineering, road cargo, and power sectors.

Both 1.5°C and 2°C scenarios require China to enhance carbon reduction and reach a carbon peak before 2025. Reference to 2005 milestone, 73% and 75% carbon reduction by 2030 are needed for 2°C and 1.5°C scenarios, respectively.

3.3.3 Institute of Atmospheric Environment, China Academy of Environmental Planning (CAEP-IAE) and Electric Power Planning and Engineering Institute (EPPEI)

The Institute of Atmospheric Environment, China Academy of Environmental Planning and China Electric Power Planning and Engineering Institute jointly established a projection model and influencing parameters/factors to study the pathway for China's power sector to peak carbon emissions under different scenarios. The influencing parameters include economic and social development, electricity demand, power source structure, and standard coal consumption rate for power generation. Three scenarios are laid out[26], as follows.

Baseline scenario: The power structure will remain the same as during the 13th five-year plan period (2016–20) in order to meet a high rate of power demand growth. Improvement in the thermal efficiency of coal-fired power plants stops and is frozen at the current level.

Low carbon scenario: To maintain a high rate of power generation growth, it is essential to maximise non-fossil fuel energy power generation within the limits set by the potential of different electricity generation sources, construction period, energy prices and other factors. The thermal efficiency of coal-fired power plants will fall at the same rate as during the 13th FYP period, resulting in a reduction in standard coal consumption of 2 g/kWh per year. Taking into account the more flexible operation of thermal power plants required to accommodate non-fossil energy sources, which tends to reduce the thermal efficiency of generation, it is assumed that coal

[25] Wang, K. et al. (2022). Research on China's carbon emissions pathway under the 1.5°C target. http://www.climatechange.cn/CN/10.12006/j.issn.1673-1719.2020.228. Research article.
[26] Wang, L. et al. (2022). Pathway of carbon emission peak in China's electric power industry. http://www.hjkxyj.org.cn/en/article/doi/10.13198/j.issn.1001-6929.2021.11.24. Research article.

consumption for power generation will fall by 1 g/kWh annually and reach 286, 280, and 275 g/kWh in 2025, 2030, and 2035 respectively, down from 289 g/kWh in 2020.

Strengthened scenario: The thermal efficiency improvements of coal-fired power plants follow the low carbon scenario, and power generation from non-fossil fuels is maximised. In addition, measures are taken to reduce the growth rate of electricity demand.

3.3.4 North China Electric Power University (NCEPU) and Peking University (PKU)

Transition pathways developed by the North China Electric Power University and Peking University are based on the understanding that China will peak CO2 emissions in 2030 and the power sector is the critical player in this mission. Combining the trends of various macroeconomic indicators, Professor Yuan and his team estimate that China's national electricity demand for the period of 2021 to 2035 will be driven by electrification in the power, industry, building and transport sectors[27].

To meet the electricity demand under different electrification processes, three pathways are set up to discuss the possible situations the low carbon power system transformation may face and pathways for the power sector to peak carbon emissions. The carbon peak time under different scenarios is projected. We selected the "Accelerated electrification with diverse power mix" and "Continued electrification led by new energy" pathways for our report, shortened to "Accelerated" and "New Energy". NCEP and PKU recommend the "Accelerated" pathway as the most effective approach to peak emissions.

Under the accelerated electrification scenario, targets of more than 50% of non-fossil fuel in the electricity mix and 1200GW wind and solar installations by 2030 are met. Coal power generation will peak in 2025 at 5,200TWh, up from 4900 TWh in 2020. The role of coal power changes from the mainstay of power generation to a supporting source of generation for non-fossil energy. Under this scenario, carbon emissions from the power sector will peak around 2025.

[27] Yuan, J. et al. (2021) Pathways and policy for peaking CO2 emissions in China's power sector. https://mp.weixin.qq.com/s/AUXybE5neN-jxCah7APZoA. Research article.

4 Measuring and benchmarking China's progress

The transition pathways allow us to break down the herculean task of making China's economy carbon neutral into more specific changes required in each key emitting sector. This section compares the development of China's emissions, energy mix, installed power generation capacity, electrification ratio, and other essential indicators to benchmarks derived from different transition pathways. The approach we take is to assess annual change in each indicator against the required rate of change from 2020 to 2030 in different pathways. We assess whether the indicators are either already in line with the benchmarks or making progress so that the benchmarks are likely to be met. The assessment is designed so that we can repeat it annually and provide an update of progress.

4.1 Total CO2 emissions

To be consistent with the 1.5°C degree target, even assuming very aggressive emissions reductions after 2030, China's CO2 emissions should reach their peak by 2025. Considering practical, economic, and political challenges in peaking emissions immediately, the ICCSD further introduced "target-oriented" (later peak) variants of the 1.5°C and 2°C scenarios[28], which assume that CO2 emissions only peak late in the decade to allow for the prioritisation of economic growth during this decade and a more gradual shift in the pattern of economic growth (termed "two-stage" development). These pathways envision an enhanced version of China's current Paris agreement pledges (NDCs) until 2030, accelerating the carbon reduction and energy systems transition from 2030, and achieving net zero carbon emissions by 2050.

These 'later peak' pathways are less ambitious over the next decade than the 1.5°C and 2°C scenarios. For example, the ICCSD 1.5°C "target-oriented" scenario sees CO2 emissions peak at 10.4 billion tonnes by 2025, up from 10.2 billion tonnes in 2020, and stay at the same level until 2030, then dropping sharply to 1.7 billion tonnes by 2050, almost converging to the 1.5°C pathway in the following decades, but with higher cumulative total emissions (Table 3). For the "ideal" 1.5°C and 2°C scenarios, CO2 emissions should peak in 2020 at 10.2 billion tonnes and fall to 7.4 and 1.5 billion tonnes and 9.4 and 2.9 billion tonnes, respectively, by 2030 and 2050. With the help of CCUS and agroforestry carbon sinks, this would allow net zero CO2 emissions to be achieved by 2050.

[28] He, J. et al. (2022). Towards carbon neutrality: A study on China's long-term low-carbon transition pathways and strategies. Environmental Science and Ecotechnology, Vol 9, 100134. https://www.sciencedirect.com/science/article/pii/S2666498421000582. Scientific article.

Table 3 | CO2 emissions under the ICCSD 1.5°C, 1.5°C target-oriented and 2°C pathways (He et al., 2022)

		2020	2025	2030	2035	2040	2045	2050
CO2 emissions, billion tCO2	1.5°C	10.2	9.3	7.4	6	4.2	2.7	1.5
	1.5°C target oriented	10.2	10.4	10.4	7.7	5	3	1.7
	2°C scenario	10.2	10.1	9.4	8.1	6.4	4.3	2.9
Annual decline of CO2 emissions per unit of GDP, %	1.5°C	4.3	7.1	8.9	8.5	10.3	11.3	14.3
	1.5°C target oriented	4.3	4.1	4.1	8.2	9.3	10	10.4
	2°C scenario	4.3	5.5	6.1	7.2	8.4	10.7	10.1
Decline from 2005 level, %	1.5°C	50.6	65.8	78.5	86.2	92	95.6	98
	1.5°C target oriented	50.6	60.3	68.4	81.3	90	95	97.6
	2°C scenario	50.6	62.8	72.8	81.2	87.9	93.1	96

4.1.1 Trends compared to benchmarks

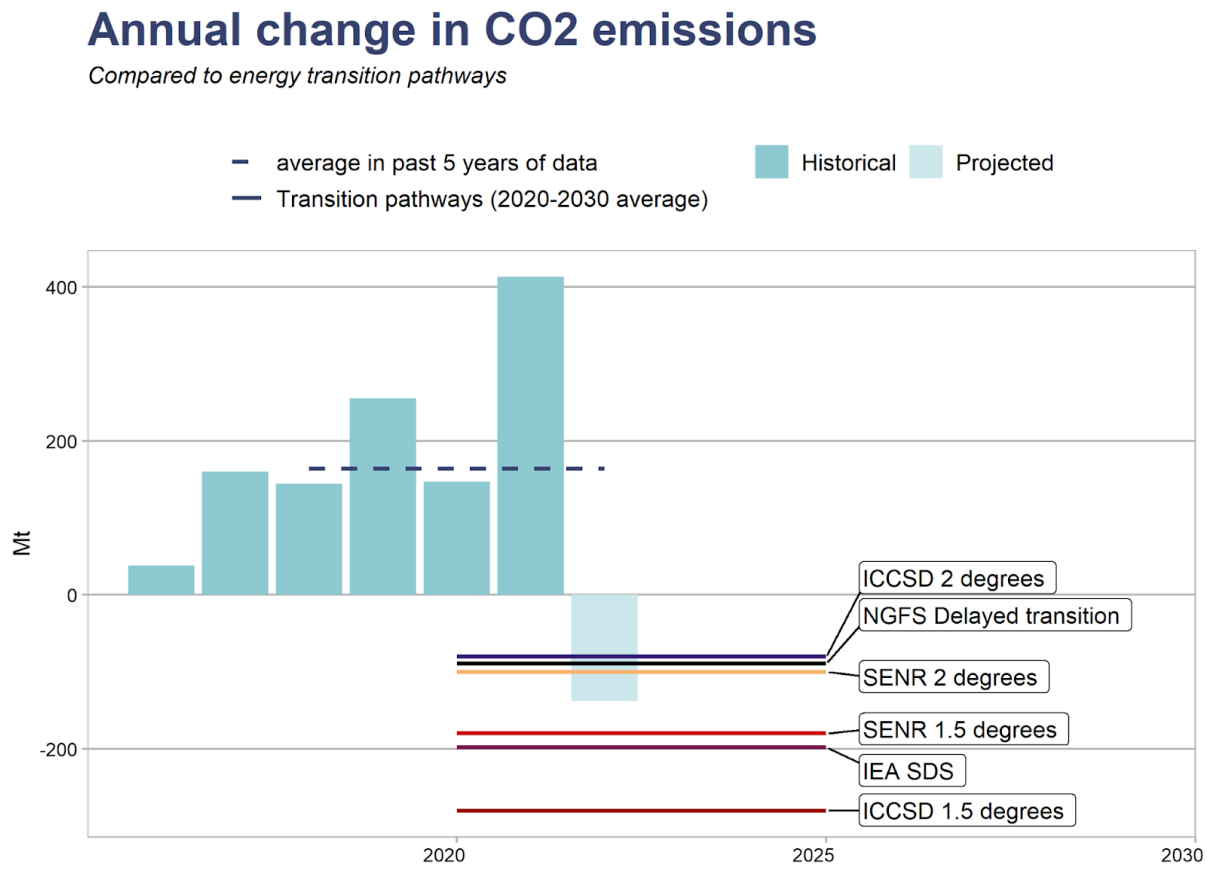

Figure 12 | Annual change in CO2 emissions compared to energy transition pathways

China's CO2 emissions have grown every year since 2015, albeit at a much slower pace than until 2013. On the other hand, emissions growth accelerated between 2016 and 2021. However, since

the summer of 2021, CO2 emissions have been falling. All the transition pathways require emissions to fall from 2020 to 2030, implying a peak well before 2030 and emissions reductions thereafter.

Our projected CO2 emissions growth rate for 2022 is in line with the annual reduction required in the pathways consistent with the warming of 2°C, while the 1.5°C pathways require more rapid reductions. However, in all transition pathways, emissions reductions need to accelerate dramatically from the rates projected for 2020–30 immediately after 2030 in order to meet their temperature targets.

4.1.2 Policies in place

The increase in CO2 emissions is currently constrained by the CO2 intensity and non-fossil energy targets for 2025 and 2030, the energy intensity target for 2025 and the commitment to peak CO2 emissions "before 2030". These targets, however, leave room for a substantial increase in CO2 emissions from 2020 to 2030, of up to 15%, assuming a 5% average GDP growth rate in 2021–30. Emissions could increase even more by the late 2020s and then fall to meet the peaking target and the 2030 targets. There are no numerical targets in place for the rate of emissions reductions after the peak, leaving the trajectory of emissions from the peak to carbon neutrality sometime before 2060 wide open. This makes it difficult to predict China's cumulative emissions in the next decades and to measure whether the country is on track to achieve the carbon neutrality target.

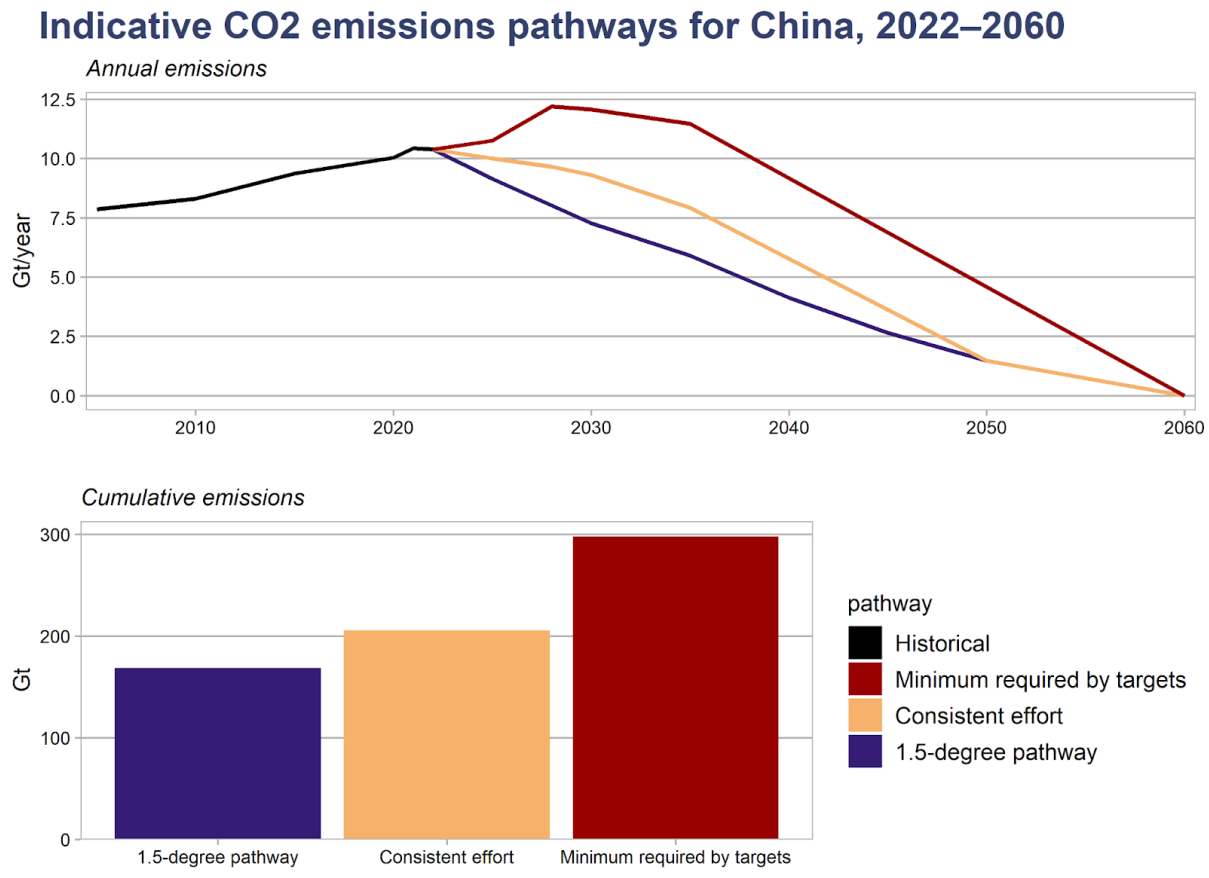

Figure 13 | Indicative emissions pathways for China

Data sources: CO2 emissions until 2020 from BP Statistical Review of World's Energy; CREA analysis.

China's current climate commitments allow for a wide range of CO2 emissions outcomes. The pathway labeled "minimum required by targets" shows the highest possible emissions pathway that China could follow while meeting the 2025 and 2030 CO2 intensity targets and the commitment to peak emissions before 2030. After 2030, emissions fall slowly and gradually, requiring very rapid reductions in the 2040s and 2050s. This does not violate China's commitments but results in large cumulative emissions and does little to demonstrate the commitment to the long-term goal over the next two decades. The "consistent effort" pathway shows a path to the carbon neutrality target in which emissions plateau until 2025 and start falling thereafter, avoiding a steep increase in the amount of effort required in the following decades. The 1.5-degree pathway would be extremely challenging to achieve, but it is what China and other countries should strive towards based on the Paris Agreement.

"3 lines and 1 list"

Pollutant emission control is another battlefront for China's environmental governance. The *Pollution Reduction and Carbon Reduction Synergy Implementation Plan*[29], released by the Ministry of Ecology and Environment of the People's Republic of China (MEE), stipulates that the carbon emission reduction target will be integrated into the "3 Lines and 1 List" (i.e. ecological protection red line, environmental quality bottom line, resource utilisation limit line, and the ecological and environmental access list), which is used by the MEE for environmental governance[30].

Carbon sinks

Besides emission control, China is also seeking to increase carbon sinks through afforestation programmes and exploring ocean sinks.

Afforestation programmes have managed to continuously increase China's forest coverage since 2012. By 2021, the national forest cover rate reached 24%, with a forest stock volume of 19.5 billion cubic metres[31].

With the context of a top-level goal set to reach a forest cover rate of 25% by 2030[32], the *National Land Greening Planning Outline (2022-2030)* stated that China should implement, among other things, afforestation and grass cultivation for 500 million mu (33.3 Mha) of land, control and transform 100 million mu (6.7 Mha) of desert, and increase the plantation coverage rate to 43% in urban areas and 32% in rural areas, during the period of the 14th FYP. The ecological carbon sink

[29] Ministry of Ecology and Environment of China. (2022). Pollution Reduction and Carbon Reduction Synergy Implementation Plan. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202206/t20220617_985879.html. Policy.
[30] Ministry of Ecology and Environment of China. (2021). Guiding Opinions on Implementing "Three Lines and One List" Ecological Environment Zone Management and Control (Trial). https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202111/t20211125_961692.html. Policy.
[31] State Council of China. (2021) By 2025 China's forest coverage rate will increase to 24.1%. http://www.gov.cn/xinwen/2021-08/21/content_5632505.htm.
[32]Central Comittee of the Communist Party of China, State Council. (2021). Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy. https://en.ndrc.gov.cn/policies/202110/t20211024_1300725.html. Policy.

should have a significant increase by 2030[33]. Supporting tools such as *Guidelines for Validation and Verification of Forestry Carbon Projects* are also promulgated[34].

The 14th FYP stated that "ocean carbon sinks should be improved", although no further detailed policy has been released yet. The fact that *Accounting Methods for Economic Value of Ocean Carbon Sink* was recently submitted for approval hints that there is progress in this area[35]. While there is no national-level policy released yet, coastal regions have made local policies. For example, Hainan Province stated that it will finish an ocean sink baseline screening and launch five ocean sink pilot programmes by 2024, according to the Hainan Province *Pilot Work Plan for Carbon Sinks in Marine Ecosystems (2022- 2024)*[36]. Shandong Province also included baseline screening for its coastal wetlands, ecological system restoration project, and several research programmes in the *Shandong Province Plan for Combating Climate Change during 14th FYP*[37].

Carbon trading

China has been developing carbon trading since the early 2010s, first through regional pilot programmes. In 2021, the national carbon trading system began operation, covering the power sector. The trading system differs from the "cap and trade" approach used e.g. in the EU in that it's not designed to limit the total CO2 emissions from the power sector but only to drive reductions in the emission intensity of coal- and gas-fired power plants.

The scope of carbon trading is meant to be expanded to cover other sectors besides power, and potentially carbon sinks. The MEE has released a regulation defining the enterprises that are meant to be included in carbon emission trading[38], namely those with annual emissions exceeding 26,000 tonnes of CO2 equivalent in the petrochemicals, chemicals, building materials, steel, non-ferrous metals, paper, and domestic civil aviation sectors. Another high-level policy document, *Opinions from Office of State Council on Establishing and Improving the Mechanism for Realising the Value of Ecological Products*, also emphasises improving carbon emission trading and calls for establishing carbon sink trading pilot programmes[39].

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[33] National Greening Commission. (2022). National Land Greening Planning Outline. (2022-2030). http://www.gov.cn/xinwen/2022-09/13/content_5709591.htm. Policy.
[34] National Forestry and Grassland Administration of China. (2021). Guidelines for Validation and Verification of Forestry Carbon Projects. https://std.samr.gov.cn/gb/search/gbDetailed?id=D4BEFFF4EA85B241E05397BE0A0AF581. National Standard.
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4.1.3 Data disclosure

The government currently reports on the improvement in CO2 intensity every year, which can be used to calculate the change in CO2 emissions based on reported GDP growth. However, this is a very rudimentary and non-transparent way of reporting and doesn't include sinks or non-energy CO2 emissions.

Actual greenhouse gas emissions disclosure only takes place through China's national communications to the United Nations Framework Convention on Climate Change (UNFCCC), the most recent of which has data for 2014. There have been statements of building a capability to control total emissions on an annual basis, an important step to ensure that the CO2 peaking target can be met. This should involve more detailed and timely disclosure of emissions.

4.2 Non-CO2 greenhouse gases

Besides rapid reductions in CO2 emissions, the transition pathways consistent with the 1.5 °C target require more efforts to control other non-CO2 greenhouse gases (NCGHGs). The total reductions in NCGHGs will reach 30% of the 2014 emission level (2,000 MtCO2-eq) in 2030 and 34% in 2050 in the 1.5 °C pathway.

In the ICCSD 1.5°C pathway, non-CO2 emissions peak and fall below the 2020 level before 2025. Emissions stand at 2.38 GtCO2-eq in 2025 and fall to 1.2 GtCO2-eq in 2050. The ICCSD's 2°C pathway projects that non-CO2 GHG emissions will peak in 2025 at 2.51 billion tCO2eq, with an average annual increase of 1.5% from 2020 to 2025, before falling to 1.76 GtCO2-eq in 2050, an annual rate of reductions of 1.4%.

After CO2, methane is the greenhouse gas that China emits the most in CO2-equivalent terms. In the ICCSD 2°C pathway, methane emissions peak before 2025 at 1,220 MtCO2-eq and fall to 1,180 MtCO2-eq in 2030. Under the 1.5°C scenario, methane emissions peak at the same level as the 2°C pathway but around 2015 and then fall more rapidly to 790 MtCO20-eq by 2030.

The ICCSD 1.5°C pathway projects a peak in N2O emissions around 2020 at 580 million tCO2e, falling to 420 million tCO2e in 2030. F-gases emissions peak in 2030 at 730 MtCO2-eq and fall to 440 MtCO2-eq in 2050. The ICCSD 2°C pathway sees N2O emissions reaching a peak also around 2020 but at 650 million tCO2e and dropping to 570 million tCO2e in 2030, while F-gas emissions peak at the same level in the same year as the 1.5°C pathway but drop to 510 million tCO2e in 2050.

4.2.1 Policies in place

China has started to take steps to control non-CO2 greenhouse gases, which was included in the *Action Plan for the 13th FYP*, published back in 2016. In the 14th FYP, this was specified as "strengthen controlling of methane, HFCs and PFCs". However, the policies have not included numerical targets, and there is no reporting on NCGHG emissions that would allow the assessment of emissions trends after 2014, the year covered by the latest official emission inventory.

It's also currently not clear whether the "carbon neutrality" target should be understood to cover all greenhouse gases or only CO2, with official statements being made both ways.

Methane accounted for 10.4% of China's total GHG emissions in 2014[40]. Coalbed methane emitted from coal mining is responsible for more than 90% of the energy sector's methane emissions. The National Energy Administration of China (NEA) released a policy in 2020 regulating coalbed methane and encouraging its utilisation, specifying that it "should" be extracted and utilised from deposits with methane volume concentrations over 8% in the trapped gas, and extraction is "encouraged" in deposits with a concentration between 2% and 8%[41]. The remaining emissions are restricted by an on-trial *Emission Standard for Coalbed Methane*[42], promulgated by the MEE. There is also a discharge standard that regulates methane emitted from municipal wastewater treatment plants[43].

In a press conference in 2021, China also pledged to enact a national action plan[44] on curtailing methane emissions in key sectors including coal, gas, and oil and waste management. The MEE also addressed that methane emissions will also be expected to be included in the national carbon emission trading market. The monitoring, report, and validation (MRV) of methane emissions, as well as the energy sector's emissions inventory, are also expected to be improved during the 14th FYP period.

At the 2021 COP26, the US and China issued the *Joint Glasgow Declaration on Enhancing Climate Action in the 2020s*[45]. The declaration specifically recognised the role that methane emissions play in climate change and agreed to enhance the measurement and mitigation of methane, including through standards to reduce methane from the fossil and waste sectors, as well as incentives and programs to reduce methane from the agricultural sector. China intends to develop a national action plan on methane to control methane emissions in key sectors.

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Table 4 | Selected policies relating to non-CO2 greenhouse gas emissions

Policy name	Release date	2025 Target	Targets for 2030 and beyond
Pollution Reduction and Carbon Reduction Synergy Implementation Plan, (Ministry of Ecology and Environment and others)	2022-06-17	In 2025, the proportion of EAF-based secondary steelmaking will increase to more than 15%. In 2025, secondary aluminium production will reach 11.5 million tonnes. By 2025, the comprehensive utilisation rate of new bulk solid waste will reach 60%.	In 2030, the proportion of EAF-based secondary steelmaking in the country will increase to more than 20%. By 2030, the proportion of renewable energy used in electrolytic aluminium will increase to more than 30%. By 2030, the sales volume of new energy vehicles in key areas for air pollution prevention and control will reach about 50% of the sales volume of new vehicles.
Implementation Guidelines for Energy Conservation and Carbon Reduction Retrofitting and Upgrading in Key Areas of High Energy-consuming Industries (2022 Edition), (National Development and Reform Commission and others)	2022-02-11	-	-
14th Five-Year Comprehensive Work Plan for Energy Conservation and Emission Reduction (State Council)	2021-12-28	By 2025, the national energy consumption per unit of GDP will drop by 13.5% compared with 2020, the total energy consumption will be reasonably controlled, and the total emissions of chemical oxygen demand, ammonia nitrogen, nitrogen oxides, and volatile organic compounds will drop by 8%, 8%, 10%, and 10%, respectively, compared with 2020.	-

4.2.2 Data disclosure

Emissions disclosure for non-CO2 greenhouse gases only takes place through national communications to the UNFCCC, the most recent of which has data for 2014, which is a major shortcoming in both tracking emissions trends and the effect of policies, and in China's ability to set emissions targets for these gases.

4.3 Total energy supply and demand

In most transition pathways, emissions peaking relies heavily on energy efficiency measures and structural changes in the economy that slow down energy demand growth, with total energy demand growth between 0 and 2%. Only the SENR scenarios project growth at over 2%. For example, the ICCSD 1.5°C pathway sees total primary energy consumption entering a plateau of 5.3 Gtce by 2025, up slightly from 5.2 Gtce in 2021, and then declining gradually to 5.0 Gtce in 2050. The share of non-fossil energy in the primary energy mix increases from 16.6% in 2021 to 38.7% by 2030 and 86.1% in 2050, while the share of coal drops from 56% in 2021 to 35.4% and 5.4%, respectively.

4.3.1 Trends compared to benchmarks

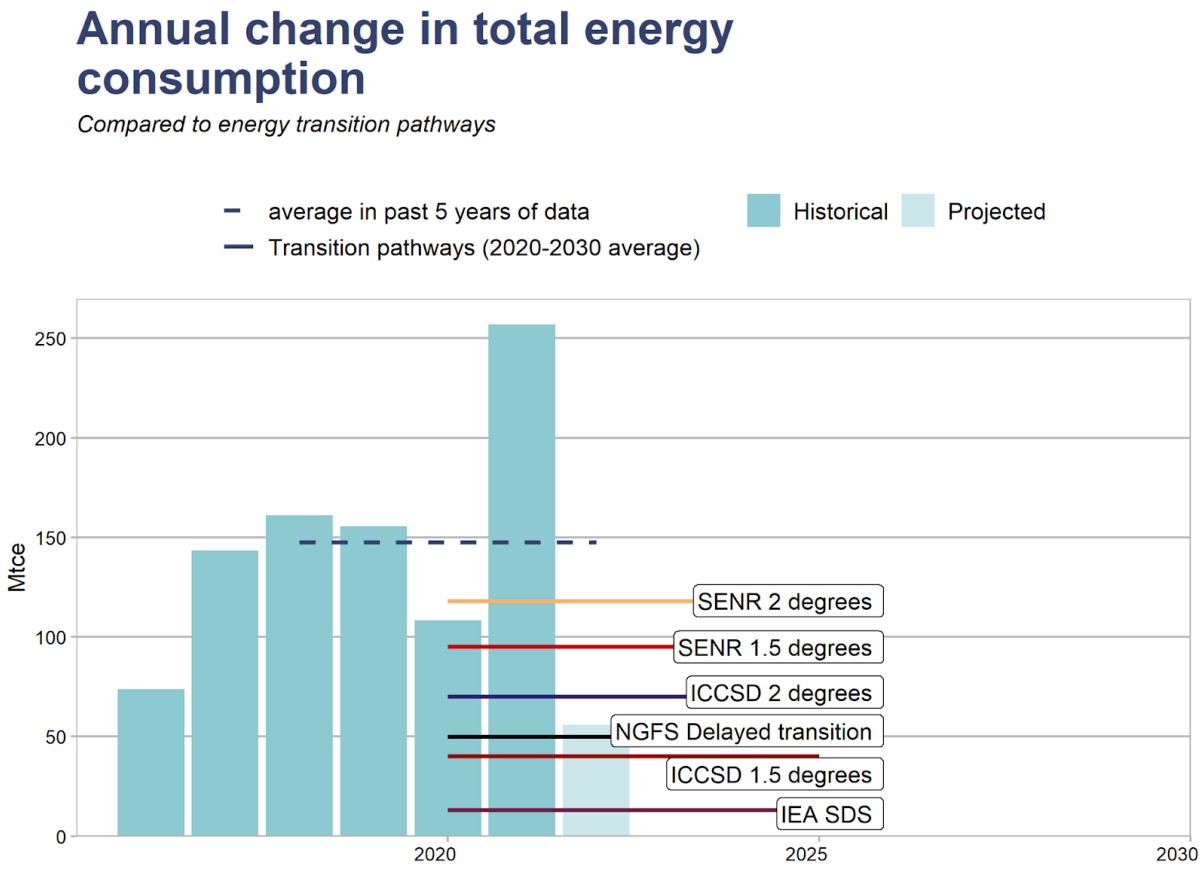

Figure 14 | Annual change in total energy consumption compared to energy transition pathways

China's total energy demand has been growing at an average of 3.5% per year over the past five years, with 2021 seeing growth at over 5%. The growth rates are much faster than projected in the transition pathways, which is the main reason that China's energy-related CO2 emissions have kept increasing despite world-leading investment in clean energy. In 2022, growth has slowed down to approximately 1%. Structural change in the economy, with reduced reliance on construction and heavy industry as growth drivers, as well as a slower rate of overall economic growth, promises to slow down total energy demand growth in the 2020s. Faster improvement in energy efficiency can also make a big contribution. However, if energy demand growth returns to the levels before 2022,

much faster clean energy growth than projected in the transition scenarios will be required to peak and decline emissions.

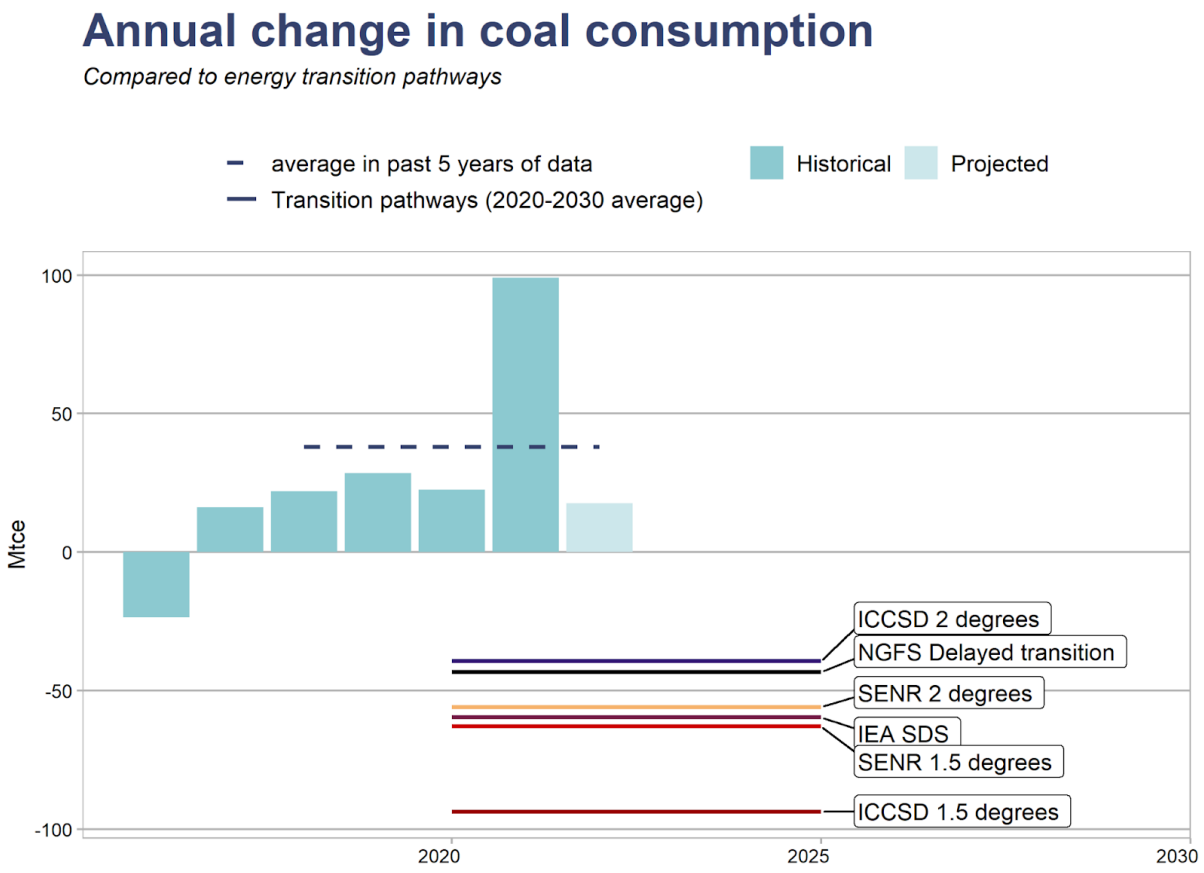

Figure 15 | Annual change in coal consumption compared to energy transition pathways

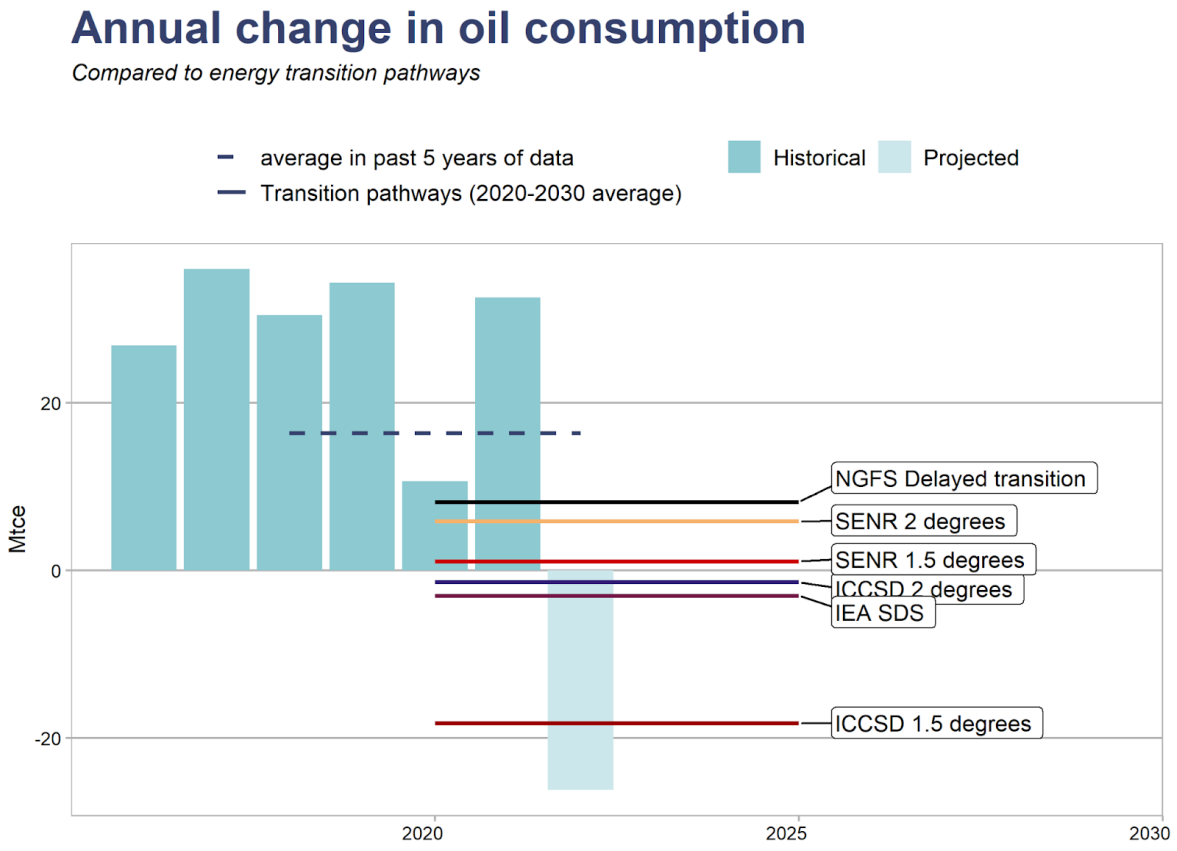

Figure 16 | Annual change in oil consumption compared to energy transition pathways

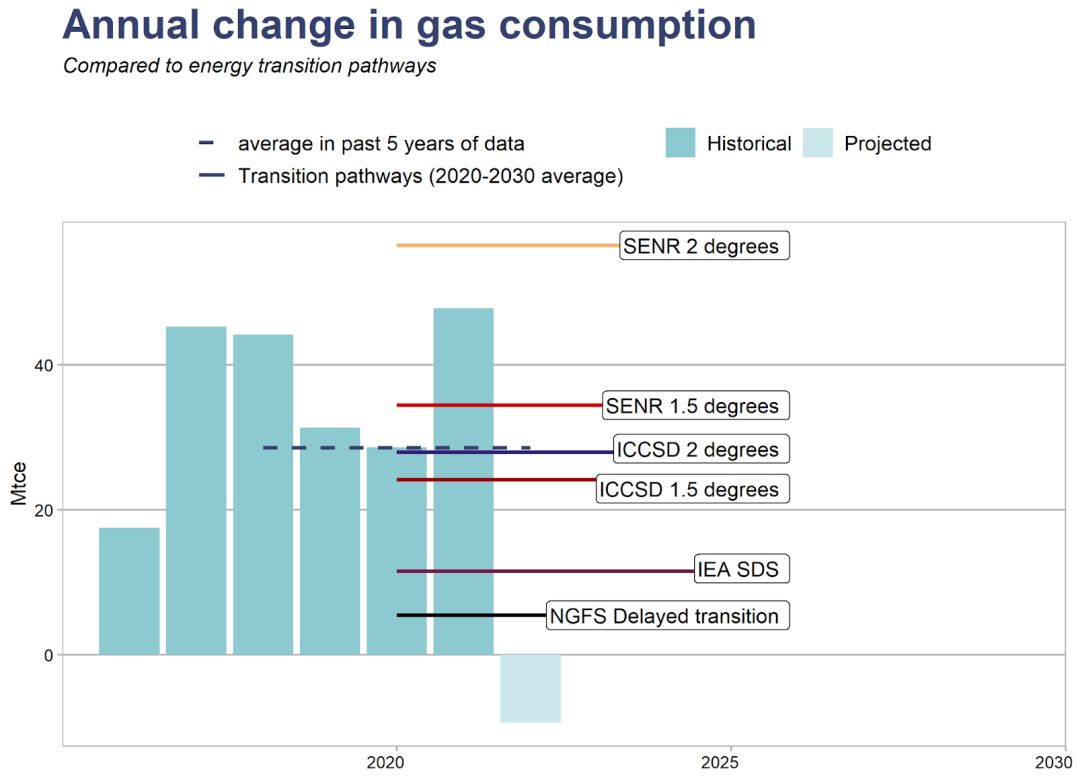

Figure 17 | Annual change in gas consumption compared to energy transition pathways

The transition pathways all require a reduction in coal consumption over the 2020s. In the past seven years, coal consumption only fell in 2016, with significant increases thereafter. Peaking and declining coal use in a sustained way remains China's greatest challenge.

Oil consumption growth slows down in the 2020s in all scenarios, but only some of them require an absolute reduction from 2020 to 2030. However, oil consumption growth was faster than in the transition pathways every year from 2016 to 2021, including 2020, the first year of the pandemic. Oil consumption only fell in 2022 due to COVID-19 control measures, and is likely to rebound when controls are relaxed.

All transition pathways include increases in gas consumption until 2030, but the growth rates vary widely from 6–8% in the SENR scenarios to 2–3% in the IEA and IPCC pathways. Overall fossil gas demand growth in the past five years is well within the range of the transition pathways, and the drop in consumption in 2022 is getting ahead of those pathways, although a rebound is possible in the coming years.

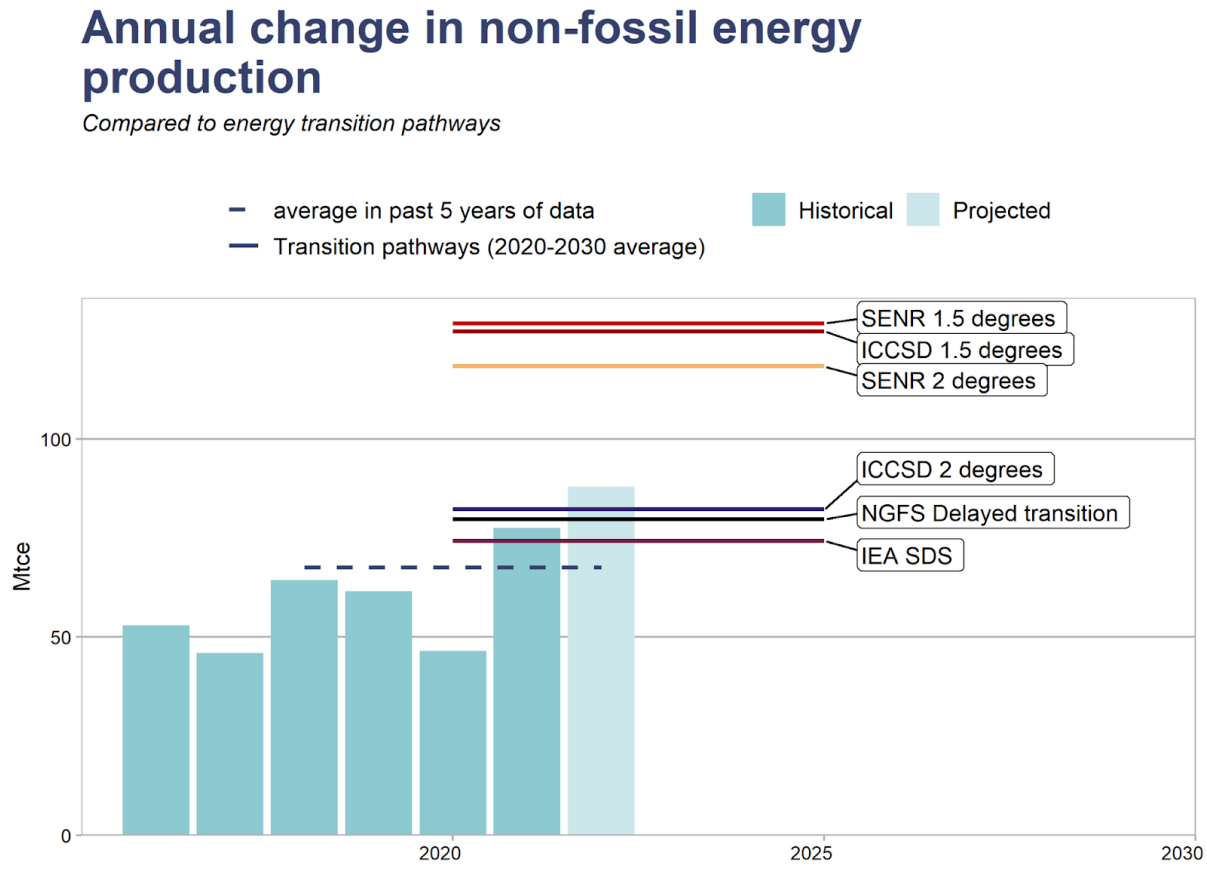

Figure 18 | Annual change in non-fossil energy production compared to energy transition pathways

In 2016–2020, the average growth rate of non-fossil energy production remained below the low end of the transition pathways. In 2021–2022, for the first time, it reached the low end of those pathways due to strong growth in wind and solar generation and strong hydropower contribution at times.

However, only 35% of total energy demand growth was met by non-fossil energy sources in 2016–2021, due to the fact that total energy demand was rising much faster than in these

pathways. Peaking and declining CO2 emissions require that this ratio rises above 100%, meaning that clean energy growth rates need to triple or the rate of energy demand growth needs to fall to one-third or any combination of the two.

Planned clean energy expansion until 2025 is sufficient to meet electricity demand growth of up to 4% per year and total energy demand growth of up to 2% per year. If growth rates are below these levels, emissions from the power sector and the whole economy, respectively, will peak.

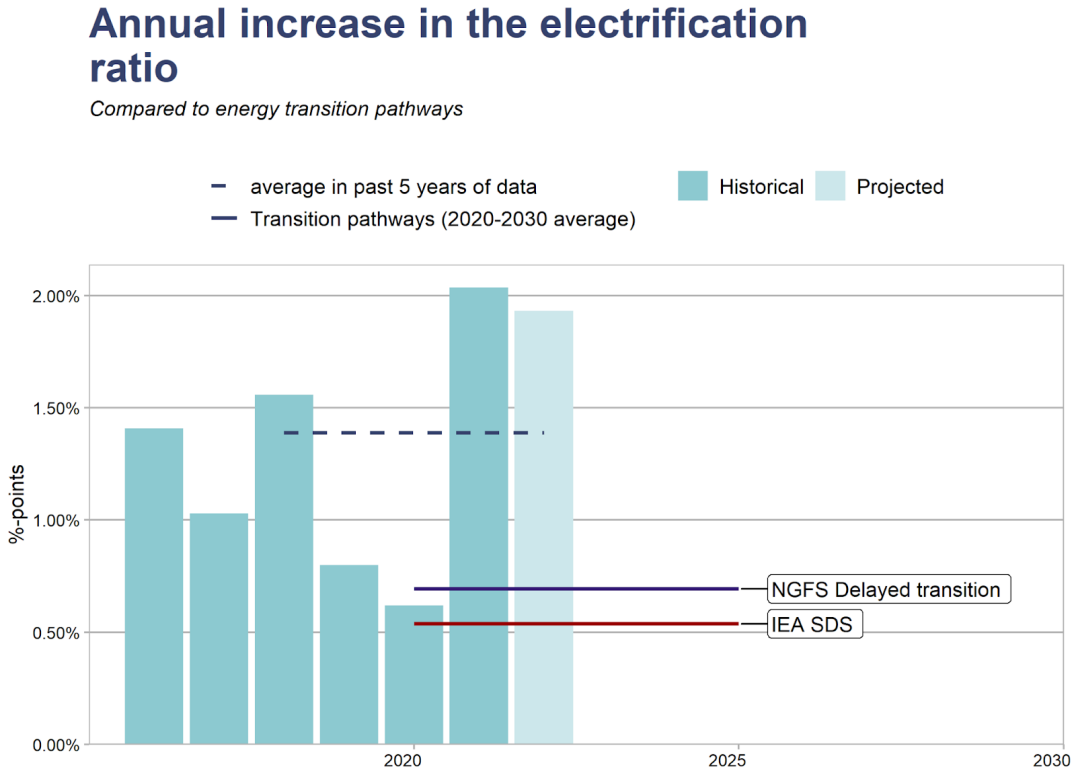

Figure 19 | Annual increase in the electrification ratio compared to energy transition pathways

In the transition scenarios, the share of electricity in final energy consumption rises from 25% in 2020 to 30% in 2030. Electrification has been progressing much faster than this in China, at more than 1%-point per year. This is creating the conditions for emissions reductions once the electricity is produced from clean sources, but currently, the increase in electricity demand has driven increases in power sector emissions, as clean energy generation growth has not been sufficient to cover the growth in demand despite the rapid increase in wind and solar power installations.

Analysing the causes of faster than projected energy demand growth

Since the main reason that China's CO2 emissions have kept increasing until 2021 is faster overall energy demand growth than projected in the transition pathways, it's important to analyse what is responsible for the "overshoot".

In the 2015–2019 period, reported GDP growth was slightly faster than assumed in the transition pathways for the 2020–2030 period. However, in 2020–2021, average GDP growth was below the rate in the transition pathways, but energy consumption and emissions growth continued above the rates in the transition pathways, implying that GDP growth rate isn't an explanation or at least not the only explanation.

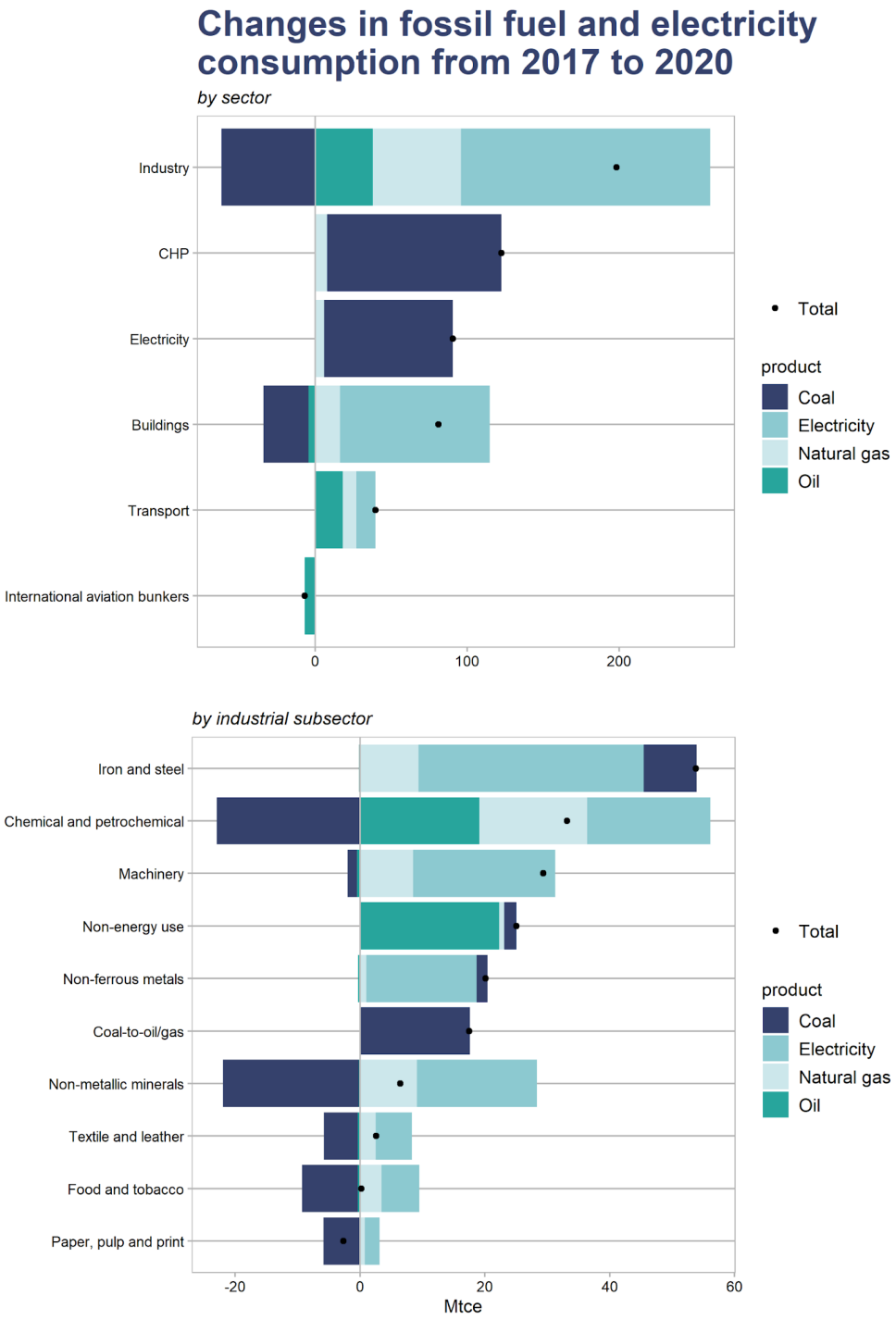

Figure 20 | Energy consumption growth by sector and fuel, from 2017 to 2020, and a decomposition of growth in industry by subsector

Note that electricity has been converted to primary energy using the average heat rate of coal-fired power generation. Data source: IEA World Energy Balances 2020.

The "overshoot" can be attributed to rapid increases in energy demand in industry and buildings. Growth in electricity consumption in these sectors led to increases in coal use for power generation (see Figure 20). In the industrial sector, the largest increases in energy demand took place in the iron and steel and chemical and petrochemical industries. The reason that industrial energy

demand has grown faster than projected in the industrial sector is rapid growth in the output of the most energy intensive industrial sectors.

While rapid progress with electrification accounts for the increases in coal use in the power sector, it cannot explain the faster-than-projected growth in overall coal use, as electrification shifts coal consumption from other sectors to the power sector but doesn't increase total coal consumption.

4.3.2 Policies in place: Action for green and low-carbon energy transition

Energy efficiency and non-fossil fuel consumption are highlighted as the "main objectives" for the top-level *Implementation Plan for Carbon Dioxide Peaking and Carbon Neutrality*[46]. The overarching targets for the plan are set in the 14th five-year plan:

- Targets by 2025:
    - Energy consumption per unit of GDP will be lowered by 13.5% from the 2020 level;
    - Carbon dioxide (CO2) emissions per unit of GDP will be lowered by 18% from the 2020 level;
    - the share of non-fossil energy consumption will have reached around 20%.
- Targets by 2030:
    - CO2 emissions per unit of GDP will have dropped by more than 65% compared with the 2005 level;
    - the share of non-fossil energy consumption will have reached around 25%.

To support these top-level goals, these targets have trickled down and are being repeated in a variety of policies.

14th Five-Year Plan for Modern Energy System[47] is the overarching policy directing the development of the energy system. Besides adopting goals from the top-level objectives, it also set up additional goals in the energy system (Table 5 shows only the energy efficiency and transition goals).

To improve energy efficiency, coal is inevitably the sector that will be constantly scrutinised and regulated. *Guiding Opinions on High-Quality Development of the Coal Industry in 14th FYP*[48] sets up the expectation for the coal industry: coal consumption is projected to be about 4.2 billion tonnes, with an average annual growth of 1%. *Benchmark of clean and efficient utilisation of coal (2022 edition)*[49] was created in April 2022, based on the National level implementation plan (as outlined

[46] Central Committee of the Communist Party of China, State Council (2021). Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy. https://en.ndrc.gov.cn/policies/202110/t20211024_1300725.html. Policy.
[47] National Development and Reform Commission of China and others. (2022). 14th Five-Year Plan for Modern Energy System.
https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220322_1320016.html?code=&state=123. Policy.
[48] Coal Industry Association of China. (2021). Guiding Opinions on High-Quality Development of the Coal Industry in 14th FYP.
http://www.coalchina.org.cn/index.php?m=content&c=index&a=show&catid=9&id=129818. Industry Document.
[49] National Development and Reform Commission of China and others. (2022). Benchmark of clean and efficient utilisation of coal (2022 edition).
https://www.ndrc.gov.cn/xxgk/zcfb/tz/202205/t20220510_1324482.html?code=&state=123. Policy.

in the Industry section below)[50]. It draws the line between "benchmark level" and "baseline level" efficiency benchmarks for coal mining, coal heating furnace, and coal gasification industries.

In August 2022, a notice for amending "Three Batches" of energy efficiency and flexibility standards for coal-fired plants was released by the NEA[51]. "Three Batches" refers to: 1) By 2023, amend binding standards for energy efficiency assessment, with the integration of current standards for general[52] and CHP[53] (combined heat and power) coal power plants, and also adding CFB plants into standard enforcement; 2) by 2023, enact or amend calculation and assessment standards; and 3) amend supporting policies. With updated emission standards, the *Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants* will direct the retrofitting and upgrading of coal-fired fleets[54]. By 2025, the average coal consumption intensity of coal power generation should decrease below 300 gce/kwh. Additionally, at least 350 GW of coal power plants need to be retrofitted for consumption efficiency, and 200 GW retrofitted to increase their flexibility.

The development of non-fossil fuel energy is the other factor that determines the progress of the energy transition. *14th Five-year plan for renewable energy development* is a promising blueprint that depicts the future vision for renewable energy development[55]. More details about renewable energy will be discussed in the Electricity section below.

Note: Highlighted numbers in Table 5 are adopted from the top-level objectives. Sector-specific policies such as electricity, industry, building, and transport are listed in the corresponding sections below.

[50] National Development and Reform Commission of China and others. (2022). Implementation Guidelines for Energy Conservation and Carbon Reduction Retrofitting and Upgrading in Key Areas of High Energy-consuming Industries (2022). https://www.ndrc.gov.cn/xwdt/tzgg/202202/t20220211_1315447.html?code=&state=123. Policy.

[51] National Energy Administration of China and others. (2022). Notice on further improvement of coal power efficiency and flexibility standards. http://www.gov.cn/zhengce/zhengceku/2022-08/30/content_5707362.htm. Policy.

[52] Standardization Administration of China. (2017). The norm of energy consumption per unit product of general coal-fired power set. https://std.samr.gov.cn/gb/search/gbDetailed?id=71F772D817D5D3A7E05397BE0A0AB82A. National Standard.

[53] Standardization Administration of China. (2017). The norm of energy consumption per unit product of combined heat and power generation. https://std.samr.gov.cn/gb/search/gbDetailed?id=71F772D823CED3A7E05397BE0A0AB82A. National Standard.

[54] National Development and Reform Commission of China and others. (2021). Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202111/t20211103_1302856_ext.html. Policy.

[55] National Development and Reform Commission of China and others. (2021). 14th Five-year plan for renewable energy development. https://www.ndrc.gov.cn/xwdt/tzgg/202206/t20220601_1326720.html?code=&state=123. Policy.

Table 5 | Selected policies relating to total energy consumption and supply

Policy name	Release date	2025 Targets	Targets for 2030 and beyond
14th Five-Year Plan for Modern Energy System (National Development and Reform Commission and others)	2022-03-22	During the "14th Five-Year Plan" period, carbon dioxide emissions per unit of GDP dropped by 18% in five years. By 2025, the proportion of non-fossil energy consumption will increase to about 20%; the proportion of non-fossil energy power generation will reach about 39%; the level of electrification will continue to improve; and electricity will account for about 30% of final energy consumption. Significant results will have been achieved in energy conservation and consumption reduction, with a cumulative reduction of 13.5% in energy consumption per unit of GDP over the five years. By 2025, the proportion of flexible power supply will reach about 24%, and the power demand side response capacity will reach 3% to 5% of the maximum electricity load.	The proportion of non-fossil energy consumption will reach 25% in 2030.
Opinions on Improving Institutions, Mechanisms and Policy Measures for Green and Low-Carbon Transition in Energy Sector, (National Development and Reform Commission and others)	2022-02-10	During the "14th Five-Year Plan" period, the basic foundation for an institutional framework for promoting green and low-carbon energy development will be established.	By 2030, the basic foundations of a complete system, including a policy system for green-energy and low-carbon development, will be established.
Benchmark of clean and efficient utilization of coal (2022 edition), (National Development and Reform Commission and others)	2022-05-10	-	-
Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants, (National Development and Reform Commission and others)	2021-11-03	By 2025, the average of coal consumption intensity of coal power generation should decrease below 300 gce/kWh; during the "14th Five-Year Plan" period, 350 GW coal power plants should be retrofitted to increase their flexibility.	-
Notice on Further Improvement of Coal Power Efficiency and Flexibility Standards, (National Energy Administration and others)	2022-08-30	-	-
Guiding Opinions on High-Quality Development of the Coal Industry in the "14th Five-Year Plan", (China Coal Industry Association)	2021-06-03	By the end of the "14th Five-Year Plan", the domestic coal output will be controlled at about 4.1 billion tonnes, and national coal consumption will be controlled at about 4.2 billion tonnes, with an average annual consumption growth of about 1%.	-

14th Five-year plan for renewable energy development, (National Development and Reform Commission and others)	2022-06-01	By 2025, non-fossil energy consumption will reach 20% in the energy mix; renewable energy will reach 1000 Mtce (million tonnes of coal equivalent); renewable energy will take over 50% of primary energy consumption growth; renewable power generation will reach 3300 TWh for power generation; wind and solar power generation should double.	By 2030, non-fossil energy consumption will reach 25% in the energy mix; solar and wind power capacity reach 1200GW.
Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035), (National Development and Reform Commission)	2022-03-23	Hydrogen production from renewable energy will reach 100,000-200,000 tonnes/year, and achieve a carbon dioxide emission reduction of 1-2 million tonnes/year.	By 2030, a relatively complete hydrogen energy industry technology innovation system, clean energy hydrogen production, and supply system will be formed. By 2035, a hydrogen energy industry system will be formed, and a diversified hydrogen energy application system covering transportation, energy storage, industry, and other fields will be built.

4.3.3 Data disclosure

Data on total energy consumption and the consumption of main energy sources (coal, oil, gas, and non-fossil energy) is released annually at the end of February in the Statistical Communique on Economic and Social Development. More detailed data is made available in the China Energy Statistical Yearbook with a delay of 1–2 years. Quarterly numbers are sometimes published by the National Energy Administration (NEA), but this varies from quarter to quarter. These occasional disclosures however show that the government has the data available internally. More systematic monthly or quarterly disclosure would greatly improve the timeliness of information about the development of China's energy sector's CO2 emissions.

4.4 Electricity generation and capacity

The energy sector is the largest emitter of CO2, and electricity generation is the largest source of energy-related CO2 emissions today. China's electricity demand has been growing and will continue to grow, even as total energy demand slows down, as energy use in all sectors is electrified. The power sector is tasked with not just replacing current fossil fuel-based power generation with clean energy, but also expanding the supply of electricity to allow the fossil fuel use in other sectors to be replaced with clean electricity. Therefore, power sector decarbonisation and the expansion of clean power generation make up the backbone of the energy transition.

China has the world's largest power generation sector, with a massive coal power fleet, which poses a major challenge to its power sector transition and achieving carbon zero. The power sector is the largest contributor to emission cuts in the transition pathways. For example, in the ICCSD's 1.5°C pathway, power sector CO2 emissions fall sharply from 4,060 million tonnes in 2020 to net negative emissions of 150 million tonnes in 2050 with the aid of bioenergy with carbon capture and storage (BECCS). Under the 1.5°C and 2°C scenarios, the power sector sees its emissions peak at 4.21 billion tonnes in 2023.

Raising the share of non-fossil fuel energy and phasing out coal are the main contributors to reaching zero-carbon electricity production. Under the ICCSD 1.5°C scenario, the installed capacity

of wind and solar reaches 5100 GW by 2050, up from 635 GW in 2021. The total installed capacity of the China power system will reach 6300 GW, up from 2400 GW in 2021. 91% of power will be generated from non-fossil fuels, with wind and solar taking up 63%.

End-use electrification and green hydrogen production will increase electricity demand significantly. For example, in the ICCSD 1.5°C target-oriented scenario, electricity demand will almost double from 2020 to 2050, reaching 14270 TWh.

The deployment of emission reduction technologies takes place in phases based on the cost and maturity of the technologies and the requirements of progressively stringent emission reductions. Cost-effective and mature technologies, particularly wind, solar, and energy storage are scaled up rapidly already in the 2020s and continue to grow until 2050, while the deployment of carbon capture and storage (CCS) and other more expensive or less mature solutions begins in earnest after 2030 (Table 6). Cost and raw material resources hinder biomass power generation from playing a major role in emission reductions, and the potential for further hydropower expansion is also very limited.

For example, under the ICCSD 1.5°C scenario, power generation with CCS starts to scale up around 2030 and achieves a capacity of 149GW with 600 million tonnes of CO2 captured in 2050. Deployment of BECCS will begin around 2040 and reach 48GW by 2050, with 280 million tonnes of CO2 captured.

Table 6 | Annual capacity additions of non-fossil power generation technologies and capacity fitted with CCS (He et al., 2021)

Technology capacity growth, GW/year	2020-2030	2030-2050
Wind	71	91
Solar	42	87
Hydropower	3	0
Nuclear	8	10
Biomass	1	1
Biomass with CCS	0	1.6
Fossil fuels with CCS	0	3.4

4.4.1 Trends compared to benchmarks

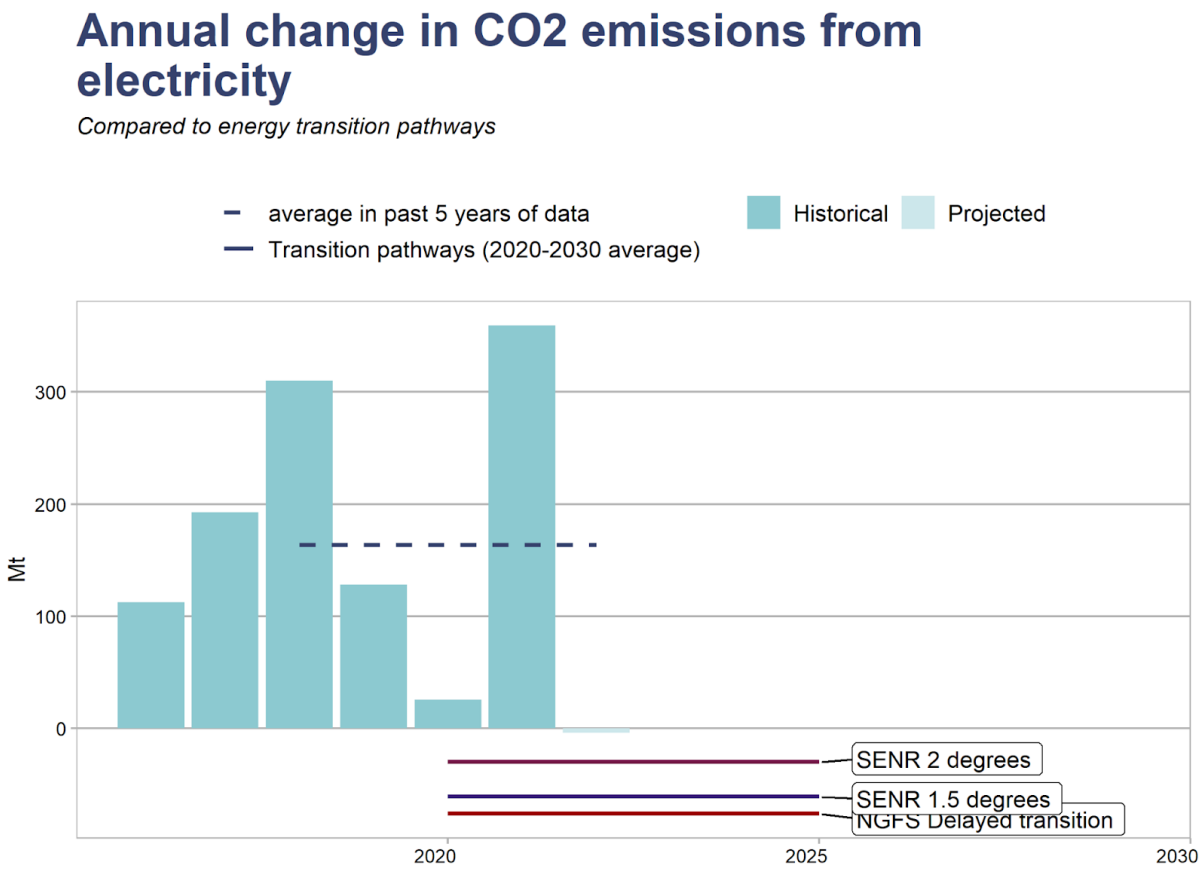

Figure 21 | Annual change in CO2 emissions from electricity compared to energy transition pathways

Power generation from coal grew by an average of 3.9% over the past five years. The transition pathways require coal power output to fall by 0.5–3.0% per year from 2020 to 2030. There is no clear trend of a slowdown in the growth of coal-fired power generation from 2015 to 2021. 2022 will witness a drop or very slow growth due to slower growth in power demand and a strong increase in solar and wind power generation.

The continued increase in coal power generation is in part due to electrification of energy use, particularly in industry, which is progressing much faster than projected in the transition pathways. Electrification shifts more of the coal use to the power sector without increasing overall coal consumption or carbon emissions, and creates conditions for decarbonisation as electricity supply becomes cleaner.

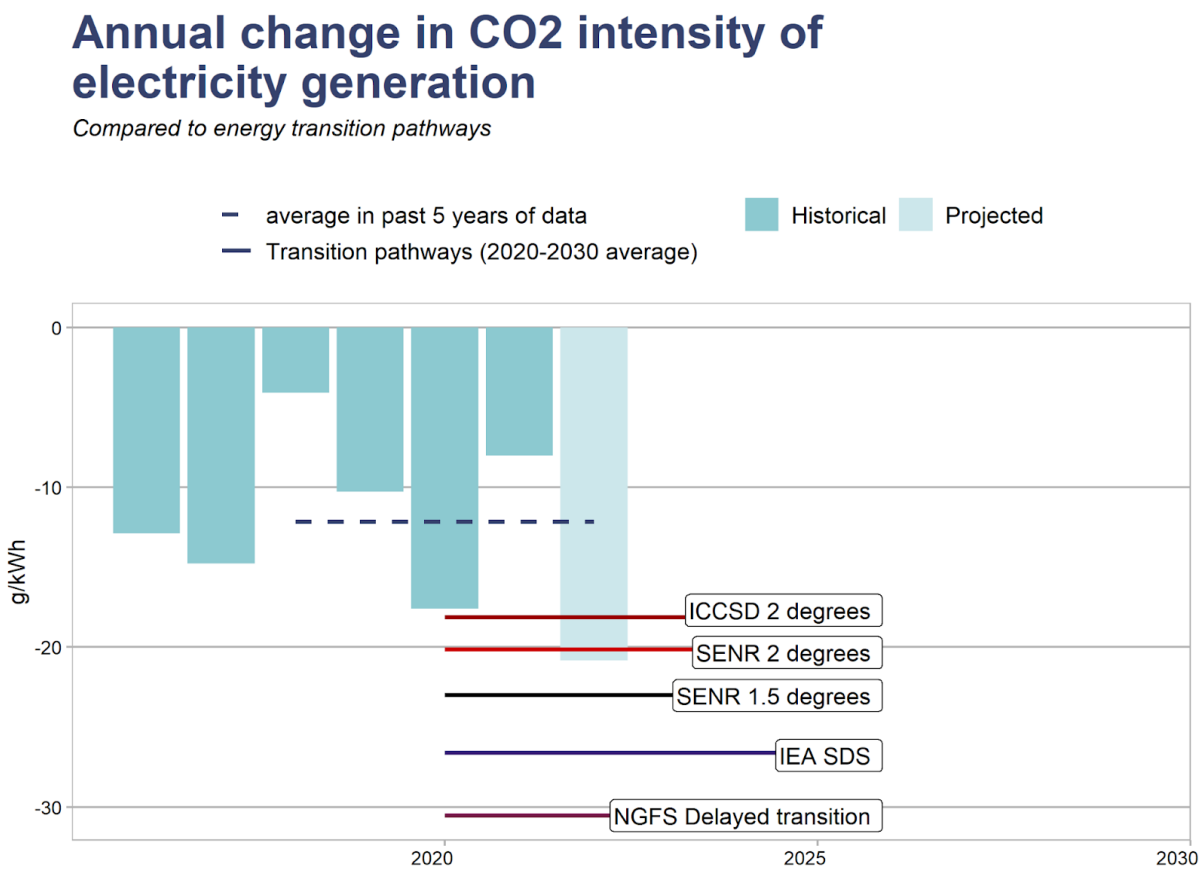

Figure 22 | Annual change in CO2 intensity of electricity generation compared to energy transition pathways

The CO2 intensity of power generation in China fell by an average of 12 g/kWh per year, from 600 g/kWh in 2017 to 540 g/kWh in 2022. The transition pathways require CO2 intensity to fall to 300–400 g/kWh by 2030, or approximately twice as fast. There is no clear acceleration in the improvement of CO2 intensity from 2015 to 2021. The improvement in 2022 will be within the range of values in the transition pathways, for the first time since 2016.

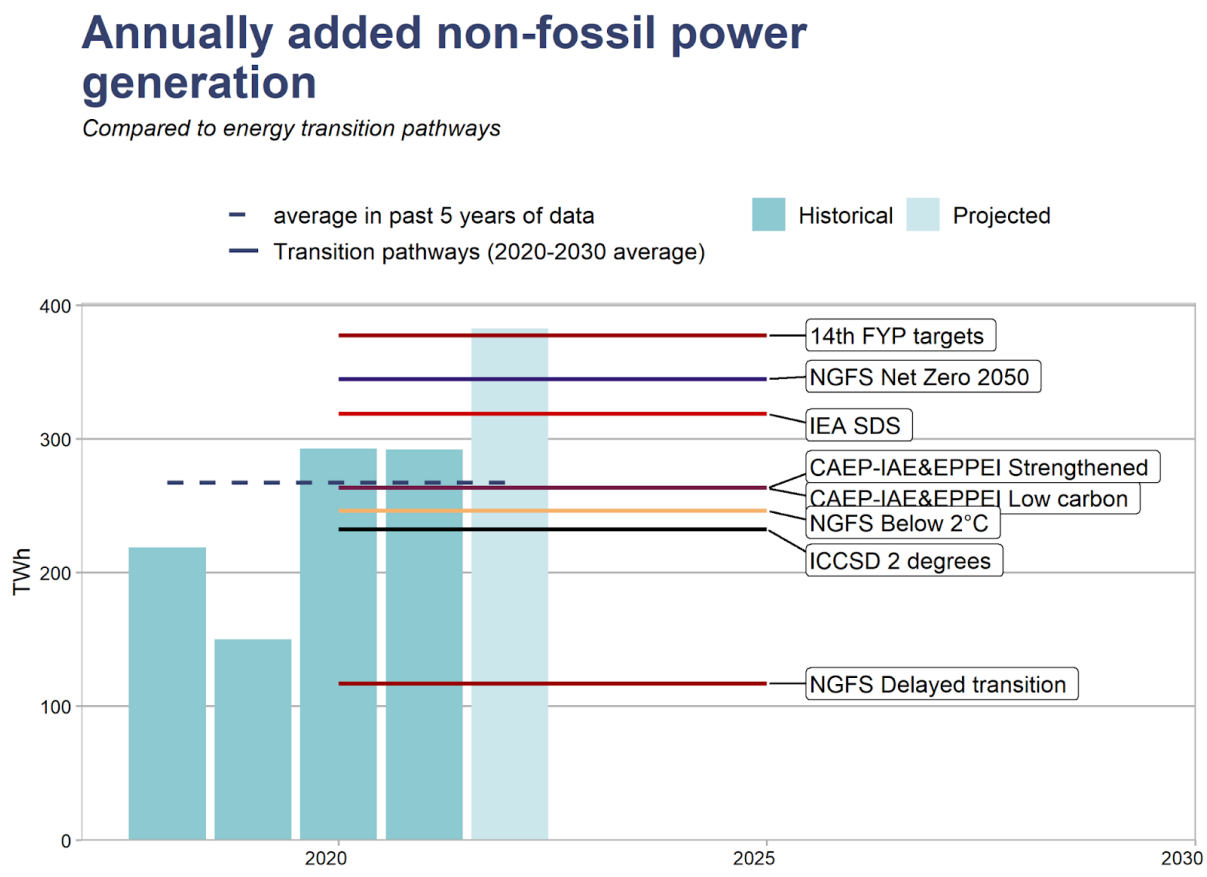

Figure 23 | Annual added non-fossil power generation compared to energy transition pathways, with wind, solar, nuclear and hydropower capacity added each year converted to annual electricity output using average capacity factors for each technology

To control for year-to-year variations in the capacity factors of different power generation technologies, we convert added wind, solar, nuclear and hydropower capacity to added annual generation using average capacity factors for each technology.

Added non-fossil generation has been in the range projected in the transition pathways during the past five years, and in 2022, additions are likely to slightly exceed the range in the pathways. Furthermore, a mapping of planned wind and solar power additions in 2021–2025 by provincial governments and the central government, shows that a total of 870 GW will be added if the targets are met[56]. This addition is far ahead of China's headline target of 1200 GW wind and solar by 2030. Combined with the national five-year plan target for nuclear power and expected expansion of hydropower, the added total non-fossil power generation will exceed the capacity additions in all transition scenarios, including the NGFS Net Zero 2050 scenario and IEA Sustainable Development Scenario.

In one sense, this should already put China's electricity sector on a pathway compatible with the global temperature goals. However, the rapid increase in power generation meant that non-fossil power generation provided only 57% of additional power generation in 2017–2022, with the rest provided by fossil fuels.

[56] International Energy Network (2022). 874.037 GW! 30 provinces' wind and solar installation targets during the 14th five-year plan period. https://www.in-en.com/article/html/energy-2319588.shtml. News article.

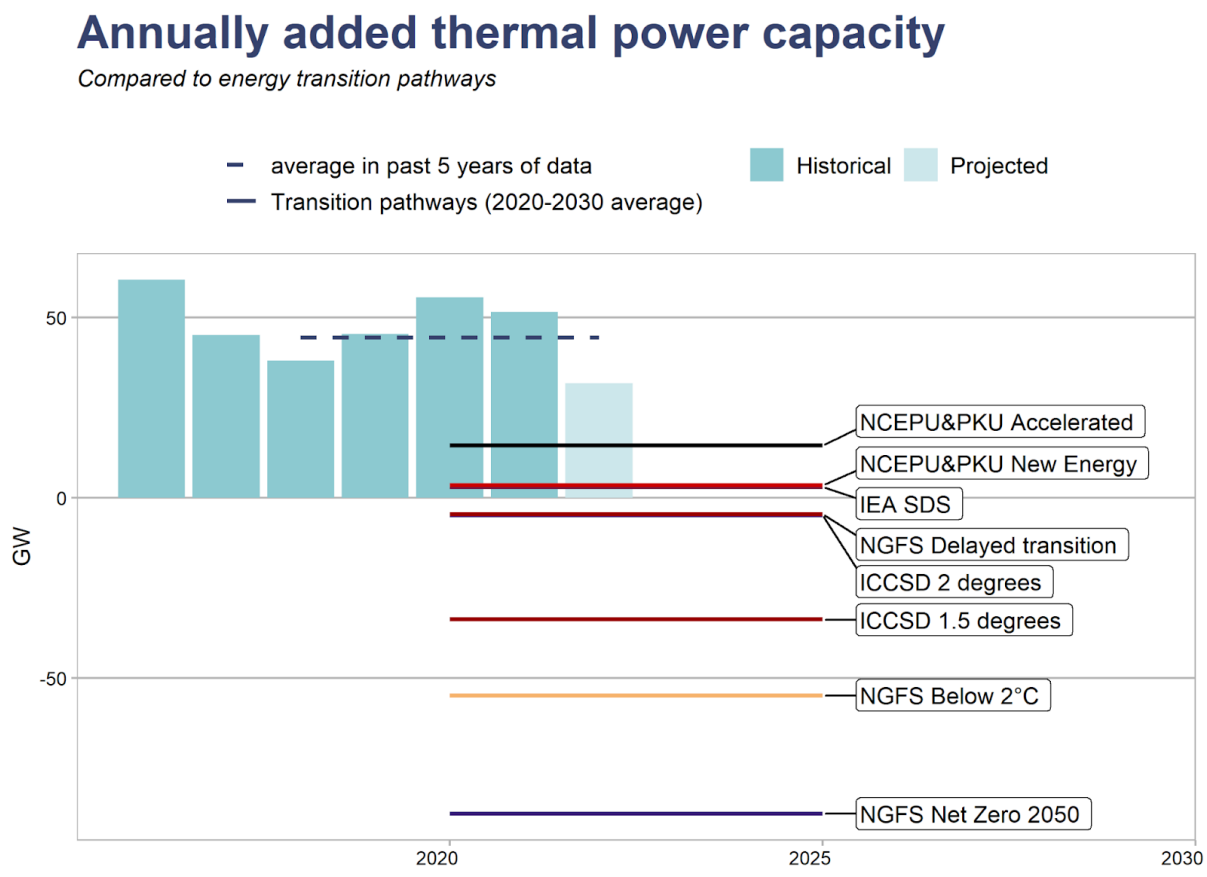

Figure 24 | Annually added thermal power capacity compared to energy transition pathways

In past years, China's net additions of thermal power capacity, mainly coal and fossil gas, have averaged almost 50 GW per year, or almost one large power plant per week. This is a much higher rate than in the transition pathways, which see either small net additions or significant reductions from 2020 to 2030.

Thermal power additions slowed down in the first half of 2022, compared with earlier years, as high fossil fuel prices have made coal and gas-fired power plants steeply lossmaking. However, the permitting of new coal power plants accelerated in 2022.

In 2021 and 2022, different parts of China have experienced power shortages. The root cause of these shortages is the rigid and inefficient way the power grid is being operated. Since generation is not shared flexibly between provinces, the only way for local officials to avoid power shortages is to build very large amounts of "dispatchable" capacity, which, in practice, means mostly coal and gas.

The situation highlights the need to reform China's grid operation. The widespread coal and electricity shortage in autumn 2021 resulted in fast-tracking changes to the power market that had

been stalled for years[57]. The most recent shortages in China's southwest in summer 2022 could speed up power system reform even further, putting a focus on the integration of provincial grids rather than long-distance bulk electricity transmission[58].

Making grid operation, particularly inter-province transmission, more flexible is the key to avoiding the kinds of electricity shortages currently being seen, reducing the need for coal-fired power capacity and facilitating the integration of variable renewable energy, according to a recent analysis by Draworld Environment Research Center and CREA[59]. The analysis found that greater flexibility would reduce the need for coal-fired power as a backup during the transition to a lower-carbon grid, avoiding the need for 30GW of coal-fired capacity in the East China grid alone.

The amount of power generated from coal and gas is determined as a residual of total electricity demand and supply from non-fossil sources. The addition of new coal- or gas-fired capacity doesn't lead directly to more power generation or increased emissions, but it can lead to putting off required grid reforms, complicating the energy transition, and give important power sector actors an incentive to slow down progress.

[57] Hove, A.. (2022). Opinion: China's new power market reforms could accelerate energy transition. China Dialogue. https://chinadialogue.net/en/energy/chinas-new-power-market-reforms-accelerate-energy-transition. Opinion column.

[58] Caixin. (2022). Power Crisis. https://weekly.caixin.com/2022-08-19/101928366.html. News report.
[59] CREA. (2022). Power system adequacy and "New Power System" development in China. https://energyandcleanair.org/publication/power-system-adequacy-and-new-power-system-development-in-china/. Research report.

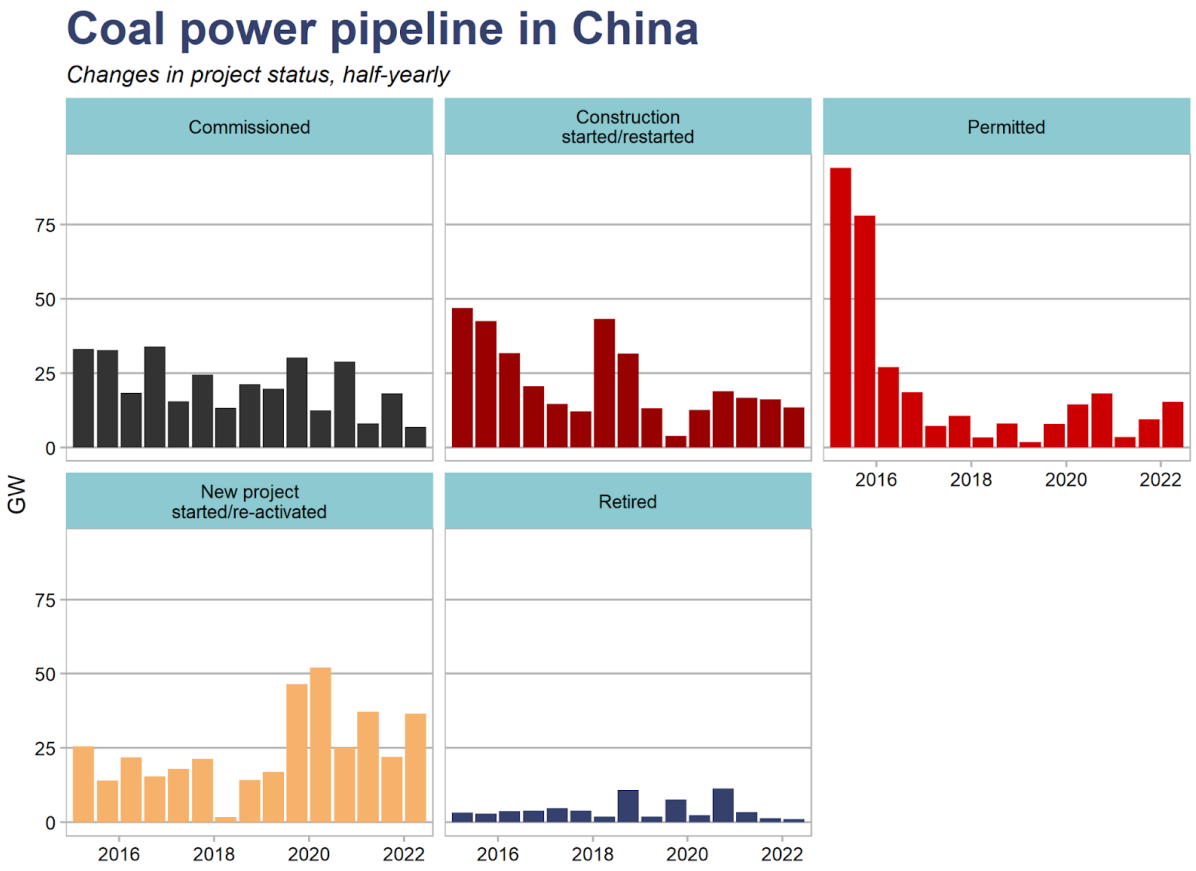

Figure 25 | Coal power pipeline in China; changes in project status, half-yearly

Source: CREA analysis of Global Coal Plant Tracker data.

4.4.2 Policies in place: Speeding up the development of the new electric power system

Renewable energy and nuclear power

The *14th Five-year plan for renewable energy development*[60] is the overarching policy that comprehensively envisions the development of renewable energy in this decade. It sets multiple generation and consumption targets by 2025:

- Renewable energy is expected to grow consumption into 1 Gtce, with the share in the primary energy consumption mix over 50%.
- Annual electricity generated from renewable energy should reach 3300 TWh. The addition of renewables should take more than half of newly added capacities, meanwhile solar and wind capacity doubled during the 14th FYP period.
- Consumption quota for renewables should reach 33%, with the non-hydro consumption quota reaching 18%.

[60] National Development and Reform Commission of China. (2022). Renewable Energy Development Planning during the 14th FYP. https://www.ndrc.gov.cn/xwdt/tzgg/202206/t20220601_1326720.html?code=&state=123. Policy.

- Non-electricity usage such as geothermal, biomass heating and fuel, solar energy heating, etc. should grow above 60 Mtce.

The *14th Five-Year Plan for Modern Energy System* sets the targets for the expansion of nuclear power capacity from 50 GW in 2020 to 70 GW in 2025, and hydropower capacity from 340 GW in 2020 to 380 GW in 2025, excluding pumped storage.

In more specific policies, *Opinions on Promoting the Development of Non-Hydro Renewable Energy Power Generation,* provides guidance on the non-hydro renewable energy subsidies[61]. It also initiated works of subsidy ramp-down mechanism, in favour of the Green Electricity Certificate for electricity trading.

Meanwhile, the *Medium and Long-term Plan for the Development of the Hydrogen Energy Industry (2021-2035)*[62] draws the roadmap with 2025, 2030, and 2035 targets for the hydrogen industry. The Development Plan for Biological Economy also highlighted biomass energy as one of the "example projects" and encouraged subsidising biomass[63].

As pointed out in section 4.4.1, the provincial five-year plans, together with central government plans for the clean energy bases, target a much larger addition of wind and solar capacity than the minimum targets set in the national five-year plans. Under these targets, 870 GW should be added in 2021–2025[64], more than doubling the total wind and solar capacity in five years and meeting the 2030 capacity target in 2025 (Figure 26).

[61] Ministry of Finance of China. (2020). Several Opinions on Promoting the Healthy Development of Non-Water Renewable Energy Power Generation. http://www.gov.cn/zhengce/zhengceku/2020-02/03/content_5474144.htm. Policy.
[62] National Development and Reform Commission of China. (2022). Medium and Long-term Plan for the Development of the Hydrogen Energy Industry (2021-2035). Medium and Long-term Plan for the Development of the Hydrogen Energy Industry (2021-2035). https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220323_1320038.html?code=&state=123. Policy.
[63] National Development and Reform Commission of China. (2021). The Development Plan for Biological Economy. https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202205/t20220510_1324436.html?code=&state=123. Policy.
[64] International Energy Net. (2021). 874.037GW! 30 provinces/cities wind and solar installation targets during the 14th Five-Year Plan period. https://www.in-en.com/article/html/energy-2319588.shtml. News.

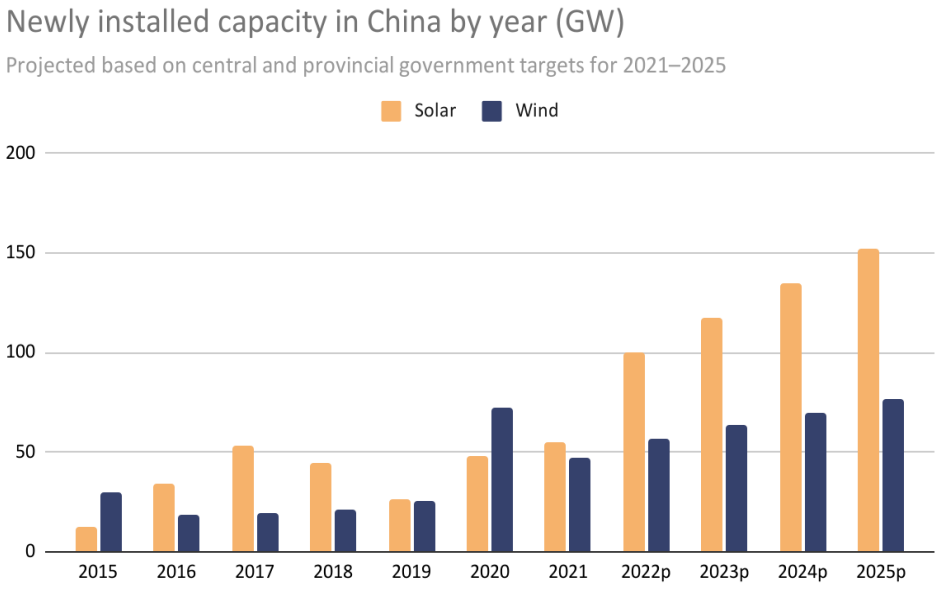

Figure 26 | Projected annual wind and solar power capacity additions needed to meet the summed up targets set by the central government and provincial governments. Sources: Historical data from China Electricity Council; 2022 projections are based on reported installation data in the first seven months of the year. The following years show the linear increase in installations required to meet the 2025 installation targets.

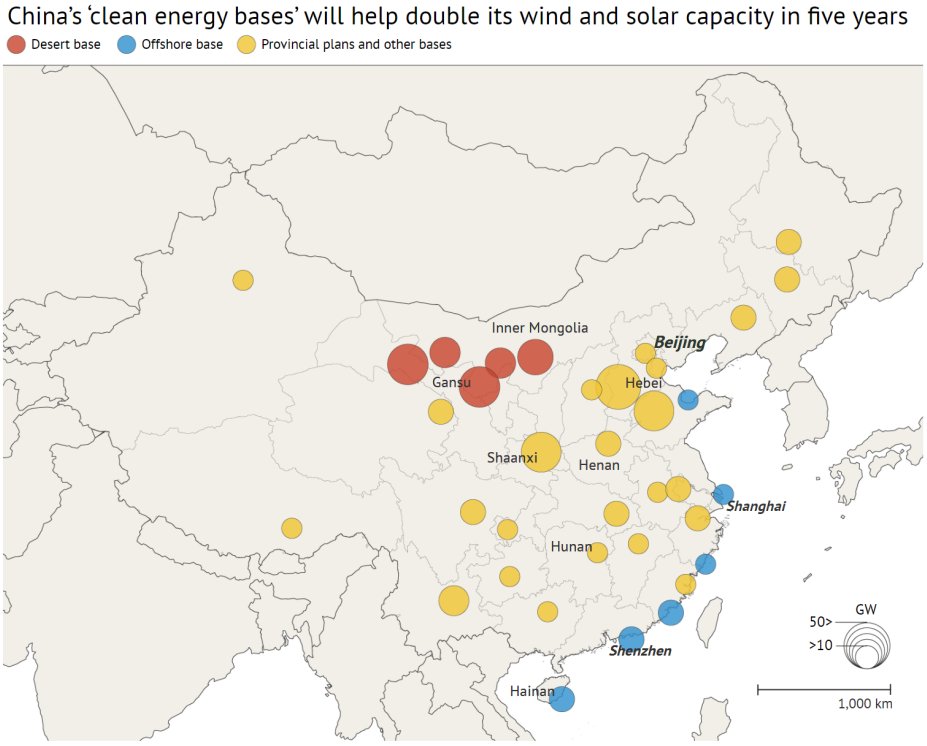

Figure 27 | China's clean energy bases envisioned in the central and provincial five-year plans[65]. Map by Tom Prater for Carbon Brief.

[65] Myllyvirta and Zhang (May 2022). Analysis: What do China's gigantic wind and solar bases mean for its climate goals? Carbon Brief. https://www.carbonbrief.org/analysis-what-do-chinas-gigantic-wind-and-solar-bases-mean-for-its-climate-goals/

Green electricity trading and tariffs

The *Green Electricity Trading Pilot Work Plan*[66] defines the framework of China's green electricity trading in several aspects:

- Definition of "Green Electricity": started with wind and solar, and qualified hydropower may be included later.
- Trading Framework: pilot with annual or multi-months trading, and also encourages long term power purchase agreement.
- Priority principle: green electricity should be prioritised in each stage of the trading, covering organising, execution and settlement.
- Format: direct purchase from generators, or purchase from grid.
- Pricing mechanism: non-restrictive, and also encourages the price to be higher than feed-in tariff (FIT) and/or purchase price from grid to "reflect the value of greenness and environment".
- Expectation for transition and future development: green electricity trading should remain prioritised, and encouraging integration with other carbon regulations such as renewable energy consumption quotas, and China Certified Emission Reduction from the carbon trading market.

Energy storage

As confirmed by NDRC and NEA's *Guiding Opinions on Accelerating the Development of New Energy Storage,* energy storage takes a "key supporting role" in carbon peaking and carbon neutrality in the energy sector[67]. It encourages a multi-track development for energy storage, including making national and provincial level development plans, a push for generation-side and grid-side storage projects, as well as supporting resident-side storage. The *Guiding Opinions on Promoting the Integration of Power Sources, Networks, Loads and Storage and the Development of Multi-energy Complementary Development* is another important piece to promote seamless integration of different roles in the electricity system[68]. This policy also confirms that "the share of renewable energy in external transmission shall be at least 50%".

Carbon trading

In 2021, China introduced a national carbon trading system covering the power sector. The trading system differs from the "cap and trade" approach used e.g. in the EU in that it's not designed to limit the total CO2 emissions from the power sector but to drive reductions in the emission intensity of coal- and gas-fired power plants, mainly through improvements in thermal efficiency. It does not, by design, encourage the replacement of fossil fuels with clean energy, or even the replacement of coal with gas. To play a significant role in power sector decarbonisation, the design

[66] National Development and Reform Commission of China. (2021). Green Electricity Trading Pilot Work Plan http://www.gov.cn/xinwen/2021-09/07/content_5636072.htm. Policy.
[67] National Development and Reform Commission of China. (2021). Guiding Opinions on Accelerating the Development of New Energy Storage. http://www.gov.cn/gongbao/content/2021/content_5636148.htm . Policy
[68] National Development and Reform Commission of China. (2021). Guiding Opinions on Promoting the Integration of Power Sources, Networks, Loads and Storage and the Development of Multi-energy Complementary Development. http://www.gov.cn/zhengce/zhengceku/2021-03/06/content_5590895.htm. Policy.

of the scheme would therefore have to be revised significantly; this can however happen quite fast if the policymakers decide to do it.

Regardless of the limited near-term impact on emissions, the introduction of the carbon trading scheme has heralded the creation of a regulatory framework and emission monitoring, reporting, and verification (MRV) systems that make up the foundation of an effective carbon trading system. The *Corporate Greenhouse Gas Emissions Accounting Methodology and Reporting Guidelines for Power Generation Facilities* (2022 version)[69] and the *Guidelines for the Verification of Corporate Greenhouse Gas Emissions Reports*[70] are the most recent guidelines for emission MRV, with many reporting guidelines that are also taking effect (accounting and reporting methods of these industries are released into three batches, by NDRC)[71,72,73]. In the trading stage, *Measures for the Administration of Carbon Emissions Trading* is regulating the trading activity[74].

[69] Ministry of Ecology and Environment of China. (2022). Corporate Greenhouse Gas Emissions Accounting Methodology and Reporting Guidelines for Power Generation Facilities (2022 version). https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202203/t20220315_971468.html. Policy.
[70] Ministry of Ecology and Environment of China. (2022). Guidelines for the Verification of Corporate Greenhouse Gas Emissions Reports. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202103/t20210329_826480.html. Policy.
[71] National Development and Reform Commission of China. (2013). Accounting and reporting methods of greenhouse gas emission for the 1st batch - 10 key industries. http://www.gov.cn/zwgk/2013-11/04/content_2520743.htm. Policy.
[72] National Development and Reform Commission of China. (2014). Accounting and reporting methods of greenhouse gas emission for the 2nd batch - 4 key industries. https://www.ndrc.gov.cn/xxgk/zcfb/tz/201502/t20150209_963759.html?code=&state=123. Policy.
[73] National Development and Reform Commission of China. (2015). Accounting and reporting methods of greenhouse gas emission for the 3rd batch - 10 key industries. https://www.ndrc.gov.cn/xxgk/zcfb/tz/201511/t20151111_963496.html?code=&state=123. Policy.
[74] Ministry of Ecology and Environment of China. (2020). Measures for the Administration of Carbon Emissions Trading. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202101/t20210105_816131.html. Policy.

Table 7 | Selected policies relating to the electricity sector

Policy name	Release date	2025 Target	Targets for 2030 and beyond
14th Five-Year Plan for Modern Energy System, (National Development and Reform Commission and others)	2022-03-22	During the “14th Five-Year Plan” period, carbon dioxide emissions per unit of GDP dropped by 18% in five years. By 2025, the proportion of non-fossil energy consumption will increase to about 20%, the proportion of non-fossil energy power generation will reach about 39%, the level of electrification will continue to improve, and electricity will account for about 30% of final energy consumption. Achieve a cumulative reduction of 13.5% in energy consumption per unit of GDP over the five years. By 2025, the proportion of flexible power supply will reach about 24%, and the power demand side response capacity will reach 3% to 5% of the maximum electricity load. Operating nuclear power capacity will reach 70 GW and hydropower capacity 380 GW.	The proportion of non-fossil energy consumption will reach 25% in 2030.
Opinions on Improving Institutions, Mechanisms and Policy Measures for Green and Low-Carbon Transition in Energy Sector, (National Development and Reform Commission and others)	2022-02-10	During the “14th Five-Year Plan” period, the basic foundation for an institutional framework for promoting green and low-carbon energy development will be established.	By 2030, the basic foundations of a complete system, including a policy system for green energy and low-carbon development, will be established.
Benchmark of clean and efficient utilization of coal (2022 edition), (National Development and Reform Commission and others)	2022-05-10	-	-
Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants, (National Development and Reform Commission and others)	2021-11-03	By 2025, the average of coal consumption intensity of coal power generation should decrease below 300 gce/kwh; during “14th Five-Year Plan” period, retrofit 200 GW coal power to increase their flexibility.	-
Notice on Further Improvement of Coal Power Efficiency and Flexibility Standards, (National Energy Administration and others)	2022-08-30	-	-
Guiding Opinions on High-Quality Development of the Coal Industry in the "14th Five-Year Plan", (China Coal Industry Association)	2021-06-03	By the end of the “14th Five-Year Plan”, the domestic coal output will be controlled at about 4.1 billion tonnes, and the national coal consumption will be controlled at about 4.2 billion tonnes, with an average annual consumption growth of about 1%.	-

14th Five-year plan for renewable energy development, (National Development and Reform Commission and others)	2022-06-01	By 2025, non-fossil energy consumption will reach 20% in the energy mix; renewable energy consumption will reach 1000 Mtce; renewable energy will take over 50% of primary energy consumption growth; renewable power generation will reach 3300 TWh for power generation; wind and solar power generation should double.	By 2030, non-fossil energy consumption will reach 25% in the energy mix; solar and wind power capacity will reach 1200 GW.
Opinions on Promoting the Development of Non-Hydro Renewable Energy Power Generation, (Ministry of Finance and others)	2020-02-03	Improve the current subsidy method; improve the market allocation of resources and the subsidy retreat mechanism; optimise the subsidy payment process.	-
Green Power Trading Pilot Work Plan, (National Development and Reform Commission and others)	2021-09-07	-	-
Guiding Opinions on Accelerating the Development of New Energy Storage, (National Development and Reform Commission and others)	2021-07-23	By 2025, realise the transformation of new energy storage from the initial stage of commercialisation to large-scale development, with an installed capacity of more than 30 million kilowatts.	By 2030, realise fully commercialisation of new energy storage.
Guiding Opinions on Promoting the Integration of Power Sources, Networks, Loads and Storage and the Development of Multi-energy Complementary Development, (National Development and Reform Commission and others)	2021-02-25	-	-

4.4.3 Data disclosure

China Electricity Council publishes monthly data on power generation and power generating capacity by technology and by province, as well as power demand by sector and by province. The heat rate of coal-fired power plants (grams standard coal per kilowatt-hour) is also published monthly. This provides a very detailed and timely view of emissions trends in the power sector. The main gap is the breakdown of thermal power generation by fuel which is only made available annually and with a delay of 1–2 years.

4.5 Industry

The industrial sector is the largest energy consumer in China, accounting for 60% of total final energy consumption. For example, under the ICCSD 1.5°C scenario, the end-use energy demand of the industry sector will peak before 2025 at roughly 2.2 billion tonnes of coal equivalent (Gtce), up from 2.18 Gtce in 2020, and then gradually decline to 1.41 Gtce by 2050.

The industrial sector also plays a dominant role in CO2 emissions, mainly due to large energy demand and coal-heavy energy mix, but also due to process emissions, particularly from cement.

With the decline in energy demand of the industry sector, improved electrification and changes in the power mix, industrial CO2 emissions will peak before its energy demand, between 2020 to 2025.

Under the ICCSD's 2°C and 1.5°C scenarios, total industrial CO2 emissions fall to approximately 1,670 and 710 million tonnes, respectively, by 2050, of which 1,200 Mt for the 2°C scenario and 460 Mt for the 1.5°C scenario are from energy activities, and 470 and 250 million tonnes from industrial processes for 2°C and 1.5°C scenarios, respectively. Compared to 2020 (5,090 million tCO2), total industrial CO2 emissions are reduced by 86.1% in 2050, of which 87.8% emission reduction is from energy activities and 81% from industrial processes in the 1.5°C pathway.

By 2050, the energy mix of the industry sector will be decarbonised. The ICCSD projects the share of non-fossil energy and electricity at more than 85%. The share of electricity in the industry's total final energy use will reach 69.4% under the 1.5°C scenario, up from 25.7% in 2020.

4.5.1 Trends compared to benchmarks

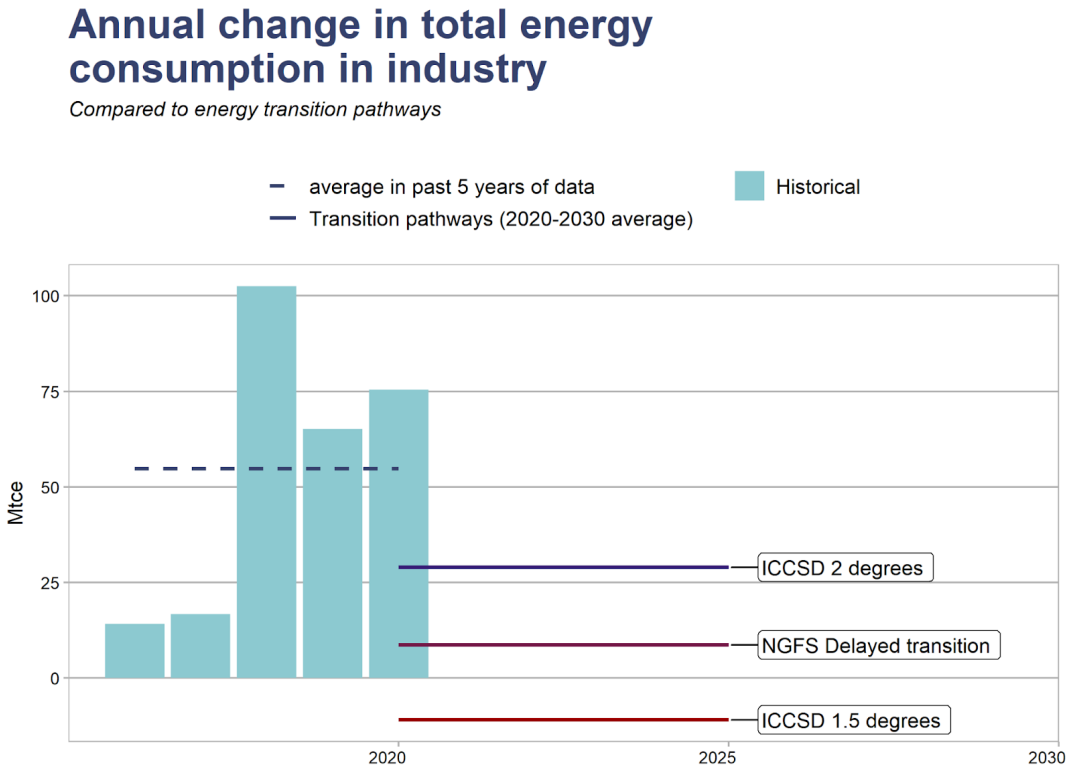

Figure 28 | Annual change in total energy consumption in industry compared to energy transition pathways

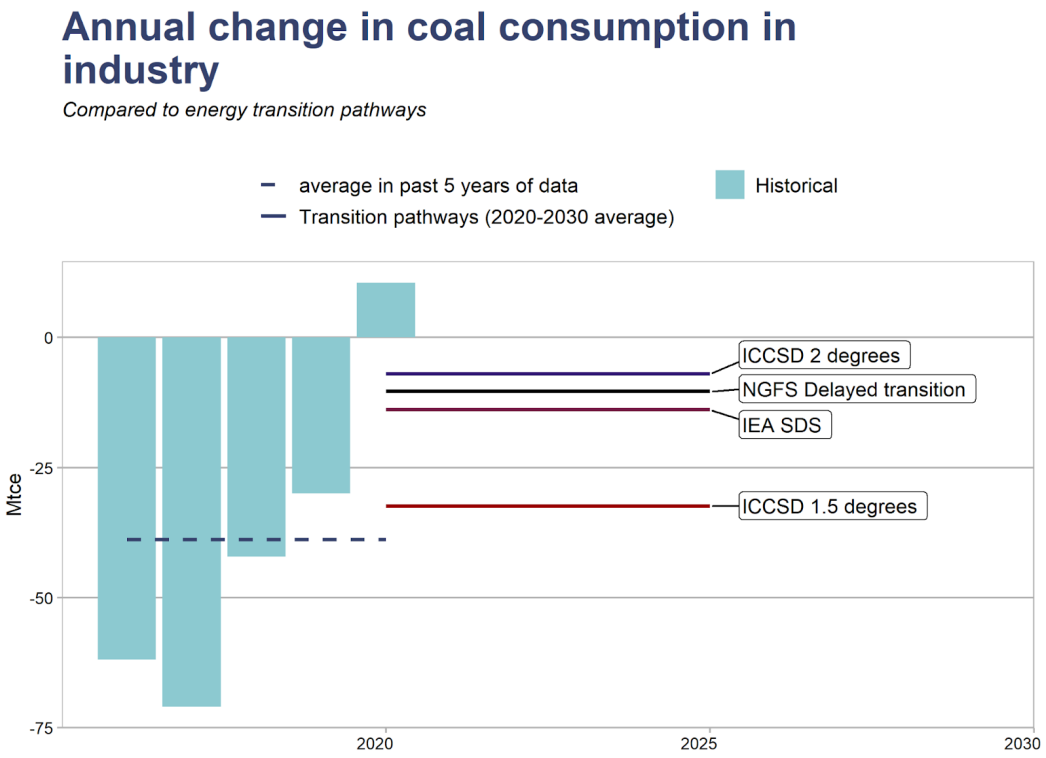

Figure 29 | Annual change in coal consumption in industry sector compared to energy transition pathways

Industrial energy consumption growth was much faster in the transition pathways over 2016–2020, with growth accelerating after 2017. This reflects the energy-intensive pattern of economic growth after President Trump's tariffs and the onset of the COVID-19 pandemic.

The sector where emissions trends are in line with the transition pathways is cement and building materials. The NGFS Delayed Transition pathway has emissions falling by 4% per year from 2020 to 2030. Cement production, the main source of emissions in the sector, fell at 3% per year from 2017 to 2022, due to the declining volume of infrastructure construction which reflects progress with the economic transition.

Even as industrial energy consumption has increased at a high rate, direct coal consumption in the industry has been falling quite rapidly, faster than in the transition pathways. This has been largely driven by air pollution policies which have required or encouraged the replacement of direct coal use with fossil gas and electricity. The use of both energy sources has increased rapidly.

Accordingly, electrification has progressed faster in the industrial sector than projected in the transition pathways.

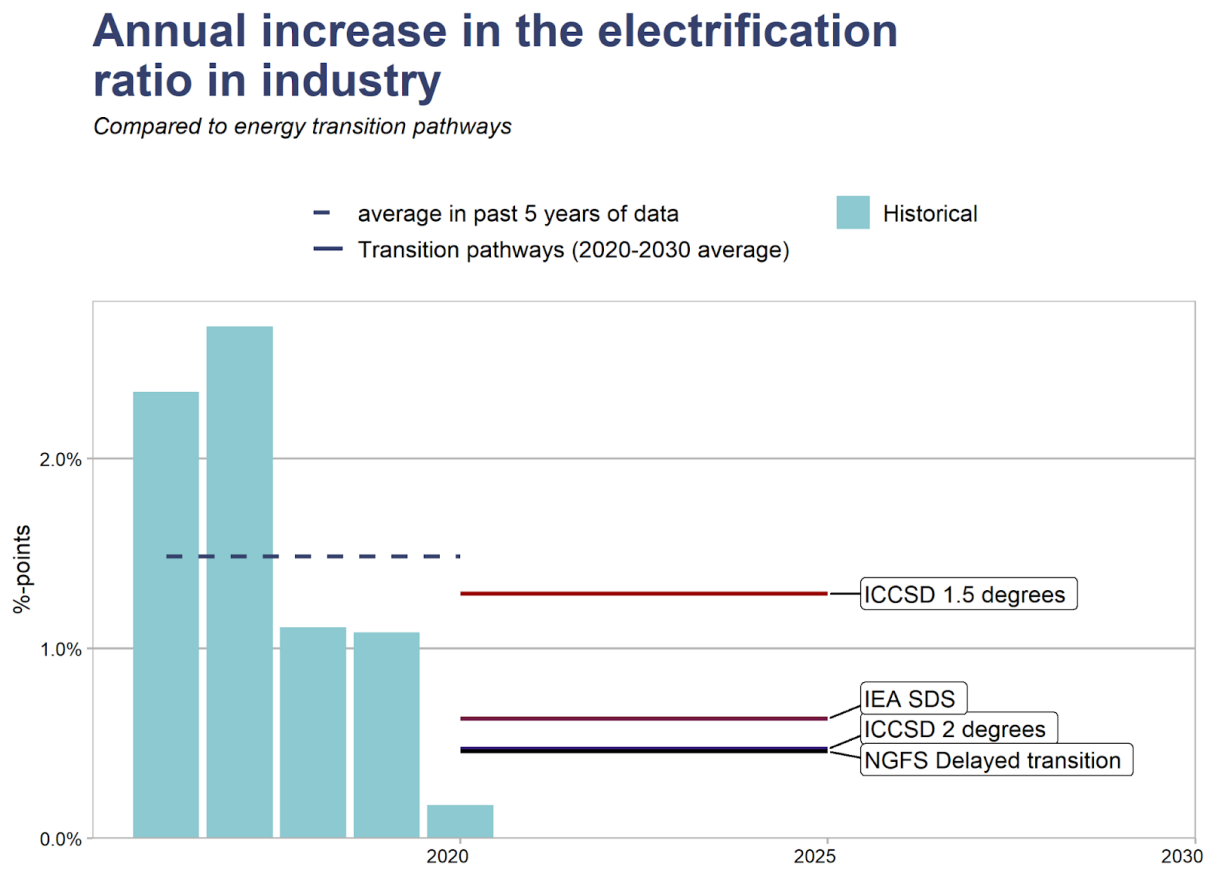

Figure 30 | Annual increase in the electrification ratio in industry compared to energy transition pathways

4.5.2 Focus: Iron and steel

China has been the dominant steel producer in the world since the mid-2010s, producing over half of the world's steel. The sector is the second-largest emitter of CO2 in China after electricity production, and the largest when emissions from electricity consumed by the sector are included. The rapid growth of steel production has been a key driver of China's emissions growth, making peaking and declining emissions from the sector an essential part of meeting China's emissions goals.

China's crude steel annual production climbed to a record high of 1,065 million tonnes in 2020, in response to a quick recovery in construction and manufacturing demand after Covid-19 lockdowns. Following Xi's announcement of the carbon neutrality goal in September 2020, the state planner stepped up efforts to cut the output to reduce pollutants and greenhouse gas emissions in its mammoth ferrous metals sector[75]. China's annual crude steel production fell 2.8%

[75] National Development and Reform Commission and others. (2021). Work Plan to Tackle Steel Industry Overcapacity. https://www.miit.gov.cn/jgsj/ycls/gt/art/2021/art_6618ea3ec1634d29a158e6b0c1c74374.html. Policy.

in 2021, the first year-on-year drop in six years, and the government is targeting a further reduction in 2022, with output falling 6.5% in the first half of the year[76,77].

As demand for steel levels off or falls, the supply of scrap steel from demolished buildings and infrastructure, as well as scrapped cars and machinery, will catch up and provide an increasing share of steel demand. This constitutes a major opportunity for the sector to shift to electric steelmaking, reducing the use of coal-based blast furnaces and cutting emissions. The steel industry targets an increase in the use of scrap steel to more than 300 million tonnes per year by 2025[78], up from 233 million in 2020[79], and an increase in the share of electric arc furnace-based secondary steel from the current 10% to 15% of steel production by 2025.

In spite of the falling demand for primary steel, announcements of new coal-based capacity for producing pig iron increased in the first half of 2022 from the level seen in the past two years. More electric arc furnace capacity was also announced than in previous years, but this is mainly replacing older electric arc capacity, not shifting the mix of capacity, which is less than 10% electric arc furnace (EAF) based production[80]. Interest in building new electric arc furnaces still indicates that the industry is starting to prepare for the shift implied by the carbon targets.

China's new iron and steel projects follow the policy of "capacity swaps". The policy requires that for all new capacity added, a specified amount of existing capacity is retired. The ratio of retired capacity to new capacity is stipulated in regulation and can vary for different provinces and regions. The latest updated swap scheme with a requirement to retire more existing capacity took effect in June 2021. It also integrated the government's efforts to curb air pollution and climate actions.

Announcements of investments in new coal-based (blast furnace) capacity continue at a high level that is not aligned with China's carbon goals. CREA's research identified 30 million tonnes per annum (Mtpa) of new blast furnace capacity announced in the first half of 2022, the largest amount for the first half-year since 2019. All of the announced capacity is planned to be put online by 2025.[81]

New electric arc furnace (EAF) capacity swap announcements significantly increased in 2021 and 2022, encouraged by the updated swap scheme that rewards EAF capacity.

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[76] National Bureau of Statistics. (2022). The growth of industrial output in June 2022. http://www.stats.gov.cn/tjsj/zxfb/202207/t20220715_1886418.html. Statistics.
[77] Reuters. (2022). China to keep 2022 crude steel output lower than last year's level. https://www.reuters.com/article/china-steel-output-idUSKCN2MB05W. News article.

[78] Ministry of Industry and Information Technology and others. Guiding Opinions on Promoting the High-quality Development of the Iron and Steel Industry. (2022). http://www.gov.cn/zhengce/zhengceku/2022-02/08/content_5672513.htm. Policy.
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[80] RMI. (2022). Pursuing Zero-Carbon Steel in China. https://rmi.org/insight/pursuing-zero-carbon-steel-in-china/. Report.
[81] Myllyvirta, L. et al. (2022). China's power and steel industries continue to invest in coal-based capacity, complicating carbon goals. CREA. (https://energyandcleanair.org/publication/chinas-power-and-steel-industries-continue-to-invest-in-coal-based-capacity-complicating-carbon-goals/. Research publication.

However, the announced EAF capacity is mainly replacing older electric arc capacity, not shifting the mix of capacity. EAF plants currently make up less than 10% of China's total steelmaking capacity[82]. Interest in building new electric arc furnaces still indicates that the industry is starting to prepare for the shift implied by the carbon targets. However, the share of EAF in the new approved steelmaking capacity is far behind what is needed to meet China's carbon targets.

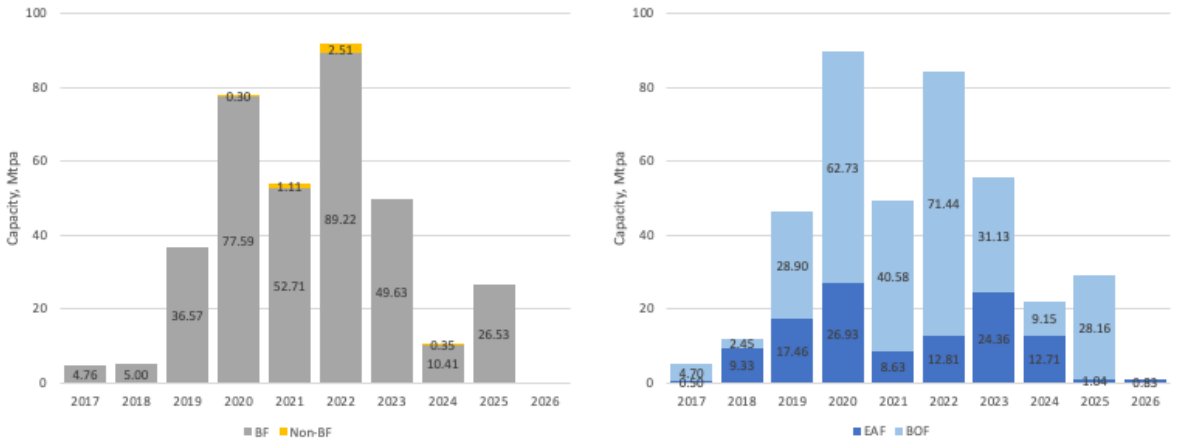

Figure 31 | New iron and steelmaking capacity additions by their estimated completion year

Source: CREA, provincial government websites. Note: Data includes announcements made during 2017-2022H1. BF=blast furnace, Non-BF=non-blast furnace (here includes hydrogen-based direct reduction plant, Hydrogen plasma smelting reduction plant, and HIsmelt plant), BOF=basic oxygen furnace, EAF=electric arc furnace.

4.5.3 Policies in place: Actions for peaking carbon dioxide emissions in industry

Due to its dominant proportion in the emission inventory, the industrial sector is heavily regulated by an abundance of policies, action plans, and emission standards.

Recall that the top level *Working Guidance* sets up the energy efficiency objectives (energy intensity down by 13.5% and carbon intensity down by 18% during 14th FYP[83]), which is also emphasised and adopted into several action plans, e.g. MIIT's *Implementation Plan for Carbon Peaking in the Industrial Sector*[84], *Implementation Plan for Energy Efficiency Improvement in the*

[82] RMI. (2022). Pursuing Zero-Carbon Steel in China. https://rmi.org/insight/pursuing-zero-carbon-steel-in-china/. Report.
[83] Central Committee of the Communist Party of China, State Council. (2021). Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy. https://en.ndrc.gov.cn/policies/202110/t20211024_1300725.html. Policy.
[84] Ministry of Industry and Information Technology and others. (2022). Implementation Plan for Carbon Peaking in the Industrial Sector. http://www.gov.cn/zhengce/zhengceku/2022-08/01/content_5703910.htm. Policy.

Industrial Sector[85], *14th Five-Year Plan for Industry Green Development*[86] and *14th Five-Year Comprehensive Work Plan for Energy Conservation and Emission Reduction*[87].

Carbon trading is another potentially effective tool to curb the emissions of industrial manufacturers. China's national carbon-trading system currently only covers thermal power plants but the MEE's official plan is to expand the scope to other sectors, including the industrial sectors with the largest greenhouse gas emissions: steel, non-ferrous metals, petrochemicals, chemicals, and paper industries[88]. The timeline for the expansion has tended to slip, with the original intention being that the system would have covered multiple sectors from its launch in 2021[89], to cement and aluminium being added in 2022[90], and now to cement, aluminium, and steel being included in 2023, with trading to commence in 2024[91]. Delays have been blamed on concerns about data and regulatory framework, but presumably also reflect conflicting economic and political interests.

Recycling plays an important role in emission control. The *14th Five-Year Plan for Circular Economy Development*[92] also set targets for waste material recycling for manufacturers.

Zooming into subsectors, most of them have already claimed their own emission target, except non-ferrous metal and building materials still under consultation.

The following chart provides a brief summary of the general and sector-specific targets for 2025, 2030 and/or 2035. These sectors are selected based on the highlights of Section 3 from the top-level Action Plan[93], with some additional coverage.

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[85] Ministry of Industry and Information Technology and others. (2022). Implementation Plan for Energy Efficiency Improvement in the Industrial Sector. https://ythxxfb.miit.gov.cn/ythzxfwpt/hlwmh/tzgg/sbfw/qyshzr/art/2022/art_0c4f930b82b1485da3054cf87afd1b62.html. Policy.

[86] Ministry of Industry and Information Technology. (2022). 14th Five-Year Plan for Industry Green Development. http://www.gov.cn/zhengce/zhengceku/2021-12/03/content_5655701.htm. Policy.

[87] State Council. (2021).14th Five-Year Plan for Industry Green Development. http://www.gov.cn/zhengce/content/2022-01/24/content_5670202.htm. Policy.

[88] Ministry of Ecology and Environment. (2021). Measures for the Administration of Carbon Emissions Trading (for Trial Implementation). https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202101/t20210105_816131.html, Policy.

[89] China Electric Power News. (2017) http://www.nea.gov.cn/2017-12/27/c_136855155.htm. News article.

[90] Carbon Pulse. (2021). China plans to add aluminium, cement to ETS next year -exchange. https://carbon-pulse.com/145937/. News announcement.

[91] China Dialogue. (2022). National carbon market expansion may be delayed to 2023. https://chinadialogue.net/en/digest/national-carbon-market-expansion-may-be-delayed-to-2023/. News announcement.

[92] National Development and Reform Commission of China. (2021). 14th Five-Year Plan for Industry Green Development. http://www.gov.cn/zhengce/zhengceku/2021-07/07/content_5623077.htm. Policy.

[93] State Council. (2021). Action Plan forCarbon Dioxide Peaking Before 2030. https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html. Policy

Table 8 | Selected policies relating to industry

Policy name	Release date	2025 Target	Targets for 2030 and beyond
Implementation Plan for Carbon Peaking in the Industrial Sector, (Ministry of Industry and Information Technology and others)	2022-08-01	By 2025, energy intensity per unit of output growth of industries above designated size reduces 13.5% compared to 2020. The reduction of carbon intensity per unit of output growth of industries above the designated size is more than that of the whole society. Significant reduction of the carbon intensity of key industries.	Ensure the emissions from the industrial sector peak before 2030.
Implementation Plan for Energy Efficiency Improvement in the Industrial Sector, (Ministry of Industry and Information Technology and others)	2022-06-29	By 2025, energy intensity per unit of output growth of industries above designated size reduces 13.5% compared to 2020.	-
14th Five-Year Plan for Industry Green Development, (Ministry of Industry and Information Technology)	2021-11-15	By 2025, the carbon intensity of the output growth of industries reduces by 18%; the emission intensity of major pollutants in key industries reduces by 10%; energy intensity per unit of output growth of industries above designated size reduces 13.5% compared to 2020; the share of recycled bulk industrial solid waste reaches 57%; water consumption per unit of the output growth of industries decreased by 16%.	-
14th Five-Year Comprehensive Work Plan for Energy Conservation and Emission Reduction, (State Council)	2021-12-28	By 2025, the national energy consumption per unit of GDP will drop by 13.5% compared with 2020, the total energy consumption will be reasonably controlled, and the total emissions of chemical oxygen demand, ammonia nitrogen, nitrogen oxides, and volatile organic compounds will drop by 8%, 8%, 10%, and 10%, respectively, compared with 2020. At least 30% of the manufacturers in key industrial sectors and data centres should reach the benchmark level for energy efficiency.	-
The 14th Five-Year Plan for Circular Economy Development, (National Development and Reform Commission)		By 2025, the national energy consumption per unit of GDP will drop by 13.5% compared with 2020. The utilisation of scrap steel reached 320 million tonnes, and the output of secondary non-ferrous metals reached 20 million tonnes, of which the output of secondary copper, secondary aluminium, and the secondary lead reached 4 million tonnes and 11.5 million tonnes, respectively.	

14th Five-Year Plan for Raw Material Industry Development, (Ministry of Industry and Information Technology and others)	2021-12-29	By 2025, the energy consumption per tonne of steel will reduce by 2%, energy consumption per unit of cement products will reduce by 3.7%, and the carbon emission of electrolytic aluminium will reduce by 5%.	-
Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035), (National Development and Reform Commission)	2022-03-23	By 2025, hydrogen production from renewable energy will reach 100,000-200,000 tonnes/year and will achieve a carbon dioxide emission reduction of 1-2 million tonnes/year.	By 2030, a relatively complete hydrogen energy industry technology innovation system, clean energy hydrogen production, and supply system will be formed. By 2035, a hydrogen energy industry system will be formed, and a diversified hydrogen energy application system covering transportation, energy storage, industry, and other fields will be built.
Guiding Opinions on Promoting the High-quality Development of the Iron and Steel Industry, (Ministry of Industry and Information Technology and others)	2022-02-08	By 2025, energy consumption per tonne of steel will be reduced by at least 2%; recycle and reuse over 0.3 billion tonnes of steel scrap; increase the share of EAF-based secondary steel to 15%.	Ensure the emissions from the iron and steel industry peaks before 2030.
Implementation Plan for Carbon Peaking and Carbon neutrality in the Iron and Steel Industry, (China Iron and Steel Association)	(under consulting)	Ensure the emissions from the iron and steel industry peak by 2025.	Total emissions will reduce by 30% compared to the peak. Further reduce emissions by 2035 and achieve decarbonisation by 2060.
Implementation Plan for Carbon Peaking in Building Materials Industry, (Ministry of Industry and Information Technology and others)	2022-11-7	Energy intensity per unit of cement product will reduce by 3% compared to 2020 by 2025.	Ensure the emission from the building materials industry peaks before 2030.
Guiding Opinions on Promoting the High-quality Development of the Petrochemical and Chemical Industry, (Ministry of Industry and Information Technology and others)	2022-04-07	By 2025, energy consumption and carbon emissions per unit of product will be significantly reduced, and total volatile organic compound emissions will be reduced by more than 10% compared with the “13th Five-Year Plan” period.	-
Implementation Plan for Carbon Peaking in Non-ferrous Metal Industry, (Ministry of Industry and Information Technology)	2022-11-15	The energy consumption and carbon emission intensity per unit product of key varieties will have been further reduced, and the supply of recycled metals will have reached more than 24%.	Ensure the emission from the non-ferrous metals industry peaks before 2030.
Implementation Plan for Carbon Peaking and Carbon neutrality in the Coke Industry, (China Coke Industry Association)	2022-08-03	Ensure the emissions from the coke industry peak before 2025.	By 2035, ensure emissions reduce 30% compared to the peak.
Guiding Opinions on Promoting the High-quality Development of Light	2022-06-19	By 2025, the efficiency of resource utilisation will be greatly improved, and the energy consumption per unit	-

Industry, (Ministry of Industry and Information Technology and others)		of output growth of industries, carbon emissions, and major pollutant emissions will continue to decline.	
The "14th Five-Year Plan" and the Medium and Long-term High-quality Development Outline of the Paper Industry, (China Paper Association)	2021-12-24	Energy intensity decreases from 350kgce/t to 320kgce/t during the 14 Five-Year Plan period (2021-2025).	Peak emissions by 2030.
Guiding Opinions on the High-Quality Development of the Textile Industry, (Ministry of Industry and Information Technology and others)	2022-04-21	By 2025, the proportion of recycled fibre and biomass fibre applications will reach 15%.	-
Guiding Opinions on the High-Quality Development of the Chemical Fibre Industry, (Ministry of Industry and Information Technology and others)	2022-04-21	During the "14th Five-Year Plan" period, the proportion of green fibres will increase to more than 25%, the output of bio-based chemical fibres and degradable fibre materials will increase by more than 20% annually.	-

4.5.4 Data disclosure

Data on industrial production, including the most important emitting sectors, is published monthly, which provides an indication of the development of emissions. However, data on industrial energy consumption is only published on an annual basis and with a delay of 1–2 years. Official information on CO2 emissions from industry has only been published twice, with the latest data covering the year 2014.

4.6 Buildings

The building sector was responsible for 11% of China's CO2 emissions from the energy sector, through the use of coal, fossil gas, and electricity. This is a smaller share than in most other countries, explained by the dominance of industry as an energy consumer in China, but still significant. The use of coal stoves for residential heating is also a major source of air pollutants, despite rapid progress in eliminating small-scale coal use.

Energy efficiency plays a major role in reducing emissions from the building sector. Under the ICCSD's 1.5°C scenario, by 2050, the energy consumption of the building sector falls to 620 Mtce, from 775 Mtce in 2020. The share of electricity in the sector's total final energy consumption rises to 78%, from 48% in 2020[94], and the use of biomass increases to around 90 Mtce, from 67 Mtce in 2020. A high level of electrification means that natural gas consumption falls as well.

Direct carbon emissions from the building sector have already plateaued and seen a fall from 2,000 MtCO2 since 2020, as fuel use in buildings has been replaced by district heating and electricity. The total emissions of the sector, including the emissions from the production of electricity and heat used in buildings, begins to fall sharply from 2030 to 2045 and reaches 80 MtCO2 in 2050.

[94] Shenzhen Institute of Building Research. (2021). Building electrification and its driving path for urban energy transition. https://www.efchina.org/Reports-zh/report-lccp-20210207-2-zh. Research report.

The ICCSD's 1.5°C pathway also sees a substantial slowdown in construction volumes, with the net growth of the total building stock coming to a halt by 2025.

Due to the fact that China has not yet banned the use of HFCs, air conditioning units for buildings are a major source of F-gases that will need to be controlled as a part of China's policymaking on non-CO2 greenhouse gases[95].

4.6.1 Trends compared to benchmarks

China's ambitious air pollution policies, targeting small-scale coal use in buildings as one of the key sources of air pollution, have led to a rapid reduction in coal use, in line with the transition pathways. However, total energy consumption in buildings increased by 5% per year from 2015 to 2020, while the transition pathways have falling total energy consumption from 2020 to 2030. As a result, the use of fossil gas and electricity increased faster than in the transition pathways. The potential for economically profitable energy efficiency measures in buildings is very large, but there are also major barriers to realising it. As the construction of new buildings slows down in China, the energy efficiency of existing buildings could be an important focus area.

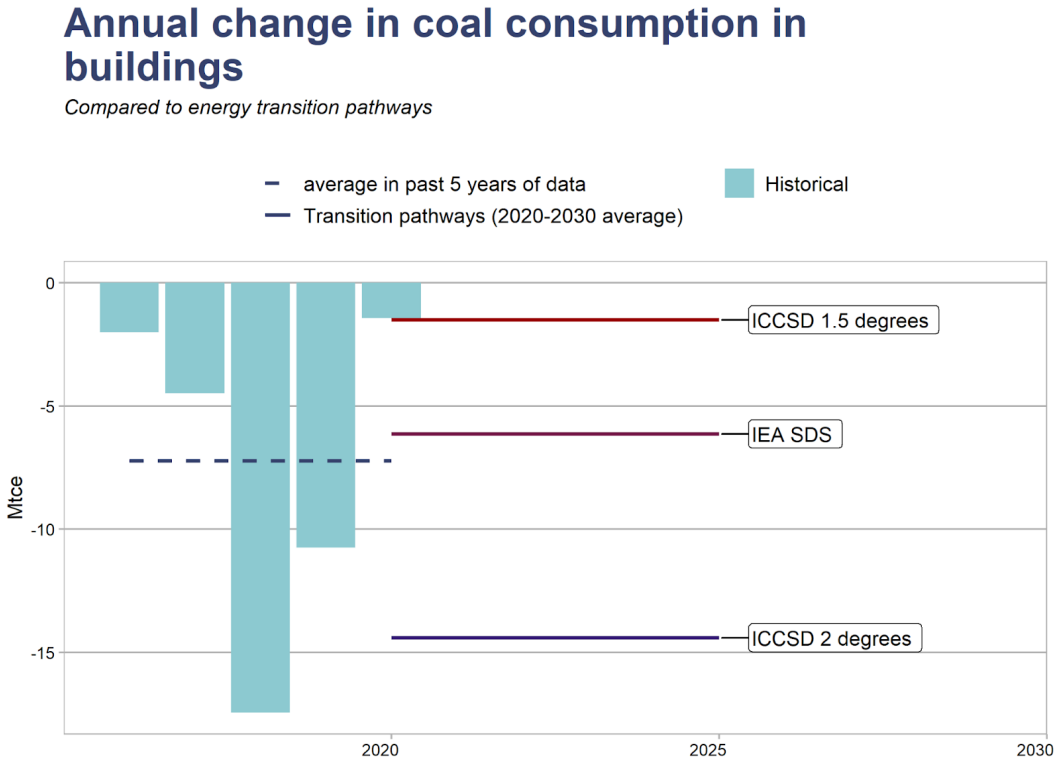

Figure 32 | Annual change in coal consumption in buildings compared to energy transition pathways

[95] Ministry of Ecology and Environment and others. (2021). Notice on Strictly Controlling the First Batch of HFC Chemical Production and Construction Projects. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/202112/t20211229_965542.html

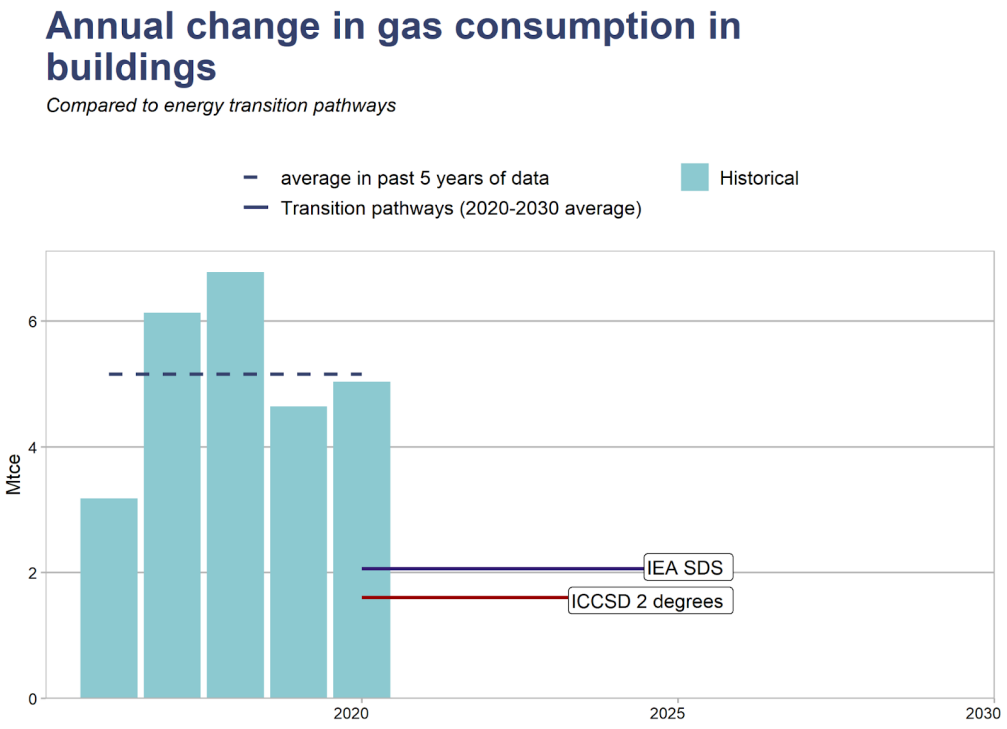

Figure 33 | Annual change in gas consumption in buildings compared to energy transition pathways

In the IEA Sustainable Development Scenario, coal use in buildings falls by 75% from 2020 to 2030. This is an even more rapid reduction than the 36% reduction achieved from 2015 to 2020. Yet gas and electricity consumption in buildings has grown much faster than in the transition pathways, indicating that progress on building energy efficiency is lagging behind the pathways. Electricity consumption is growing faster than in the transition pathways, but it's largely not replacing coal and gas.

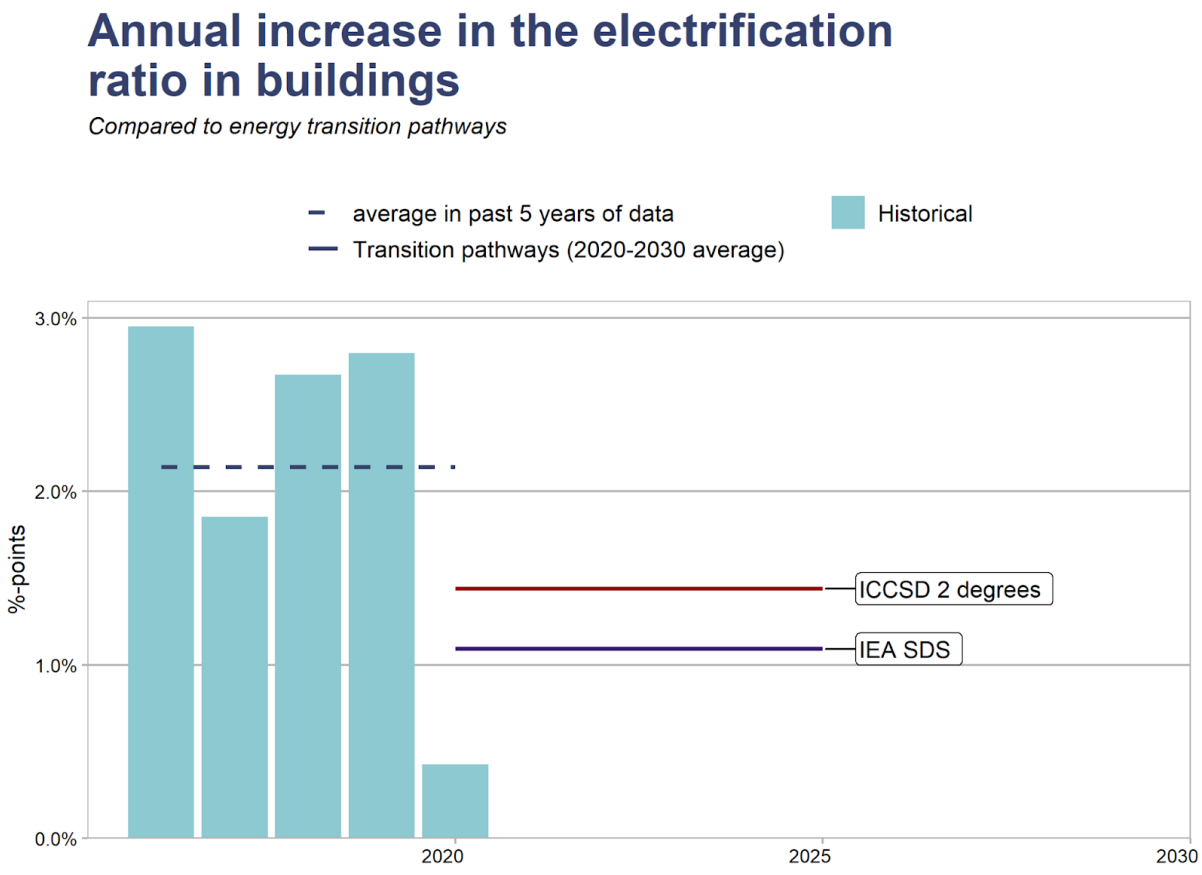

Figure 34 | Annual increase in the electrification ratio in buildings compared to energy transition pathways

4.6.2 Policies in place: The action for peaking carbon dioxide emissions in urban-rural development

The building sector is covered in China's CO2 peaking action plan under "urban and rural development". The *14th Five-Year Plan for Building Energy Efficiency and Green Building Development* defined the following non-binding targets for green building development[96].

Overall targets by 2025:

- Cap (primary and secondary) energy consumption used in building operation at 1150 mtce;
- Increase the energy efficiency of newly built residential buildings by 30%;
- Increase the energy efficiency of newly built public buildings by 20%.

Specific indicators by 2025:

- Renovate 350 million m^2 of existing buildings for energy-saving technology;
- Construct 50 million m^2 of ultra-low or near-zero energy consumption buildings;
- Increase proportion of prefabricated buildings in newly added urban buildings to 30%;

[96] Ministry of Housing and Urban-Rural Development of China and others. (2022). 14th Five-Year Plan for Building Energy Efficiency and Green Building Development. http://www.gov.cn/zhengce/zhengceku/2022-03/12/content_5678698.htm. Policy.

- Increase solar installed capacity in newly added buildings to 50 GW;
- Increase geothermal energy application in newly added buildings to 100 million m^2;
- Increase renewable energy used in urban buildings to 8%;
- Ensure that the proportion of electricity consumption in building energy consumption reaches 55%.

A later released implementation plan for carbon peaking in urban and rural construction provides further details on the measures[97].

For urban areas, it covers city development planning, residential community planning, energy-saving and efficiency requirements for heating, ventilation, and air conditioning (HVAC), public lighting and elevators, waste management, appliance electrification, and green construction.

For rural areas, it emphasises clusterization to minimise energy consumption, improving energy efficiency for residential farmhouses, encouraging solar heating, high-efficiency lighting and cooking appliances, low consumption wastewater treatment, source reduction for residential waste, and electrification for cooking, HVAC, lighting, and commuting.

Green appliances

The *Notice on Several Measures to Promote the Consumption of Green and Smart Home Appliances* promotes high energy efficiency appliances by encouraging measures such as trade-in programs and calls for "improving standard green and smart Home appliances"[98]. Currently, there is a green appliance evaluation standard for refrigerators, A/C, and washing machines[99].

Data centres

Data centres are a novel infrastructure that is growing rapidly in many cities in China. An *Implementation Plan*[100] released by the NDRC states that by 2025:

- Power Usage Effectiveness should decrease to below 1.3 for large and ultra-large data centres, and further down to below 1.25 for national nexus nodes. Data centres that have PUE over 1.5 should undergo energy-saving retrofitting.
- The Green Low Carbon assessment should rank at the "AAAA"[101] level.

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[97] Ministry of Housing and Urban-Rural Development of China and others. (2022). Implementation plan for carbon peaking in urban and rural construction. http://www.gov.cn/zhengce/zhengceku/2022-07/13/content_5700752.htm. Policy.

[98] Ministry of Commerce and others. (2022). Notice of Several Measures to Promote the Consumption of Green and Smart Home Appliances. http://www.gov.cn/zhengce/zhengceku/2022-08/04/content_5704274.htm. Policy.

[99] Standardization Administration of China. (2021). Green product assessment—Household electric appliances—Part 1： Refrigerators, air-conditioners and washing machines. https://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=D055E567F29672FD38B65A479656CA26. National Standard.

[100] National Development and Reform Commission of China and others. (2021). Implementation plan for promoting the green and high-quality development of new infrastructure such as data centres and 5G. https://www.ndrc.gov.cn/xwdt/tzgg/202112/t20211208_1307105.html?code=&state=123. Policy.

[101] Chinese Institute of Electronics. (2021). Grade Evaluation Rule of Green Data Centers (Trial). http://www.dcrencai.org.cn/uploadfile/2021/0303/20210303112657447.pdf. Industry Standard.

- Data centres in western regions should improve utilisation rate from 30% to 50%; for regions that have less than 50% overall utilisation rate, no new data centre clusters should be planned.

The plan also encourages using renewable energies such as wind and solar, as well as piloting scaled usage of novel energy technologies such as hydrogen battery modules.

Residential coal heating

Bulk coal is one of the recent focuses for both air pollution control and carbon peaking. In fact, the top-level *Action Plan* has emphasised that multiple measures should be applied to "replace and reduce bulk coal burning until it's eventually prohibited"[102]. The national-level action plan for air quality improvement during the 14th FYP period will be released soon[103], in which more details about bulk coal usage and clean heating are expected to be found.

Table 9 | Selected policies relating to the buildings sector

Policy name	Release date	2025 Target	Targets for 2030 and beyond
Implementation plan for carbon peaking in urban and rural construction, (Ministry of Housing and Urban-Rural Development and others)	2022-07-13	By 2025, new urban buildings will fully implement green building standards.	Ensure the emissions from urban and rural construction peak before 2030. Before 2030, the new residential buildings in severe cold and cold areas should meet the 83% of energy-saving requirements; the new residential buildings in the areas with hot summers and cold winters, hot summers and warm winters, and mild areas should meet 75% of the energy-saving requirements; and new public buildings should meet 78% of the energy-saving requirements. By 2030, the utilisation rate of urban residential waste will reach 65%.
14th Five-Year Plan for Building Energy Efficiency and Green Building Development, (Ministry of Housing and Urban-Rural Development)	2022-03-12	1) Set a coal consumption cap, 1.15 billion tonnes of standard coal, for building maintenance by 2025; 2) Increase the energy efficiency of newly built private buildings by 30% by 2025; 3) Increase the energy efficiency of newly built public buildings by 20% by 2025.	-
Opinions on promoting green development of urban and rural construction, (Central Committee of the Communist Party of China, State Council)	2021-10-21	-	-
The 14th Five-Year Plan to Promote the Modernization of	2022-02-11	Promote carbon emission reduction and carbon sequestration in agriculture and rural areas.	-

[102] Department of Resource Conservation and Environmental Protection. (2021). Action Plan for Carbon Dioxide Peaking Before 2030. https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html. Policy.
[103] National Business Daily. (2022). The National "14th Five-Year Plan" Air Quality Improvement Action Plan will be released and implemented in the near future. https://finance.sina.com.cn/china/2022-09-23/doc-imqqsmrp0213428.shtml?cref=cj. News.

Agriculture and Rural Areas, (State Council)			
Notice on Several Measures to Promote the Consumption of Green and Smart Home Appliances, (Ministry of Commerce and others)	2022-08-04	-	-

4.6.3 Data disclosure

Data energy consumption in the residential and commercial sector is only published on an annual basis and with a delay of 1–2 years. Official information on CO2 emissions from the sector has never been published, with China's official greenhouse gas emission inventories submitted to the UN, where residential emissions are delegated to the "Other" category.

4.7 Transport

If China's economic development and urbanisation continue at a fast pace, the demand for passenger and freight transportation will rise sharply until around 2040. Limiting the increase in CO2 emissions will require further development of sustainable transport modes and options and increasing their share of total transport volumes; accelerated electrification; as well as the use of biofuel and hydrogen in aviation. In both the ICCSD 1.5°C and 2°C pathways, total CO2 emissions from the transportation sector will peak around 2030, at 1.04 and 1.08 billion tonnes, respectively, up from 991 million tonnes in 2020, before a drastic decline to 172 and 550 million tonnes in 2050, respectively. The energy efficiency of transportation increases by 65% in 2050 from 2015 levels, compared with 30% in the ICCSD's policy scenario, depicting a continuation of policies before the carbon neutrality announcement.

In 2050, under the ICCSD 1.5°C scenario, the share of public transport in all travel modes reaches 60%, up from 45% in the policy scenario. The total length of the railway network grows to 70,000 km in the 1.5°C scenario, compared with 50,000 km in the policy scenario. The growth in private car ownership continues, albeit slowly, reaching 27%, from 17% in 2020[104], and the share of commuters using carpooling reaches 25% by 2050.

Modern life demands decentralised, time-sensitive, small-sized, and high-value freight transport. After the restructuring of the transport sector under the ICCSD 1.5°C scenario, the share of freight transported by railway increases from 8.9% in 2021[105] to 24% in 2050 and by ship from 15.6% to 22%, while the share of road freight falls from 73.9% to 51%. In passenger transportation, the share of rail in 2050 is increased from 38% in the policy scenario to 43.5% in the 1.5°C pathway, while the

[104] China National Bureau of Statistics (2021). Statistical Communiqué of the People's Republic of China on National Economic and Social Development in 2020. http://www.stats.gov.cn/tjsj/zxfb/202102/t20210227_1814154.html

[105] National Bureau of Statistics of China, (2022). Statistical Communiqué of the People's Republic of China on the 2021 National Economic and Social Development. http://www.stats.gov.cn/english/PressRelease/202202/t20220227_1827963.html. Scientific article.

share of road transport falls from 34% to 26.5%. The share of aviation falls slightly from 33% in 2021 to 29% in 2050.

For road vehicles, electrification represents the main thrust of emission reductions. For private cars and light vehicles, battery-electric vehicles dominate, while fuel-cell vehicles are also used to electrify coaches and mid- to heavy-duty trucks. The share of new energy vehicles (NEVs), a category comprising both electric and fuel cell vehicles, out of all vehicles reaches 20% and 85% in 2030 and 2050 respectively, compared with 1.5% in 2020. In freight, the share of new energy vehicles rises to 5% by 2030 and 60% by 2050, up from 0.2% in 2020.

4.7.1 Trends compared to benchmarks

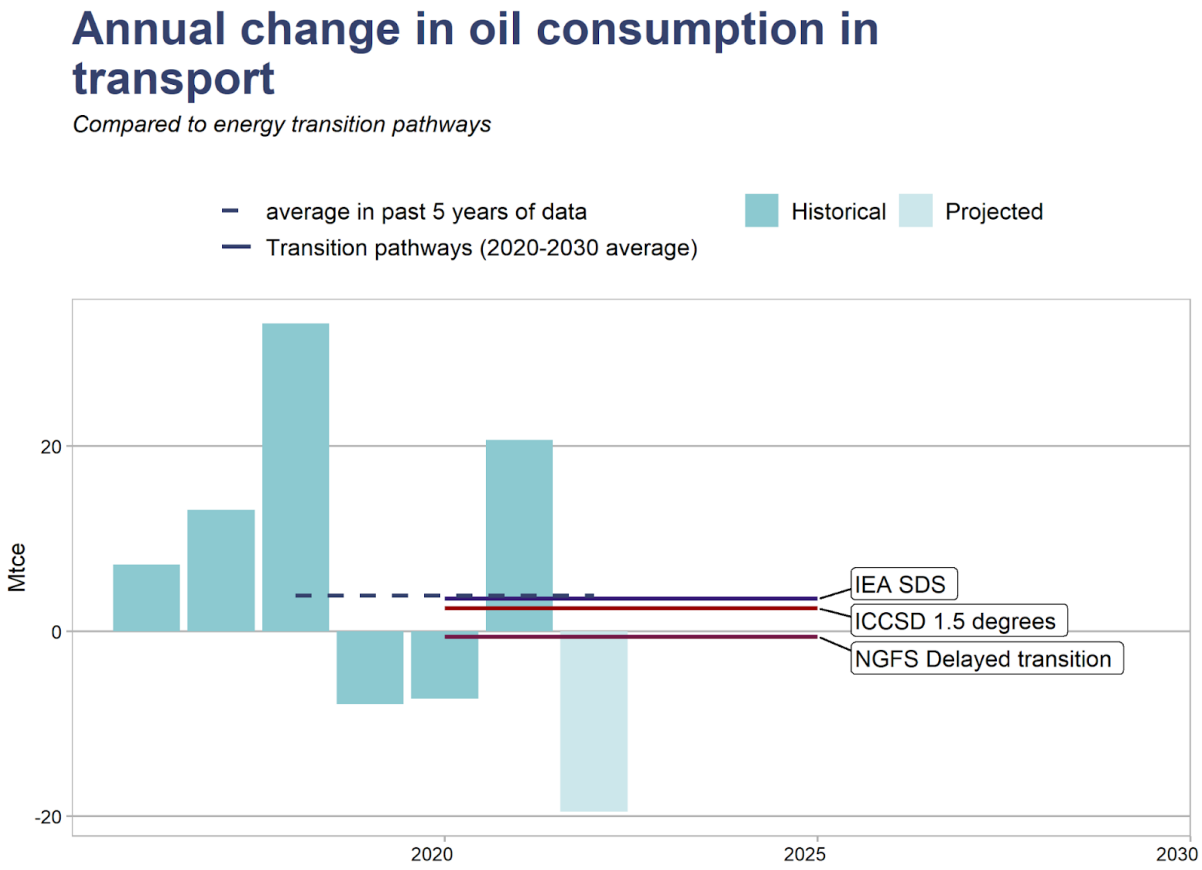

Figure 35 | Annual change in oil consumption in transport compared to energy transition pathways

China's oil consumption has been almost stable since 2019, but this is largely due to the reduction in mobility caused by COVID-19 control measures. The transition pathways consistent with 1.5 degrees project near-zero growth in transport oil demand from 2020 to 2030. The current trend appears consistent with the latter, but the removal of pandemic control measures could result in a significant rebound.

The decarbonisation and electrification of transport in China are supported by a highly developed network of high-speed rail connections between cities, as well as urban rail and bus transport. Bus fleets are being electrified rapidly, often as part of air pollution action plans.

More than half of China's transport emissions originate in freight, which is also being shifted onto rail. Recent years have seen major investments in rail-based logistics for commodities.

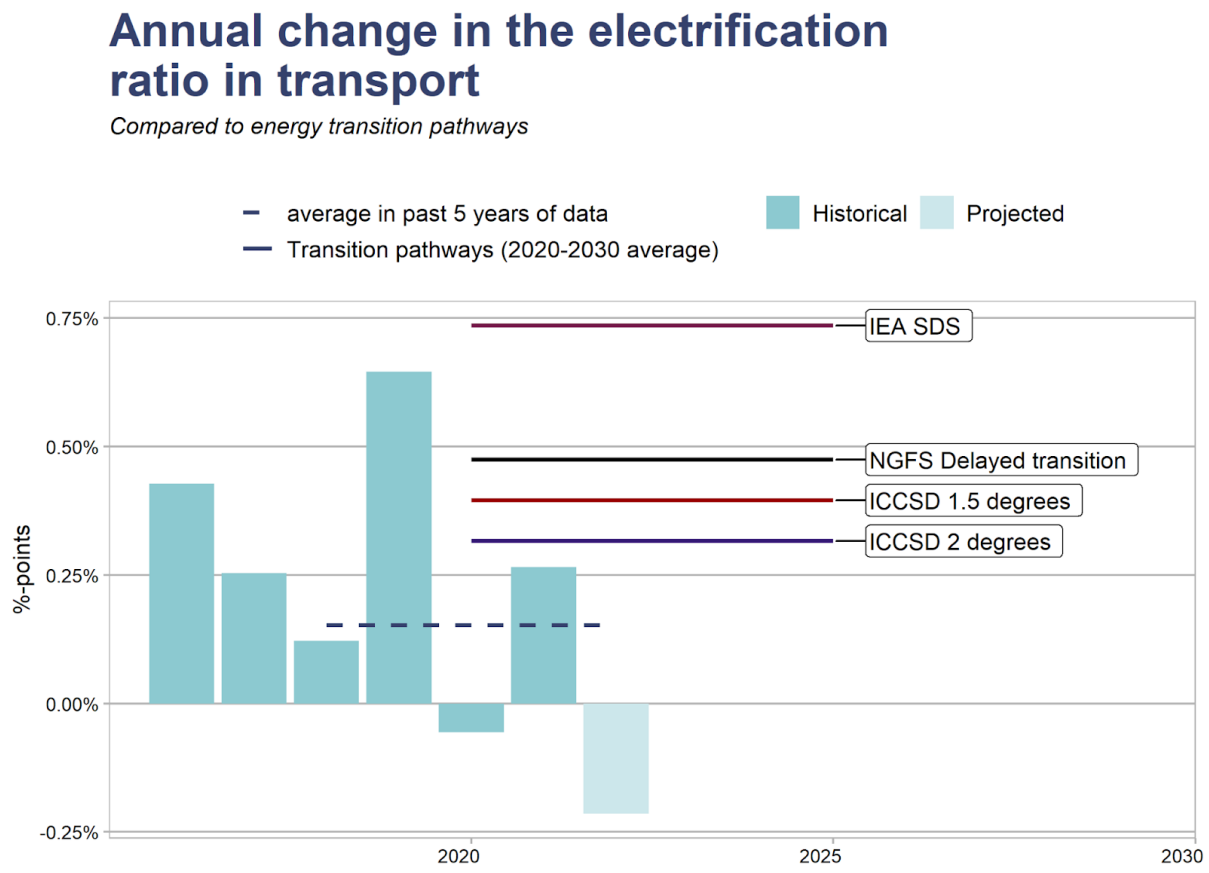

Figure 36 | Annual change in the electrification ratio in transport compared to energy transition pathways

The share of electricity in transport energy use rose from 2.3% in 2015 to 3.7% in 2022. This is much slower than the approximately 0.5%-points/year rate achieved in the transition pathways. However, electric vehicle production and sales have been skyrocketing, with the share of EVs out of all vehicles produced increasing from 4.7% in 2019 to 21% in the 12 months up to August 2022. The figures are similar for the share of EVs in vehicle sales. It is likely that not all EV charging is showing up in transport electricity consumption, so the actual rate of electrification is likely to be faster and better in line with the transition pathways. The IEA Energy Technology Perspectives projects a 65% share of electric vehicles (EVs) in new vehicle sales by 2030 globally, which China could well be on track to achieve given the rate of growth. The 20% share of NEVs out of all vehicles on the road projected in the ICCSD's 1.5°C pathway in 2030 should be met comfortably on the current trajectory as the share of sales continues to increase beyond 20% and there is almost a decade of time for the fleet to turn over.

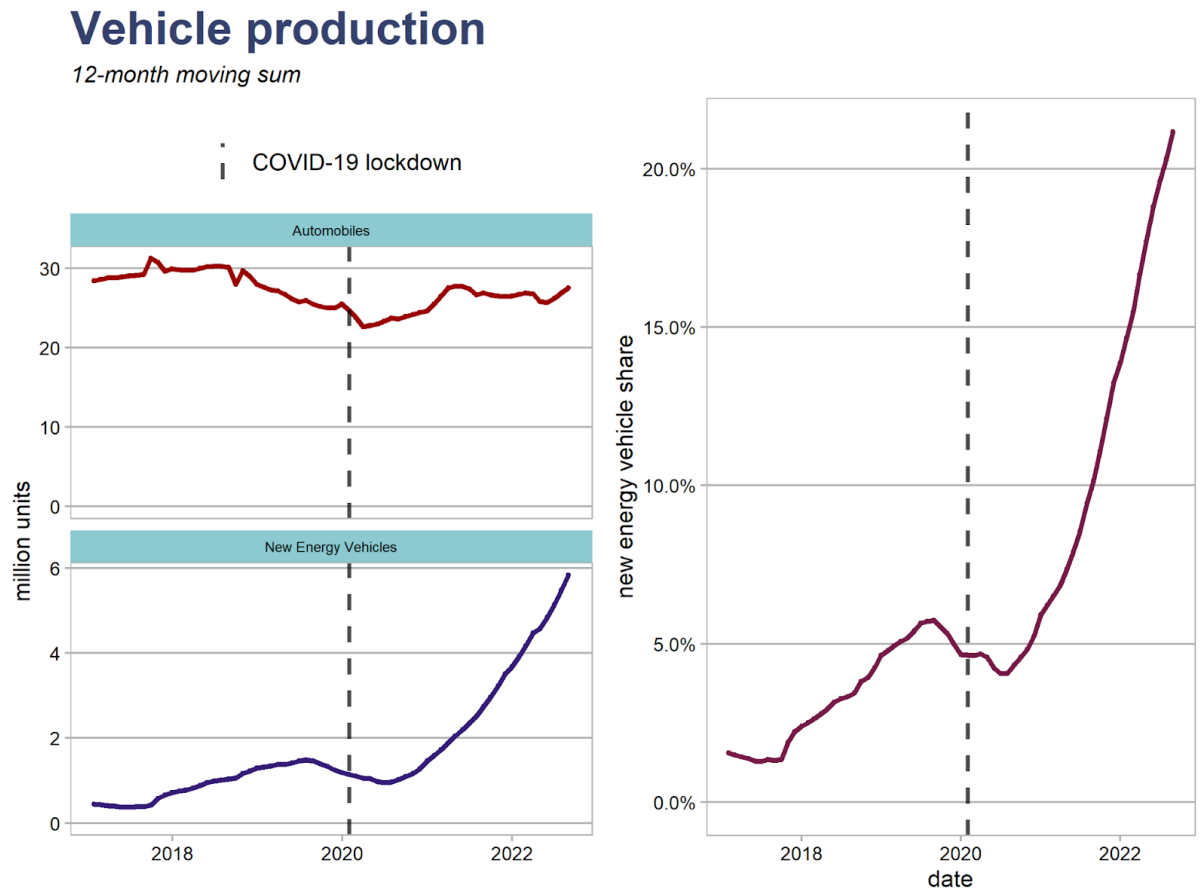

Figure 37 | Vehicle production; 12-month moving sum

4.7.2 Policies in place: Actions for promoting green and low-carbon transportation

The *14th Five-Year Plan for Green Transportation Development* defined non-binding targets by 2025[106]:

- Decrease CO2 emissions per unit transport turnover of operating vehicles by 5%.
- Decrease CO2 emissions per unit transport turnover of operating ships by 3.5%.
- Increase growth of the proportion of new energy vehicles in urban public transportation, taxis (including ridesharing), and urban supply chain and delivery to 72%, 35%, and 20%, respectively.
- Increase growth of the proportion of new energy and clean energy trucks in international container hub seaports to 60%.
- Increase use of railway, waterway, conveyor belts, or new energy vehicles in north China coastal seaports for ore and coke transport to 70%.

To support EVs, the *14th Five-Year Plan for the Development of Modern Transportation System* pledges to achieve a charging port coverage of at least 80% for key areas for air pollution

[106] Ministry of Transport. (2021). 14th Five-Year Plan for Green Transportation Development. http://www.gov.cn/zhengce/zhengceku/2022-01/21/content_5669662.htm. Policy.

prevention and control in the *National Ecological Civilization Pilot Zone*[107] (Fujian, Guizhou, and Jiangxi), and at least 60% for the rest of the country. It also calls for electrification replacement for public service vehicles and sets a target of having 80% of the (new or refreshed) public service vehicles - including buses, urban supply chain and deliveries, postal service, taxis, government cars, and sanitation vehicles - to be EVs[108].

It also encourages the usage of rail transport and new energy vehicles for seaports and large industrial and mining enterprises.

Table 10 | Selected policies relating to transportation

Policy name	Release date	2025 Target	Targets for 2030 and beyond
New Energy Vehicle Industry Development Plan (2021-2035), (Office of State Council)	2020-11-2	By 2025, the competitiveness of China's new energy vehicle market will be significantly enhanced. The average power consumption of new pure electric passenger cars will drop to 12.0 kWh/100 kilometres, and the sales of new energy vehicles will account for about 20% of the total sales of new cars.	After 15 years of continuous efforts, the core technology of China's new energy vehicles will reach the international advanced level.
"14th Five-Year" Development Plan for Green Transportation, (Ministry of Transport)	2022-01-21	Decrease the rate of carbon dioxide (CO2) emissions per unit of transport turnover of operating vehicles compared to 2020 (5%). Decrease rate of carbon dioxide (CO2) emissions per unit of transport turnover of operating ships compared to 2020 (3.5%). Increase the proportion of new energy vehicles in the field of urban public transportation, taxis (including online car-hailing), and urban logistics and distribution nationwide (72%, 35%, 20%). Increase the proportion of new energy and clean energy trucks in international container hub seaports (60%).	-
14th Five-Year Plan for the Development of Modern Transportation System, (State Council)	2022-01-18	The high-speed railway network with a speed of 250 kilometres per hour and above will cover more than 95% of cities with a population of more than 500,000. Transportation CO2 emission intensity reduction rate (5%).	-

The development of fuel cell EVs is affected by the Hydrogen industry. The *Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035)* set a target that by 2025, fuel cell

[107] Central Committee of the Communist Party of China, State Council. (2016). Opinions on the establishment of a unified and standardised national ecological civilization pilot zone. http://www.gov.cn/gongbao/content/2016/content_5109307.htm. Policy.
[108] State Council. (2021). 14th Five-Year Plan for the Development of Modern Transportation System. http://www.gov.cn/zhengce/content/2022-01/18/content_5669049.htm. Policy.

EV ownership shall grow to 50,000, and hydrogen production is expected to reach 100,000-200,000 tonnes per year[109].

As a final note, although missing a quantifiable objective, support for EVs (and charging ports) are also recognised in urban planning policies such as the *Implementation plan for carbon peaking in urban and rural construction*[110].

4.7.3 Data disclosure

Data on the apparent consumption of oil products used to be published by the National Energy Administration on a monthly basis until early 2022, but is not publicly available anymore. Total refinery throughput and imports and exports of oil products are published monthly, but this data is not disaggregated by type of product. These datasets are not specific to the transport sector but nevertheless provide an indication of the development of emissions.

Actual energy consumption data for the sector is published on an annual basis and with a delay of 1–2 years. Official information on CO2 emissions from transportation has only been published twice, with the latest data covering the year 2014.

[109] National Development and Reform Commission if China. (2021). Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035). https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=18747. Policy.
[110] Ministry of Housing and Urban-Rural Development of China and others. (2022). Implementation plan for carbon peaking in urban and rural construction. http://www.gov.cn/zhengce/zhengceku/2022-07/13/content_5700752.htm. Policy.

5 Expert survey and interviews

To gain insights into the views and expectations driving China's policymaking, we carried out a survey of Chinese energy specialists involved in policymaking and analysis. We contacted 30 experts, of which 26 agreed to respond to the survey by sharing their expectations for the trajectory of China's total CO2 emissions and CO2 emissions from the power, industry, building and transport sectors. Of these 26 experts, 20 are located inside China, and six are outside China. The experts are from different sectors, including coal science and coal mining, power generation, renewable energy, oil, energy storage, carbon capture, environmental science, and buildings. Their roles include media, legal, academics, and civil servants, and they all specialise in energy.

In contrast to the transition pathways, which are based on model projections and normative targets, the experts responded to the survey based on their expertise and experience. The interviews were oral or written depending on the preference of each respondent. The overall outcome from the discussion with the experts was that peaking total CO2 emissions before 2030 is achievable but achieving carbon neutrality is a challenge. Economic development and creating and securing job opportunities are the first priorities after the Covid-19 pandemic and national energy security is the second. Sectors are not aiming to peak their carbon emissions as early as possible or minimise the level at which emissions peak. Rather, they intend to make use of the time before emissions are due to peak to develop and expand, including in ways that increase emissions.

5.1 Total CO2 emissions

According to the IPCC, the world's CO2 emissions need to peak between 2020 to 2025 in the pathways consistent with Paris Agreement goals, while the Chinese government announced China will peak carbon emissions in 2030. In order to limit the temperature increase to 1.5°C, some academics (Wang et al., 2021) suggested that China should peak CO2 emissions at 10.8 billion tonnes in 2020 and then reduce CO2 emissions to 9 billion tonnes in 2030 and 0.6 billion tonnes in 2050.

However, no experts we interviewed think that China has already peaked CO2 emissions and their predictions of the year for China to peak CO2 emissions are varied. Only four people believe that China can peak CO2 emissions before 2025 and 12 people believe that CO2 emissions in China will peak in 2030 or after (see Table 11). 14 people chose the carbon peak year between 2026 to 2030.

Table 11 | Survey results on the peak year for China's CO2 emissions

What year do you expect China's CO2 emissions to peak?	
A. Peaked already	0
B. Before 2025	4
C. After 2030	8
D. Between 2026 and 2030	14

Peak year	2026	2027	2028	2029	2030	Total
Number of responses	0	2	5	3	4	14

During the interview, most of the experts believed that peaking carbon should not be a challenge but achieving carbon neutrality in China might need a lot of work depending on the level of CO2 emissions at the peak. This concern was reflected in the answer to question 2: At what level do the national carbon emissions peak? 18 out of 26 experts projected that the peaking level will be more than 15% of the 2020 CO2 emission level (see Figure 38), indicating that although it will peak, China still has a CO2 mountain to remove.

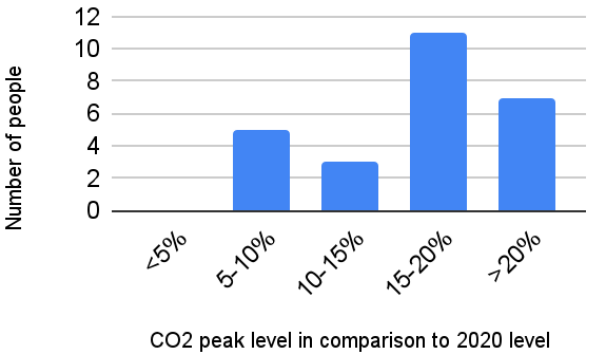

Figure 38 | Total CO2 peaking level

5.2 Primary energy consumption and coal consumption

According to the ICCSD's projection, under the 2°C scenario, China's total primary energy consumption will peak at 5.64 billion tce around 2030 while under the 1.5 °C scenario, primary energy consumption will hit a peak of 5.34 billion tce in 2025. Other academics are not as optimistic. For example, research from the School of Environment and Natural Resources at Renmin University (SENR-RMU) predicts that under the 1.5°C scenario, China will peak its primary energy consumption at 6.8 billion tce in 2045 and slightly drop to 6.7 billion tce by 2050 (Wang et al., 2022).

Our experts' survey result is in line with the ICCSD's 2°C scenario projection and SENR-RMU's study. Half of the experts interviewed believe that primary energy consumption will peak by 2030 and another seven experts expect the peak by 2035. However, there are five experts who think that China's primary energy consumption will continue to increase after 2035.

Table 12 | Survey results on the peak year for China's total primary energy consumption

When do you think the primary energy consumption in China will peak?	
A. Already peaked	1
B. By 2030	13
C. By 2035	7
D. After 2035	5

China has announced it will strictly limit the increase in coal consumption over the 14th five-year plan period and phase it down in the 15th five-year plan period. This implies that China will peak its coal consumption by 2025. Four experts we interviewed think that coal consumption has already peaked and three people answered 'unsure', giving the reason as depending on political and economic situations in the next few years. The majority (19 out of 26) of experts believe that coal consumption in China has not peaked yet. One person predicted 2024 and three people predicted 2025 for coal consumption to peak but this was under the assumption that there would be no significant national or international political, economic, or natural disasters in the near future. 12 out of 26 experts think that coal consumption in China will peak after 2027, with three choosing 2030, three choosing 2035 and one even choosing 2040. All the experts interviewed specified that peaking coal depends on the correlation between the energy transition and the global and national economic situation, and energy security is also an influencing factor before carbon control.

Table 13 | Survey results on the peak year for China's total coal consumption

Do you think coal consumption in China has already peaked?	
A. Yes	4
B. Not sure	3
C. No	19

Peak year	2024	2025	2027	2028	2030	2035	2040	Total*
Number of responses	1	3	2	3	3	3	1	16

* 3 respondents did not specify a year

5.3 Power sector

As the key player in China's carbon reduction mission, publications on the power sector's pathway of carbon emissions peak are plentiful compared to the industry and transport sectors. The projected year for the power sector to peak carbon emissions ranged between 2020 to 2031 (see Table 14).

Table 14 | CO2 peak year for power sector from different projections

Projector	Peak year
CAEP-IAE&EPPEI - without CHP	2031
CAEP-IAE&EPPEI - incl. CHP	2028
CEC - New energy accelerate[111]	2030
CEC - New energy accelerate+Nuclear	2028
CEC - New energy leap	2025
CEEP-BIT[112]	2029
ICCSD 1.5°C and 2°C	2023
NCEPU&PKU	2025
SENR-RMU	2020

Although it is commonly agreed that the power sector is the largest CO2 emitter and plays an instrumental role in the decarbonisation of other sectors, there are still five experts who project that the power sector will peak carbon emissions after 2030 and three people project in 2030, the year the Chinese government set for total carbon emissions to peak. In the interview, experts stressed that energy security and economic development are more important, for example dealing with the impacts of extreme weather and Covid-19 restrictions. International political events will also affect energy security. "Holding the meal bowl" of energy in their own hands is more important than reducing carbon emissions.

Table 15 | Survey results on the peak year for China's power sector CO2 emissions

When do you expect CO2 emissions from the power sector to peak in China?	
A. Peaked already	0
B. Before 2025	11
C. After 2030	5
D. Between 2026 to 2030	10

Peak year	2026	2027	2028	2029	2030	Total
Number of responses	1	3	2	1	3	10

[111] China Electricity Council (CEC). (2021). Report on power sector carbon peak. http://www.tanpaifang.com/tanguwen/2022/0118/81901.html

[112] Wei et al. (2022). Timetable and roadmap for carbon neutralization in China. https://mp.weixin.qq.com/s/1hAzyxapTPmH9-x6bgsd-Q

5.4 Industry sector

The steel sector is China's second-largest carbon emitter. As shown in Table 16, more than half of the experts we interviewed do not have confidence that the Chinese iron and steel sectors will achieve carbon peak goal before 2025. Of the nine people who believe the sector can peak carbon emissions before 2025, two experts think that carbon emissions from the iron and steel sector have already peaked.

Table 16 | Survey results on the peak year for CO2 emissions from China's iron and steel sector

When do you expect CO2 emissions from the iron and steel sector to peak in China?	
A. Peaked already	2
B. Before 2025	7
C. After 2030	6
D. Between 2026 and 2030	11

Peak year	2026	2027	2028	2029	2030	Total
Number of responses	2	1	3	1	3	10

The cement sector ranked as China's third largest carbon emitter. Two experts think that China's cement sector has already peaked its carbon emissions and nine experts project it to peak before 2025. Our questionnaire did not ask to specify which year before 2025. However, although the demand for cement has passed a rapid growth period with China's real estate development slowing down, 15 experts project that the cement sector will not peak carbon emissions before 2026, of which 12 experts think the carbon peak will not happen before 2030.

Table 17 | Survey results on the peak year for CO2 emissions from the cement sector

When do you expect CO2 emissions from the cement sector to peak?	
A. Peaked already	2
B. Before 2025	9
C. After 2030	10
D. Between 2026 to 2030	5

Peak year	2026	2027	2028	2029	2030	Total
Number of responses	0	1	1	1	2	5

5.5 Transport sector

Since the 1980s, the transport sector in China has experienced sharp growth in passenger cars and cargo. The sector also sees a surge in energy consumption and CO2 emissions. The biggest CO2 emission contributor is road transport which mainly depends on fossil fuels for energy at the moment. Mixture measures are needed to reduce CO2 emissions from the transport sector.

Projections in publications for China to peak carbon emissions from the transport sector are listed in Table 18. SENR-RMU suggested peak carbon emissions in 2025 under the 1.5°C scenario. The latest peak year of 2035 is from Wei and the team at the Center for Energy and Environmental Policy Research, Beijing Institute of Technology (CEEP-BIT).

Table 18 | Transport sector CO2 emissions peak year projected by different organisations

Projector	Peak year
ICCSD 1.5C + 2C	2030
CEEP-BIT	2035
SENR-RMU	2025
CAEP-IAE&EPPEI - high growth normal reduction methods	2029
CAEP-IAE&EPPEI - high growth strengthened reduction methods	2027

However, seven experts from our survey are not as optimistic as the publications. They project carbon peak from the transport sector will be after 2035, with two predictions even after 2045, close to the world net zero target year. Only six people believe the transport sector will peak its carbon emissions before 2030. Half of the experts think the peak will happen between 2030 and 2035.

Table 19 | Survey results on the peak year for CO2 emissions from the transport sector

When do you expect CO2 emissions from the transport sector to peak?	
A. Before 2030	6
B. 2030-2035	13
C. 2035-2040	5
D. 2045 and after	2

6 Conclusions

The CO2 emissions peaking and carbon neutrality targets are a high domestic political priority for China. President Xi Jinping has staked his personal credibility on delivering the first of the two, peaking CO2 emissions before 2030. This target is, therefore, very likely to be met.

On the other hand, a comparison of China's current emissions targets with the global pathways consistent with Paris Agreement goals shows that it is crucially important for China to not just meet but significantly exceed the targets by 2030. After 2030, rapid emission reductions will be needed to align China's emissions trajectory with the global temperature goals. Some of the academic studies on China's emissions pathways show how these can be achieved, but they are not yet reflected in China's official plans or targets.

Xi Jinping's announcement of the carbon neutrality target in September 2020 has set in motion rapid progress on some aspects of the transition. This is creating conditions for a faster peak and decline of emissions than the 2030 targets require. Clean energy investments are approaching the scale projected in 1.5-degree scenarios, a remarkable achievement. Rates of electrification are also close to or aligned with deep decarbonisation scenarios. However, until mid-2021, total energy demand growth far exceeded the growth rates projected in these scenarios, and future energy demand growth is highly uncertain. Unless a slower rate of energy demand growth is achieved through stronger energy efficiency measures and structural transformation of the economy, decarbonisation targets will be hard to attain.

To measure China's progress, we benchmarked the country's emissions and energy trends in key emitting sectors against transition pathways aligned with Paris Agreement goals. Our assessment found multiple indicators that are on track:

- Clean energy investments
- Electrification
- Building sector emissions
- Electric vehicle sales

We also found the following indicators to be still off track until 2021:

- Total energy consumption
- Industrial energy consumption
- Transport energy consumption
- Buildings energy consumption

The rapid increase in total energy consumption meant emissions kept increasing despite the impressive progress with clean energy expansion and electrification. Rapid energy demand growth was driven by a pattern of economic growth that favoured the most energy intensive industries, especially iron and steel, non-ferrous metals and chemicals industries, as well as the coal-to-chemicals industry. Energy consumption in buildings also increased faster than in the transition pathways. Most growth was in electricity consumption, which then resulted in increased coal use in the power sector as clean power generation additions were insufficient to meet increased demand.

Resolving this issue requires a combination of increased energy efficiency measures, a shift in an economic structure away from the most energy-intensive industries, or an even larger scale of clean energy investment than projected in the transition scenarios. One important step would be prioritising electrification in those applications where electricity can replace fossil fuels at a high ratio, for example, large-scale heat pumps and electric vehicles.

China's emissions and fossil fuel consumption have been falling since summer 2021. This has aligned total emissions trends with the transition pathways in the short term. However, even in 2022, two indicators remained off track:

- Investments in coal-based power capacity
- Investments in coal-based industrial capacity, particularly iron and steel capacity

For non-CO2 greenhouse gases, while some policy measures are being put in place, there are no official quantitative targets or regular emissions reporting that would allow the assessment of trends or progress. It is currently not specified whether the 2060 carbon neutrality target includes all greenhouse gases or only CO2, with official statements pointing both ways.

Official monitoring and disclosure of greenhouse gas emissions are lacking, with the most recent complete greenhouse gas emissions inventory published for the year 2014. Delivering the carbon targets and demonstrating progress will require improved reporting of energy use and emissions, ideally on a monthly and annual basis. In the energy sector, data on electricity generation, consumption, and generating capacity is published in a timely and detailed way. Other key sectors — industry, transport, and buildings — have a much longer delay, but detailed data is published on an annual basis, generally with a lag of 1 to 2 years. Monitoring of emissions needs to be improved particularly for non-CO2 greenhouse gases and emissions outside the energy sector.

China’s GDP growth is expected to be at 2.2–4.1% in 2022, a rate that policymakers almost certainly find too low[113]. The main question about future CO2 emissions and energy demand growth concerns the measures they will pursue in an attempt to accelerate growth.

Our survey of 26 Chinese energy sector analysts and officials revealed that the experts are sceptical about the prospect of emissions peaking before 2025 or having already peaked. Although most of the surveyed experts believed that peaking carbon by 2030 should not be a challenge, China achieving carbon neutrality by 2060 might need a lot of work depending on the level of CO2 emissions at the peak.

Many expert interviews reflected the thinking that economic development, as well as creating and securing job opportunities, are the first priority after the Covid-19 pandemic, and national energy security is the second. Sectors are not aiming to peak their carbon emissions as early as possible and minimise the level at which emissions peak. Rather, they intend to make use of the time before emissions are due to peak to develop and expand, including in ways that increase emissions.

It appears that Chinese analysts and officials expect a return to the growth pattern that prevailed before mid-2021, when energy consumption and CO2 emissions experienced a sharp turnaround. These expectations likely go a long way in explaining the mismatch between current falling trends

[113] Kihara and Cheung. (2022). Economists cut China's 2022 GDP outlook to 3.2%: Nikkei survey. Nikkei Asia. https://asia.nikkei.com/Economy/Economists-cut-China-s-2022-GDP-outlook-to-3.2-Nikkei-survey. News article.

in coal consumption and emissions, and the policies and investment decisions leading to more coal-based capacity being put in place.

China's long-term target of achieving carbon neutrality before 2060 is aligned with the low end of the Paris Agreement goals (limiting the global temperature rise to 2°C) but not the high end (1.5°C). On the other hand, the level of ambition is at least comparable to that of most developed economies (net zero emissions by 2050), a fact frequently and justifiably pointed out by Chinese policymakers. This points to the importance of raising the bar across the key emitting countries, including but not limited to China.

Appendix: Historical data sources

Historical data was obtained from the China Energy Statistical Yearbook 2021, with data for 2020, from the National Bureau of Statistics, IEA World Energy Balances 2022, which includes officially reported data for China, and the annual and monthly electricity statistics from the China Electricity Council.

For 2022, full-year data was projected based on year-on-year changes in year-to-date data until September. The breakdown of thermal power generation by fuel for 2021 was taken from the BP Statistical Review of the World's Energy and for 2022 from the Ember Global Electricity Review.

Table 20 | Historical data sources

Sector	Indicator	Product	Data source	2022 Data source
All	GHG emissions	CO2	CAT	Projected based on fossil fuel consumption and cement production
All	Energy consumption	Coal	NBS	Monthly apparent consumption data from Wind Information
All	Energy consumption	Oil	NBS	Apparent oil products consumption based on refinery throughput data from National Bureau of Statistics of China (NBS) and net exports from China Customs
All	Energy consumption	Gas	NBS	Monthly apparent consumption data from Wind information
All	Energy consumption	Electricity	CEC	CEC
All	Energy consumption	Total primary energy	NBS	Calculated based on coal, oil and gas consumption and non-fossil power generation
All	Energy consumption	Non-fossil energy	NBS	Non-fossil power generation reported by CEC
Electricity	GHG emissions	CO2	IEA	Changes in thermal power generation from CEC
Electricity	Total installed capacity	Wind	CEC	CEC
Electricity	Total installed capacity	Solar	CEC	CEC

Electricity	Total installed capacity	Nuclear	CEC	CEC
Electricity	Total installed capacity	Coal	CEC	CEC
Electricity	Total installed capacity	Thermal power	CEC	CEC
Electricity	Total installed capacity	Gas	CEC	CEC
Electricity	Total installed capacity	Hydropower	CEC	CEC
Electricity	Power generation	Wind	CEC	CEC
Electricity	Power generation	Solar	CEC	CEC
Electricity	Power generation	Nuclear	CEC	CEC
Electricity	Power generation	Biomass	IEA	Ember Global Electricity Review
Electricity	Power generation	Coal	BP	Ember Global Electricity Review
Electricity	Power generation	Thermal power	CEC	CEC
Electricity	Power generation	Gas	BP	Ember Global Electricity Review
Electricity	Power generation	Hydropower	CEC	CEC
Electricity	Power generation	Non-fossil	CEC	CEC
Electricity	Power generation	Total	CEC	CEC
Industry	Energy consumption	Coal	IEA	–
Industry	Energy consumption	Oil	IEA	–
Industry	Energy consumption	Gas	IEA	–

Industry	Energy consumption	Electricity	CEC	–
Industry	Energy consumption	Total energy consumption	IEA	–
Iron and steel	Energy consumption	Coal	IEA	Consumption of coking coal and consumption of thermal coal by the metallurgical industry from Wind Information
Iron and steel	Energy consumption	Gas	IEA	–
Iron and steel	Energy consumption	Electricity	CEC	CEC
Cement	Production	Cement	NBS	NBS
Transport	Energy consumption	Oil	IEA	Apparent consumption of oil products
Transport	Energy consumption	Electricity	CEC	CEC
Buildings	Energy consumption	Coal	IEA	–
Buildings	Energy consumption	Gas	IEA	–
Buildings	Energy consumption	Electricity	CEC	CEC

Abbreviations

AR6: the Sixth Assessment Report

BECCS: Bioenergy with carbon capture and storage

CAEP-IAE: Institute of Atmospheric Environment, China Academy of Environmental Planning

CA: Climate Analytics

CAT: Climate Action Tracker

CCS: carbon capture and storage

CCUS: carbon capture, utilisation and storage

CEC: China Electricity Council

CEEP-BIT: Center for Energy and Environmental Policy Research, Beijing Institute of Technology

CHP: combined heat and power

CO2: carbon dioxide

CREA: Centre for Research on Energy and Clean Air

EAF: electric arc furnace

EIB: European Investment Bank

EPPEI: China Electric Power Planning and Engineering Institute

ETHZ: ETH Zürich

EU: European Union

EV: electric vehicle

FIT: feed-in tariff

FYP: Five-year-plan of China

GDP: Gross domestic product

GHG: greenhouse gas

Gtce: billion tonnes of coal equivalent

HVAC: heating, ventilation, and air conditioning for buildings

HFCs: hydrofluorocarbons

IAMs: integrated assessment models

ICCSD: Institute of Climate Change and Sustainable Development, Tsinghua University

IEA: International Energy Agency

IMF: International Monetary Fund

IPCC: The Intergovernmental Panel on Climate Change

IIASA: International Institute for Applied Systems Analysis

MEE: Ministry of Ecology and Environment of China

MIIT: Ministry of Industry and Information Technology

MRV: monitoring, reporting, and verification

Mtce: million tonnes of coal equivalent

NBS: National Bureau of Statistics of China

NCEPU: North China Electric Power University

NCGHGs: non-CO2 greenhouse gases

NDC: nationally determined contribution

NDRC: National Development and Reform Commission

NGFS: The Central Banks and Supervisors Network for Greening the Financial System

NEA: National Energy Administration of China

NEV: new energy vehicles

NIESR: the National Institute of Economic and Social Research

OECD: Organisation for Economic Co-operation and Development

PFCs: Perfluorochemicals

PIK: Potsdam Institute for Climate Impact Research

PKU: Peking University

SDS: Sustainable Development Strategy

SENR-RMU: School of Environment and Natural Resources, Renmin University

tce: tonne of coal equivalent

TCEP: the Tracking Clean Energy Progress

UMD: University of Maryland

UN: the United Nations

UNFCCC: United Nations Framework Convention on Climate Change

WEO: IEA World Energy Outlook