China's Climate Transition: Outlook 2023

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Authors
Lauri Myllyvirta, Qi Qin, Chengcheng Qiu, Xinyi Shen

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Contributors
Xunpeng Shi, Muyi Yang, Shurui Wang

Editor
Kathryn Miller, Hannah Ekberg

Translator
Xiaoying You

Designer
Wendi Wu
Photo by Li Yang on Unsplash

Project coordinator
Ella Soesanto, Xinyi Shen

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This report is originally written in English and translated into Chinese subsequently. In case of a discrepancy, the English version prevails.

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Executive summary

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. Currently, progress on clean energy deployment is undermined by continued coal capacity expansion and a rapid growth of energy consumption. To successfully achieve a peaking and rapid decline of emissions, China will need increased efforts on energy efficiency, a successful transformation of the economic growth model, or even higher investments into clean energy.

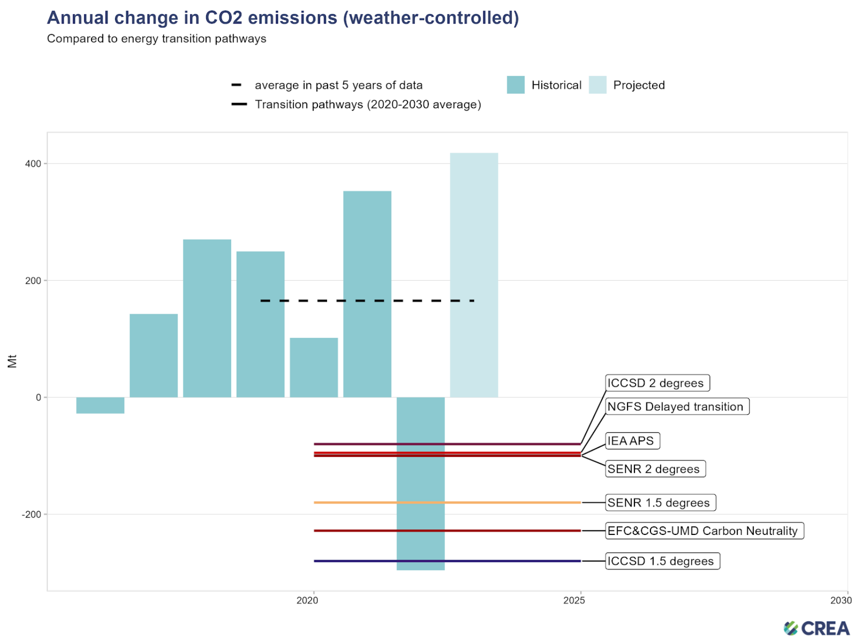
China, the world's largest greenhouse gas emitter and the main source of emissions growth in the past two decades, holds a crucial role in global climate efforts. To enable global emissions to peak fast enough, China needs to not only meet but exceed its current emissions commitments.

In this series of annual reports, we break down China's progress to benchmarks for different sectors and variables that can be compared to available data from China. Each one is based on a suite of climate transition scenarios from Chinese and international institutions.

In this second annual edition of the outlook report in November 2023, we reassess China's progress towards the country's climate commitments and towards emissions pathways aligned with the Paris Agreement goals. Below we have highlighted our key findings.

Emissions rebound

China's carbon dioxide (CO_2) emissions rebounded forcefully in 2023. The emissions increase was not reflective of a structural trend but rather caused by two extraordinary factors: a collapse in hydropower generation caused by the historically low rains that drove up coal-fired power generation. The re-opening of the economy after almost three years of zero-COVID-19 policies caused a rebound, particularly in oil consumption. In addition, energy and materials demand for manufacturing clean energy and clean transportation technologies offset much of the fall in demand from the real estate sector.



Clean energy surge

The most important development of 2023 is that **China's deployment of clean energy generation has reached the scale projected in 1.5-degree scenarios, a remarkable achievement** that was predicted in our Outlook last year. Maintaining annual additions of clean electricity production capacity at the 2023 level or increasing them further will enable China to peak and decline its CO_2 emissions in the coming years.

Production and sales of electric vehicles are also growing in line with 1.5-degree scenarios. Electrification of energy use in the industrial and building sectors is similarly on track. Electrification will enable emissions reductions.

Progress in reforming the growth model

China's clampdown on financial risks and speculation in the real estate sector has put an end to growth in steel and cement output, which were the key drivers of China's emissions growth for most of the past two decades. This is another area where trends in the country have aligned with climate transition scenarios.

Clean technology manufacturing boom

China's clean technology ('cleantech') manufacturing sector is undergoing rapid expansion to deliver not just an increase in demand in China but also anticipated exponential growth in demand from the rest of the world.

This has meant an unprecedented boom in investment, making cleantech a major economic driver, absorbing an estimated 10% of all investment in 2023 and the underlying reason for the net growth in investment.

Experts grew more optimistic

To gauge the views and expectations of practitioners in the field, Outlook 2023 surveyed an expanded pool of 89 experts representing diverse specialisations in the field of climate and energy. The experts in this year's survey are more optimistic than those interviewed last year, with 21% of experts believing China's CO_2 will peak before 2025, up from 15% in 2022's survey. The percentage of experts expecting China's CO_2 emissions to rise more than 15% above their 2020 before peaking fell from 69% to 56%.

Energy consumption growth and investments in coal-based capacity remain off track

Overall, however, China isn't yet on track to start reducing emissions at the rates required in climate transition pathways. The growth rate of total energy consumption is much faster than in the transition pathways, with consumption in industry, buildings and transportation all running ahead. Economic policies during the zero-COVID-19 period increased activity in the energy intensive parts of the economy, undermining reductions in energy intensity.

To tackle this issue, China will need increased efforts on energy efficiency, a successful transformation of the economic growth model, or even higher investments into clean energy than projected in the transition scenarios.

Investments in coal-based power capacity have accelerated. Since the start of 2022, Chinese authorities have granted permits to 152 gigawatts (GW) and started construction on 92 GW of new coal power capacity. Even if we assume existing coal capacity will be retired at an accelerated pace, China's coal-fired power capacity is still on track to increase 23% by 2030 from existing levels. It is entirely possible for emissions to fall while capacity increases, but the buildup of new coal power plants makes emissions peaking economically and politically more challenging to implement.

Investments in coal-based industrial capacity, particularly iron and steel capacity, have continued. With demand declining, the steel and building materials sectors are expected to have peaked their emissions. To pave the way for carbon neutrality, policies restricting new carbon-intensive capacity and incentives for low-carbon technology are needed.

As a result, **China is badly off track to two commitments it has made under the Paris Agreement: 'strictly controlling' new coal power projects during the 2021 to 2025 period, and reducing energy intensity (energy consumption per unit of GDP) by 13.5% from 2020 to 2025.** The progress on reducing CO_2 emissions intensity is also off track, but the expected surge in clean electricity generation in the next two years is highly likely to enable China to meet the target.

Halting progress on policies

In terms of policymaking, the 2023 focus was on enabling policies, after the policy framework was completed last year. This includes the monitoring, reporting and verification of emissions, development of market-based instruments supporting emission reductions, as well as power market reform. Steps were taken to promote green electricity trading and use the emissions trading system to promote emission reductions through certified emissions reductions (CCER). Coal power capacity payment mechanism was established, incentivizing an increase in coal power capacity and deferment of retirements.

Policies promoting the deployment of solar and wind power proved highly effective, as did industrial policies stimulating new capacity in the solar, battery, electric vehicle and other cleantech industries.

Emissions monitoring and reporting obligations were strengthened for industrial sectors, encouraged in part by the European Union (EU) carbon tariffs on carbon-intensive imports, which create an incentive for improved emissions data.

There was unclear or no progress on several other areas: no timeline was specified for controlling total emissions or for the expansion of the carbon market. For power market reform, regulatory work continued but no new milestones were specified beyond the long-held aim of creating a unified national market by 2030.

While China has recently unveiled its national methane emission reduction action plan and has declared intentions to "seek to establish a monitoring, reporting and verification (MRV) system for methane", the action plan stops short of setting quantifiable targets for methane emission reduction. Progress in other areas of non-CO_2 greenhouse gas emissions remains stalled. There has been no advancement in improving the MRV for the broader spectrum of non-CO_2 emissions, nor in the public reporting of energy use and emissions at a granular level.

1 Introduction

In 2023, clean energy and clean transportation technologies became a major economic driver in China. Capital expenditure on manufacturing and supply chains for solar power, batteries and electric vehicles drove growth in overall investment. Investment in clean power generation and high-speed rail reported some of the highest growth rates among all investment categories.

The clean energy and clean technology expansion has supported aggregate demand and industrial activity despite the weakness in real estate, contributing to the economic recovery after COVID-19 controls were lifted in late 2022. The expansion has also contributed to increases in energy consumption and carbon dioxide (CO_2) emissions during the year, but this part of the emissions increase will pay back manifold in the coming years — both as a reduction in China's own emissions and as reductions in those countries where China exports clean energy equipment, such as solar panels, batteries and electric vehicles.

China's clean energy technology exports have surged, enabling the energy transition in the rest of the world but also causing increasing concerns about excessive reliance on China.

This year has also seen a rebound in oil and electricity consumption after the removal of COVID-19 controls, along with historically weak rains and hydropower generation, which meant that the clean energy expansion didn't result in an immediate fall in emissions. China's greenhouse gas (GHG) emissions rebounded to the record levels of 2021 in the first eight months of 2023, after falling in 2022. However, there are strong reasons to believe that the latest jump in emissions will be temporary because the impressive additions of clean energy and an inevitable recovery in hydropower generation will push emissions down in late 2023 and in 2024.

Extreme weather events were observed in 2023. The dry winter in Northern China contributed to sandstorms that were also felt in Beijing and other large cities in the north. Torrential rains in August heavily affected rice farming, raising concerns once again about the impact of climate change on China's food security.

China's nationwide temperature record was broken in July, as a part of another historic heatwave. Without global warming, the 2023 heatwave would have been a once-in-250-years event, but global warming means that an equally severe heatwave is now expected to occur every five years[1].

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 European Union (EU) and North America[2]. 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.

The country's emissions have more than quadrupled over the course of the past two decades, making

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[1] World Weather Attribution. (July 2023). https://www.worldweatherattribution.org/extreme-heat-in-north-america-europe-and-china-in-july-2023-made-much-more-likely-by-climate-change/. Scientific blog.

[2] 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.

China the primary driver of global emissions growth over the period. Emissions growth in 2000–2008 was predominantly due to an export-driven industrial and investment boom. After 2009, emissions growth was mainly driven by real estate, infrastructure and industrial expansion. China's high emissions relative to 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. Now, massive clean energy expansion and the prospect of an economic transformation away from heavy industry-driven growth open up the possibility of reversing the factors behind China's high emissions.

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, increased risk of intense flooding, and increased risk of other extreme weather events such as cyclones. China's coastline includes low-lying, very densely 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 average annual temperatures, or extended periods of extreme heat, also facilitates the spread of vector-borne infectious diseases such as 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[3].

Agriculture is affected among other sectors through increased droughts, floods and heatwaves. 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[4].

Food security is a key priority for China, therefore 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 the fifth edition of the European Investment Bank Climate Survey, 91% of respondents said that climate change has an impact on their everyday lives, a higher percentage than in the EU (80%) or the United States (67%)[5].

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[3] China Meteorological Administration. (2021). Blue Book on Climate Change in China 2021. http://www.cma.gov.cn/2011xwzx/2011xqxxw/2011xqxyw/202108/t20210805_582404.html. Official document.
[4] 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. Scientific publication.
[5] European Investment Bank (EIB). (2022). EIB Climate Survey.

However, there is also strong opposition to climate action and reduction in fossil fuel use in China, including from 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 CO_2, and there is no sign of investment in coal-based capacity being scaled back. A complete shift of new investments into clean capacity is needed to put China on track to peak CO_2 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 CO_2 emissions peak before 2030 and carbon neutrality before 2060 ("dual carbon goals")[6], as well as a series of policies to support these goals.

China's policies and commitments

Chinese President Xi Jinping reaffirmed China's determination to realise the 2030/2060 goals in July 2023, stating the commitment is steadfast. He also called for an acceleration of the green and low-carbon transformation of China's development model and accelerating the construction of a new electricity system[7].

After announcing the targets in 2020, the Communist Party and the government has put in place a policy framework for carbon peak and carbon neutrality, known as '1+N'.

"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[8]. China aims to gradually increase the share of non-fossil energy consumption to around 20% by 2025, around 25% by 2030, and more than 80% 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[9].

China officially added the dual carbon goals to its nationally determined contributions (NDCs) targets on 28 October 2021[10], just before COP26 in Glasgow in 2021.

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.

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https://www.eib.org/en/surveys/climate-survey/5th-climate-survey/index.htm. Research report.

[6] 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.

[7] Xinhua News. (July 2023). Xi Jinping emphasised at the National Conference on Ecological and Environmental Protection. https://www.gov.cn/yaowen/liebiao/202307/content_6892793.htm. News report.

[8] 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.

[9] State Council. (2021). Action Plan for Carbon Dioxide Peaking. https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html. Policy.

[10] NDC Registry China (2021) China first NDC (Updated submission) https://unfccc.int/NDCREG. Official document.

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:

- 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 emissions outlook. Chapter 2 presents an overview of the 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.

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

2 Understanding China's greenhouse gas emissions

2.1 The meteoric rise of emissions

China is the world's largest greenhouse gas emitter, and the second-largest historical emitter, after the United States. In 2021, it produced 27% of global greenhouse gas emissions[12], 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 73% of the increase in global CO_2 emissions from 2010 to 2022 and as of the end of 2022, was 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[13]. 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.

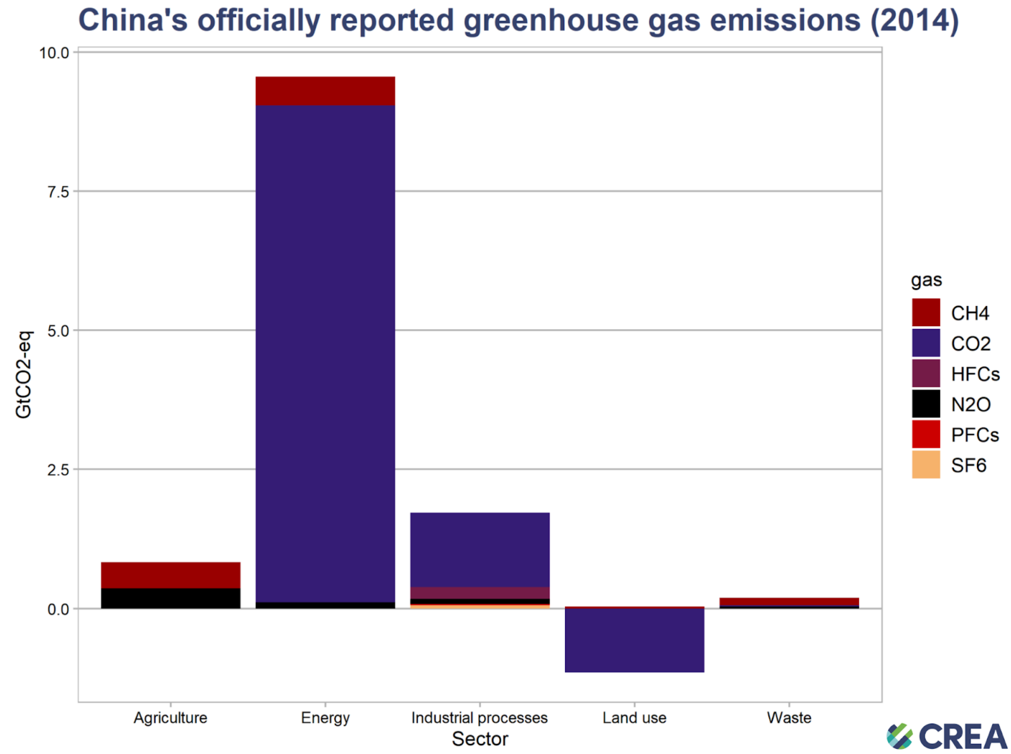

Figure 1 | China's reported greenhouse gas emissions in 2014, the most recent year for which official data are available

[12] Alfredo Rivera, Shweta Movalia, Hannah Pitt, and Kate Larsen. Rhodium Group. (Dec, 2022). https://rhg.com/research/global-greenhouse-gas-emissions-2021/. Research note.
[13] Energy Institute. 2023 Statistical Review of World Energy.(2023). https://www.energyinst.org/statistical-review. Research report.

China has committed to CO_2 emissions and clean energy targets since the Copenhagen climate summit in December 2009. Actions to achieve the targets have made the country the world leader in deploying renewable energy and nuclear power, but have not been sufficient to peak CO_2 emissions from fossil energy consumption.

China committed to peaking CO_2 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 CO_2 emissions "before 2030"[14].

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 World Trade Organization (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. 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 President 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 CO_2 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 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 supply-side stimulus measures.

As a result, China's emissions surged in late 2020 and early 2021, due to economic recovery policies aimed at stimulating construction and industrial output, including export industries. In 2020, the Global Carbon Project attributes two thirds of the increase in China's emissions to an increase in emissions embedded in trade[15]. COVID-19-related stimulus policies in the rest of the world boosted demand for China's exports, while the country's own policies boosted production while doing little to create domestic demand.

The surge in industrial output reversed in mid-2021, due to economic policies aimed at tamping down real estate speculation and low-value construction projects, strict COVID-19 control policies, and clean

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[14] 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.
[15] Friedlingstein, P. et al. (2022): Global Carbon Budget 2022. *Earth System Science Data*, 14, 4811–4900, 2022, https://doi.org/10.5194/essd-14-4811-2022.

energy expansion. A record heatwave and drought caused emissions to increase again in late 2022 and in 2023, as hydropower generation plummeted and was substituted by coal in the short term. In addition, oil consumption rebounded after the removal of zero-COVID-19 policies.

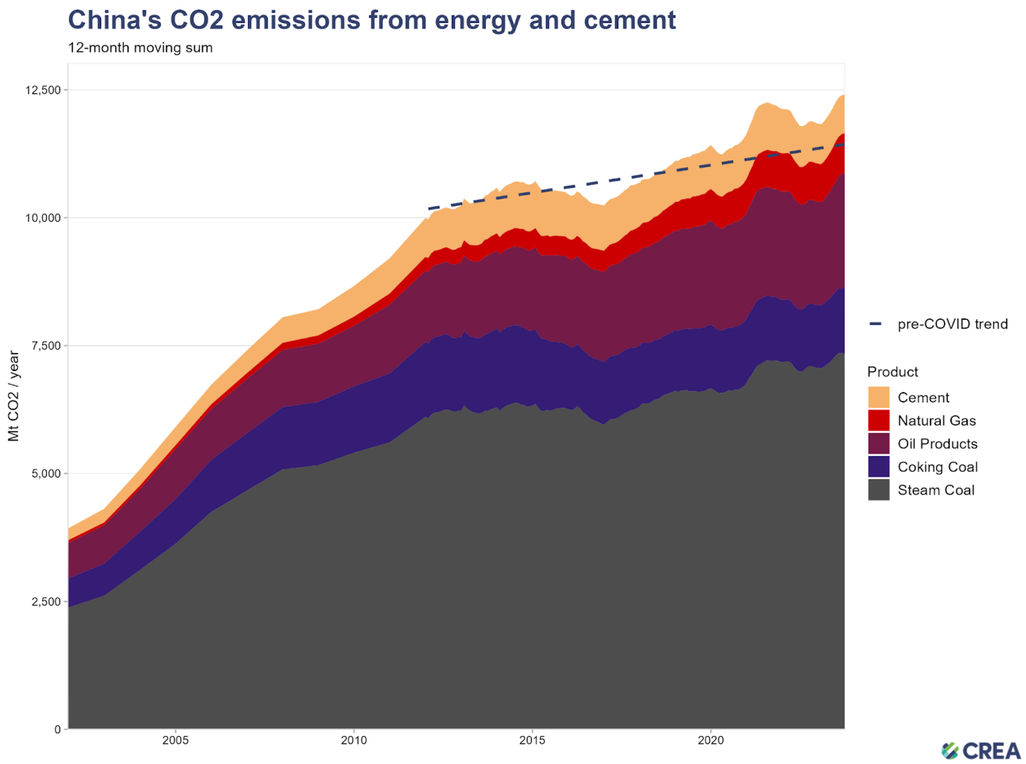

Figure 2 | China's CO_2 emissions from energy and cement, 2000 – September 2023

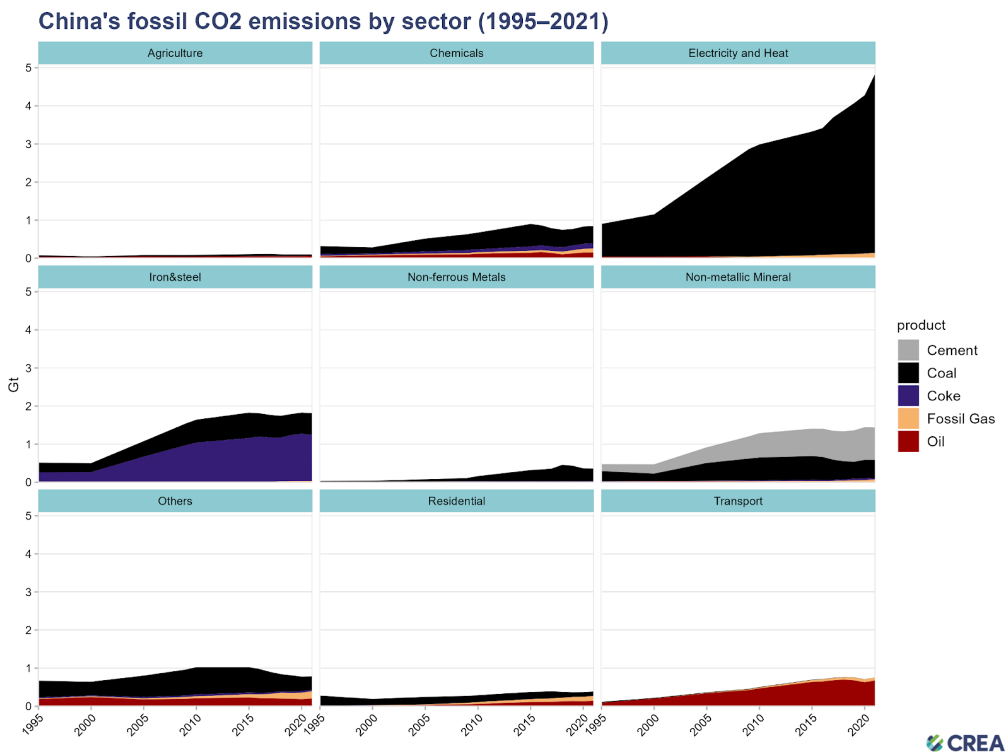

Figure 3 | China's fossil CO_2 emissions by sector (1995–2021)

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.

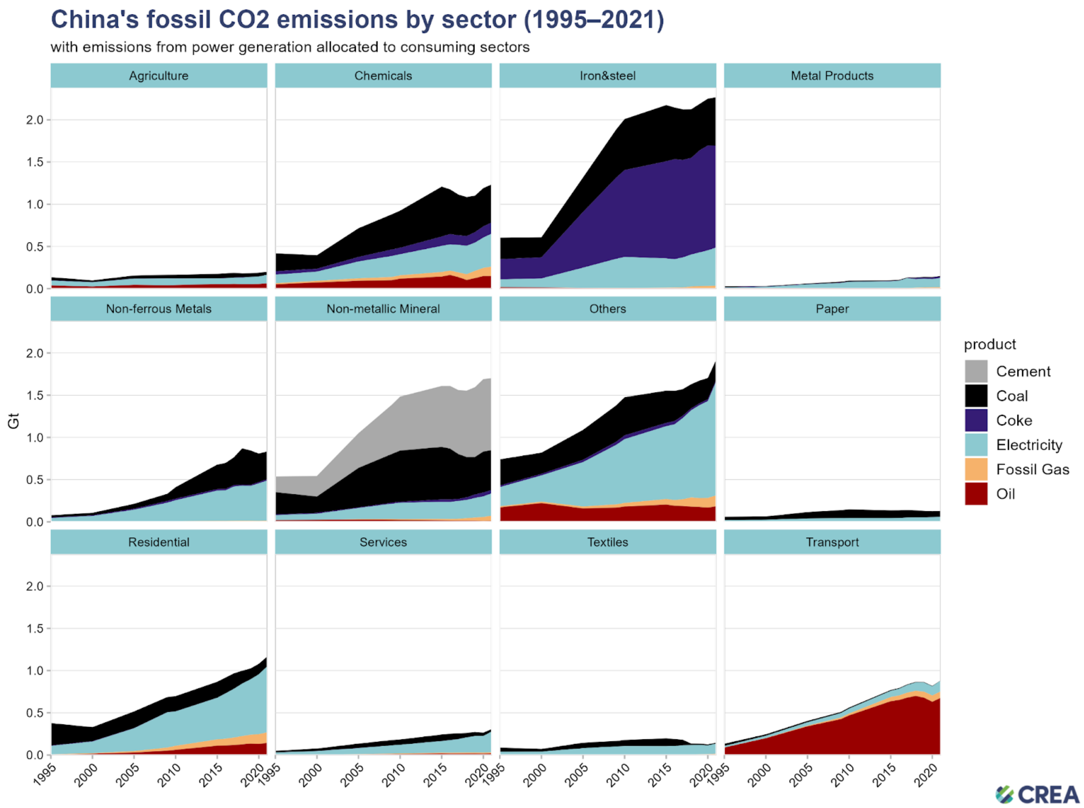

Figure 4 | China's fossil CO_2 emissions by sector; with emissions from power generation allocated to consuming sectors

Satellite-based estimates suggest that China's methane emissions were increasing by approximately 1.5% per year from 2010–2017, with increases across all emitting sectors (coal, oil and gas, rice and livestock farming as well as landfills and wastewater)[16]. However, emission inventories based on activity data (e.g. coal production) suggest that emissions growth is likely to have slowed down or halted from 2012–2018 when coal production growth was slow or negative. There is significant uncertainty about emissions levels and trends.[17]

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.

[16] 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.

[17] 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.

When emissions are allocated based on where goods are consumed, rather than based on where they are produced, China's emissions are approximately 10% lower. In other words, China's large export industry does contribute to its high emissions, but less than is generally perceived.

China's consumption-based emissions per capita were equal with the EU in 2020.

China's consumption-based emissions are high relative to the level of 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 to China's emissions growth since 2008.

A major focus of China's climate targets has been reducing the CO_2 intensity of the economy, i.e. CO_2 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-Organisation for Economic Co-operation and Development (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 CO_2-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 CO_2 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.

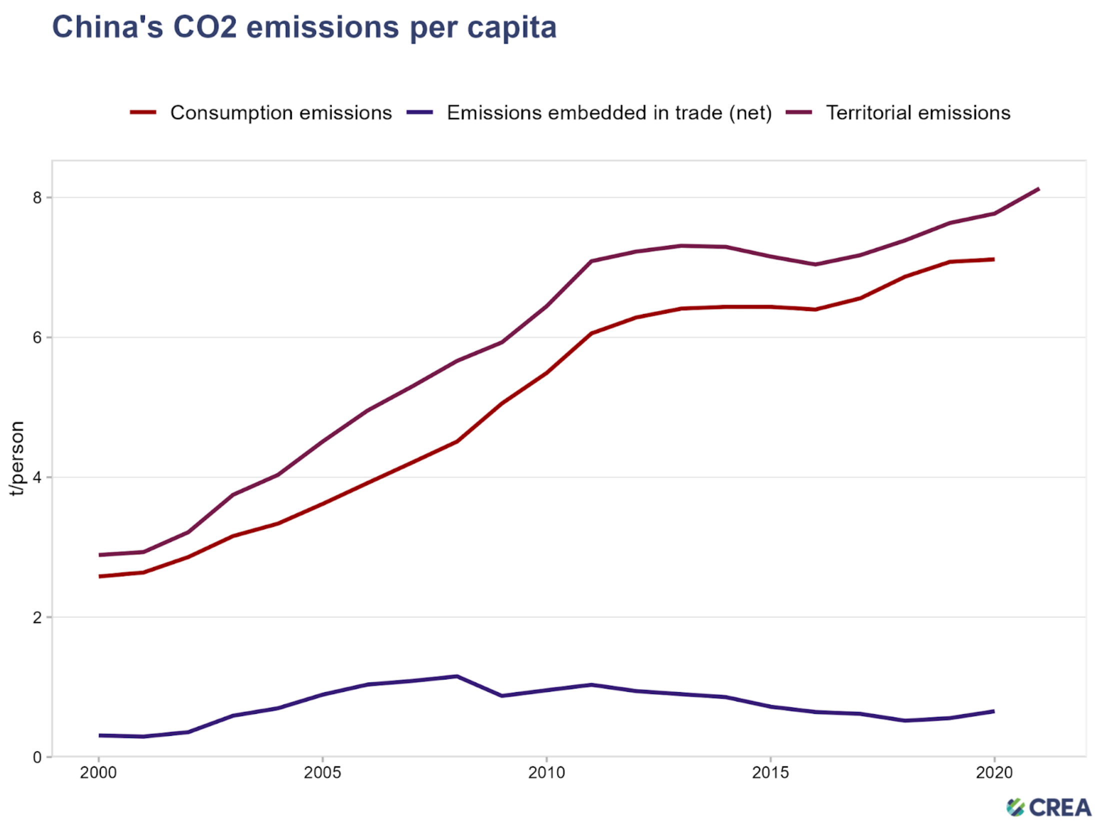

Figure 5 | China's CO_2 emissions per capita

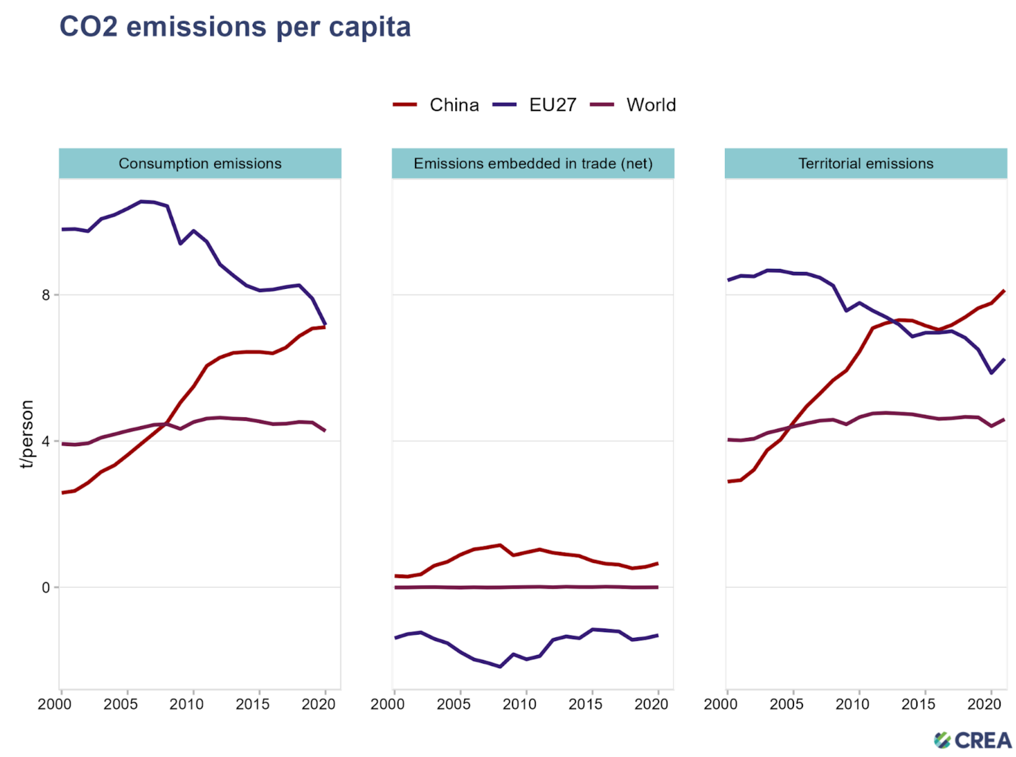

Figure 6 | Comparison of China's CO_2 emissions per capita in relation to global and EU27 emissions

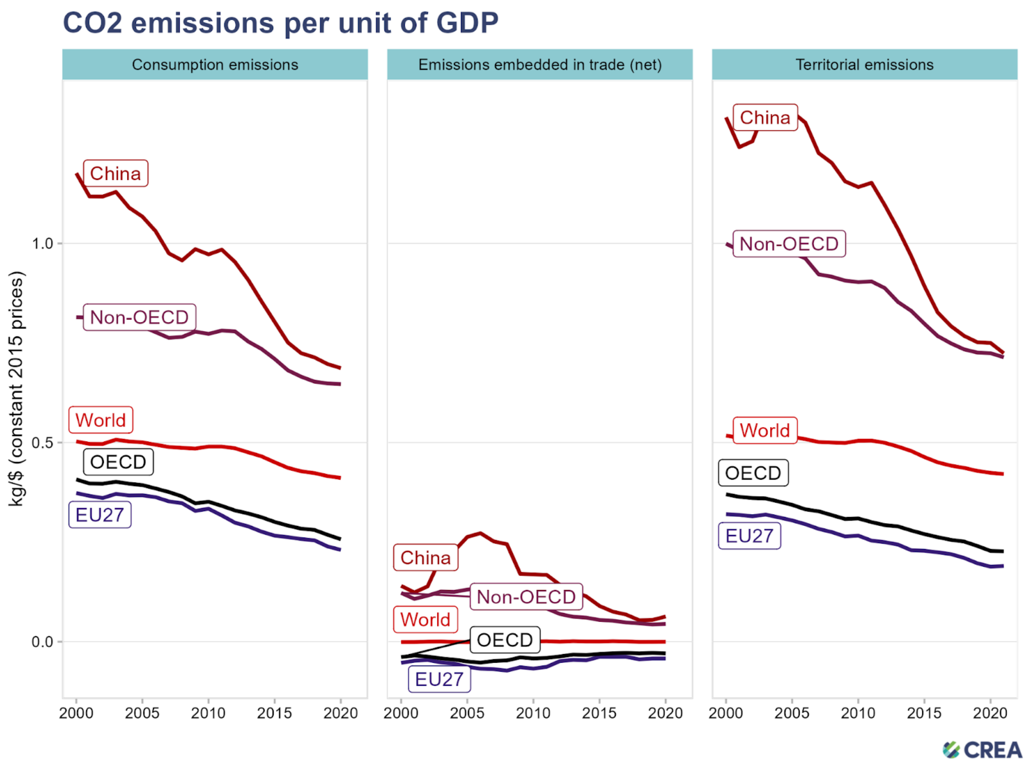

Figure 7 | Comparison of China's CO_2 emissions per unit of Gross domestic product (GDP) in relation to other regions

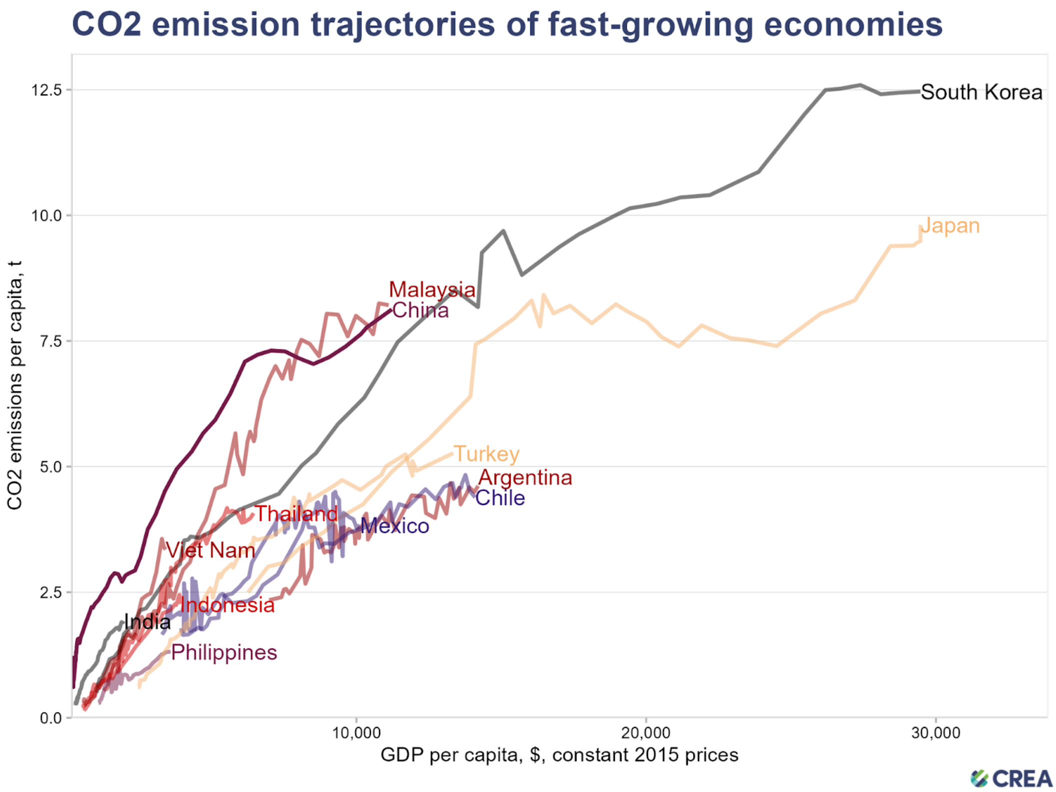

Figure 8 | CO_2 emission trajectories of fast-growing economies

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 2°C requires addressing the world's energy systems, industry, agriculture and land use, among other things. The most effective and cost-efficient ways to explore widespread systems change 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); North China Electric Power University (NCEPU) and Peking University (PKU); and Energy Foundation China (EFC) and Center for Global Sustainability at the University of Maryland (CGS-UMD).

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 similarities. In all scenarios, 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 emissions 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 2020–2023, given the current World Bank projection for 2023 of 5.6% (and therefore the average for 2020-2023 would be 4.8%).[18] Global pathways, in terms of IEA, NGFS and CAT have updated climate transition pathways adjusted for economic projections to the latest historical year of publication. Recently, however, China's growth forecasts have been revised down due to the sluggish post-reopening recovery. For example, the IMF projects 5.0% for 2023, 4.2% for 2024, and less than 4.0% for 2027–2028, further lowering the average projected GDP growth rate.[19]

The scenarios differ in terms of their projections of total energy demand growth, and in 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 CO_2 emissions. That viewpoint is 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. Considering that China had accelerated coal power approvals between 2021 and 2022, the IEA increased the share of coal power generation to adapt to the new reality and projected that China will not fully quit coal power by 2050 as was projected in 2021's edition. The ICCSD scenarios factor in structural change in the economy and energy efficiency potential, resulting in low projections for total energy demand. The EFC&CGS-UMD scenarios based on six different models produced results over a wide range, covering the results projected by the other scenarios. Among them, the AIM-China and MESSAGEix−China models weighted heavily on nuclear power as the dominating energy for China's power generation, followed by solar and wind, which are the dominating energy in the other models.

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 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 CO_2, 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 CO_2, 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 emissions reduction potential vary widely. It's evident that a target covering all greenhouse gases would require deeper reductions in CO_2 emissions because it won't be plausible to reduce the emissions of the other gases to zero and there are no foreseeable

[18] The World Bank. (Jun 2023). Priority Reforms Key for Sustaining Growth and Achieving China's long-term goals - World Bank Report. https://www.worldbank.org/en/news/press-release/2023/06/14/priority-reforms-key-for-sustaining-growth-and-achieving-china-s-long-term-goals-world-bank-report. Research report.
[19] International Monetary Fund. (Oct 2023). People's Republic of China: Country Data. https://www.imf.org/en/Countries/CHN. Database.

solutions to achieve negative emissions for the other gases whose concentrations in the atmosphere are far lower than those of CO_2 (see section 4.2 on non-CO_2 greenhouse gases).

3.2 Global pathways

Significant research and modelling is being conducted by international organisations and universities to develop pathways under different scenarios to achieve carbon net zero emissions. Work by NGFS, CAT, and IEA has been selected for this report. The 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.

Table 1 | Overview of the global scenarios included

Institute	Scenario	Source
IEA	Announced Pledges (APS)	World Energy Outlook 2022 https://www.iea.org/reports/world-energy-outlook-2022
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/; https://climateactiontracker.org/publications/paris-aligned-benchmarks-power-sector/
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 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.

The latest set of NGFS scenarios was published in September 2022, entailing updated scenarios adjusted for new GDP projections, new policy pledges and targets, and new model versions on a number of techno-economic parameters[20].

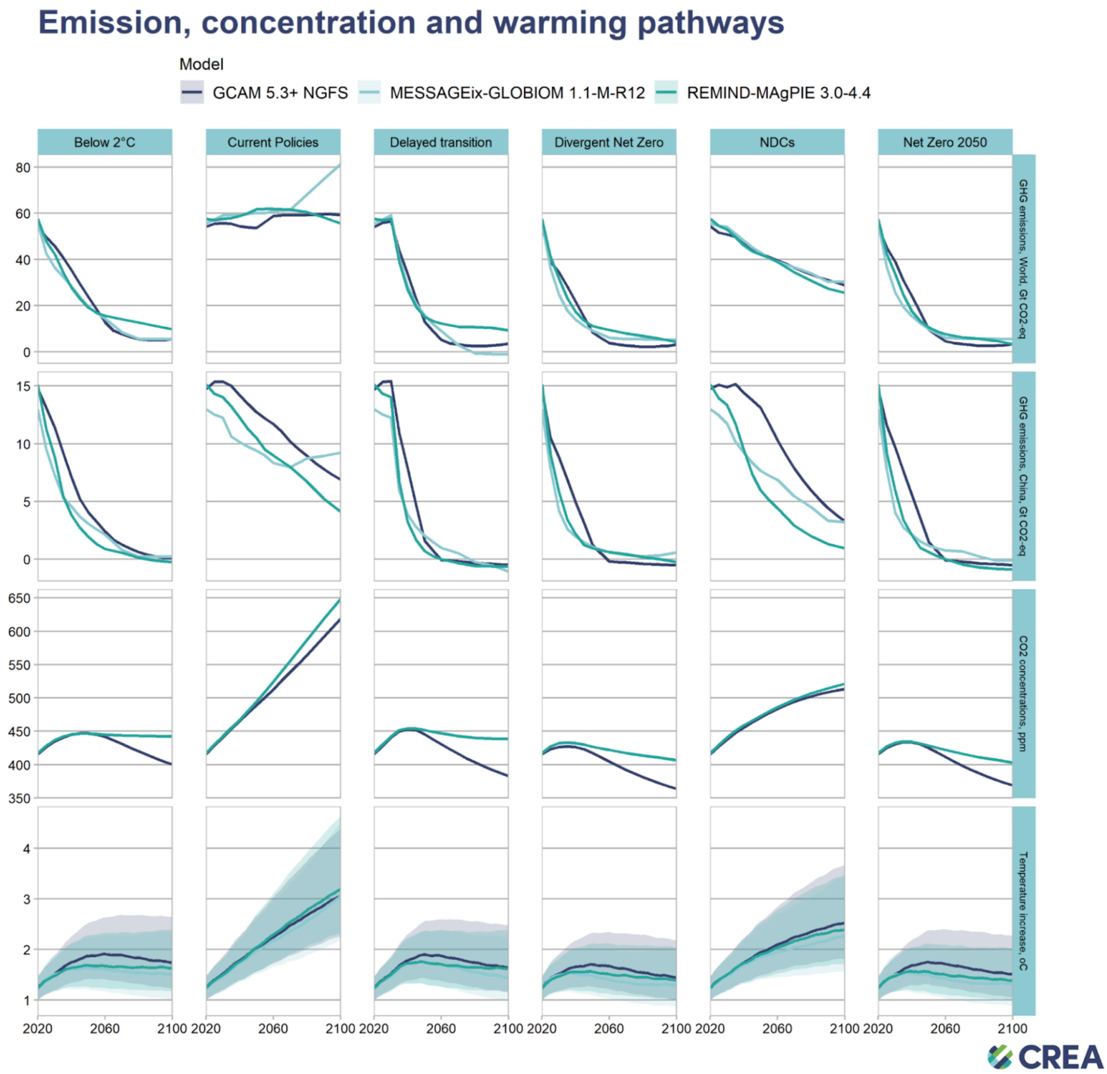

Figure 9 | Emission, concentration, and warming pathways in China

[20] NGFS Climate Scenarios Database. (Sep 2022). Technical Documentation V3.1. https://www.ngfs.net/sites/default/files/media/2022/11/21/technical_documentation_ngfs_scenarios_phase_3.pdf. Database.

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*[21], 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*[22], 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. Six countries and the EU were selected for further analysis: Brazil, China, India, Indonesia, South Africa, and the US.

In September 2023, CAT published *Clean electricity within a generation: Paris-aligned benchmarks for the power sector*[23], in which it provides benchmarks compatible with 1.5°C for the power sector both at the global level and for 16 selected countries. China and the other 15 countries were selected based on their share of global power generation, scale of power sector emissions, geopolitical importance, and geographic and economic diversity. CAT provides benchmarks for the future shares of coal, fossil gas and renewables, and emission intensity in power generation. The benchmarks were derived by downscaling the latest global pathways assessed by the IPCC, and an in-depth literature review of national studies on power systems modelling.

3.2.3 International Energy Agency (IEA)

The International Energy Agency (IEA) assessment has a focus on energy but also covers industry, transport, and building sectors. The power sector is the single largest source of energy-related CO_2 emissions. Decarbonising the energy system is important to achieve the goal of limiting the global annual average temperature increase to 1.5°C. At the same time, decarbonising other sectors through electrification relies on electricity from carbon-free power generation sources. The 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[24]. We use the *WEO Announced Pledges Scenario* (APS) as the benchmark for China because the *net zero* scenario does not include disaggregated projections for China. APS assumes that all aspirational targets announced by governments are met on time and in full, and thus is in line with China's long-term carbon neutrality goal.

Compared with WEO 2021, the projection of a bigger emissions reduction is seen in the APS of WEO 2022, reflecting updated NDCs and announced net zero emissions pledges that have been made over the past year.

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[21] IPCC. (2018). Global Warming of 1.5°C https://www.ipcc.ch/sr15. Special scientific report.
[22] Climate Action Tracker. (2020). Paris Agreement Compatible Sectoral Benchmarks. https://climateactiontracker.org/documents/753/CAT_2020-07-10_ParisAgreementBenchmarks_FullReport.pdf Analytical report.
[23] Climate Action Tracker. (2023). Clean electricity within a generation: Paris-aligned benchmarks for the power sector. https://climateactiontracker.org/documents/1159/CAT_2023-09-19_Briefing_ParisBenchmarks_PowerSector.pdf . Research report.
[24] IEA. (2021). World Energy Outlook. https://www.iea.org/topics/world-energy-outlook. Research report.

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 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 to meet 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 is believed to have 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 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 CO_2 Emissions in China's Power Sector https://mp.weixin.qq.com/s/AUXybE5neN-jxCah7APZoA

Institute	Scenario	Source
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 CO_2 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
Energy Foundation China (EFC) and Center for Global Sustainability at the University of Maryland (CGS-UMD)	Based on updated NDC	Synthesis Report 2022 on China's Carbon Neutrality: Electrification in China's Carbon Neutrality Pathways https://www.efchina.org/Reports-en/report-snp-20221104-en?set_language=en

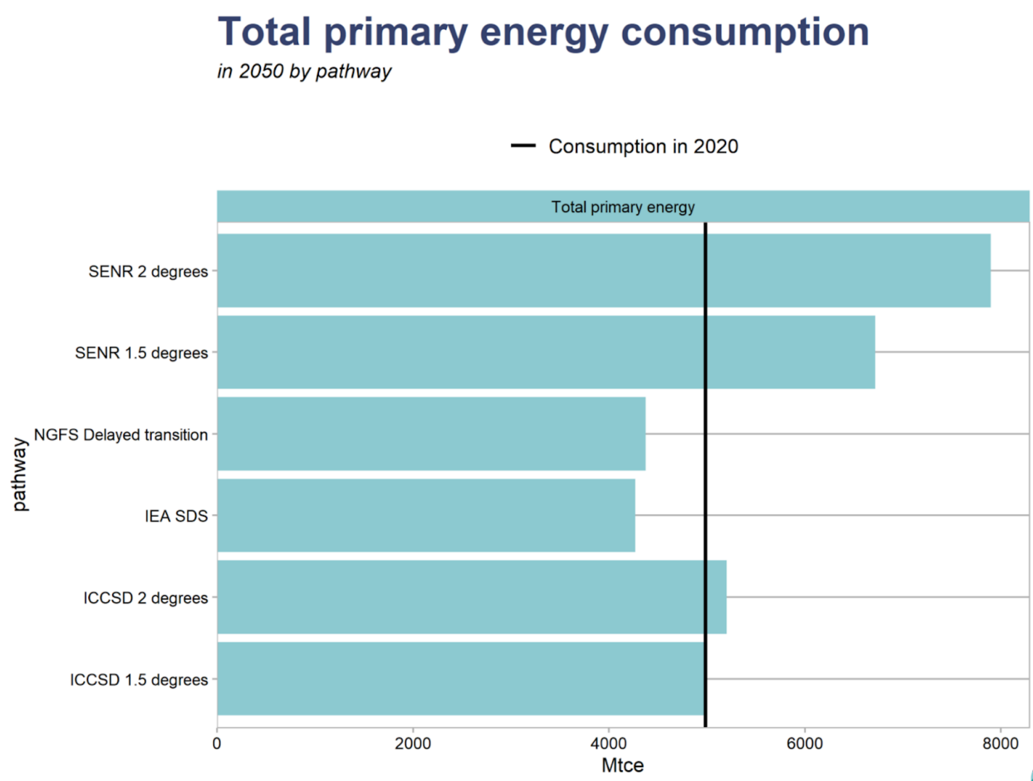

Figure 10 | Total primary energy consumption in China in 2050 by pathway

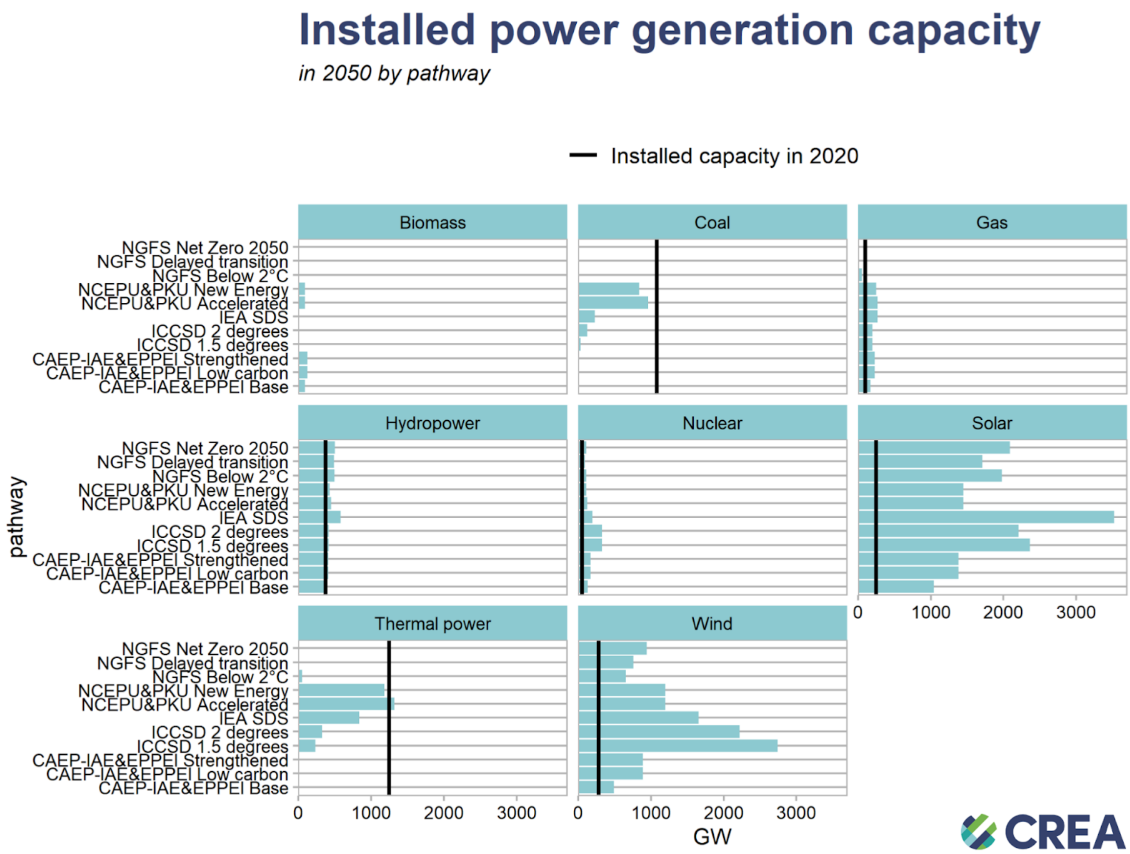

Figure 11 | Installed power generation capacity in China in 2050 by pathway

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[25].

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 CO_2 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 annual average temperature rise to 1.5°C and achieving net zero CO_2 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[26], which assumes that CO_2 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 emissions 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 China's long-term CO_2 emissions reduction requirements, sectoral contributions, and key emission

[25] 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.

[26] 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*,9, 100134. https://www.sciencedirect.com/science/article/pii/S2666498421000582. Scientific article.

reduction measures under 1.5°C and 2°C scenarios[27].

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 emissions reduction measures based on the existing NDC target, strive to achieve peak carbon emissions as soon as possible, and 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 peak carbon before 2025. With reference to the 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[28], as follows.

Baseline scenario: The power structure will remain the same as during the 13th Five-Year Plan (FYP) period (2016–2020) 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 consumption for power generation will fall by

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[27] 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.
[28] Wang, L. et al. (2022). Pathway of carbon emission peak in China's electric power industry. *Research of Environmental Sciences*, 35, 329–338. doi: 10.13198/j.issn.1001-6929.2021.11.24 . Research article.

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 CO_2 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[29].

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.

3.3.5 Energy Foundation China (EFC) and Center for Global Sustainability at the University of Maryland (CGS-UMD)

Led by Energy Foundation China, and coordinated by the Center for Global Sustainability at the University of Maryland, United States, with contributions from 21 expert authors from nine research organisations, the multi-team research conducted deep dives into decarbonizing the electricity sector to achieve China's carbon neutrality target. In the *Synthesis Report 2022 on China's Carbon Neutrality: Electrification in China's Carbon Neutrality Pathways*[30], the role of electrification and associated electricity system transformation in achieving China's '30/60' goals were identified, based on synthesised analyses on a number of national and global models, including China DREAM, China

[29] Yuan, J. et al. (2021) Pathways and policy for peaking CO_2 emissions in China's power sector. https://mp.weixin.qq.com/s/AUXybE5neN-jxCah7APZoA. Research article [in Mandarin].
[30] Energy Foundation China. (Nov 2022). Synthesis Report 2022 on China's Carbon Neutrality: Electrification in China's Carbon Neutrality Pathways. https://www.efchina.org/Reports-en/report-snp-20221104-en Research report.

TIMES, GCAM-China, MESSAGEix-China, AIM-China, PECE_LIU_2021, and PECE V2.0. Two scenarios, ‘Updated Nationally Determined Contribution (NDC) To Carbon Neutrality’ and ‘Original NDC to Carbon Neutrality’ were explored in this report. We use the average of the results from the seven models as our benchmark.

Under the Updated Nationally Determined Contribution (NDC) to Carbon Neutrality scenario that we included in our report, net zero greenhouse gas emissions will be achieved by 2060, and China’s emissions will peak before 2030 in line with the updated NDC submitted by China in October 2021. It differs from the original NDC scenario in that the original NDC scenario assumes China’s CO_2 emissions do not peak earlier than 2030.

4 Measuring and benchmarking China's progress

To base China's entire economy on carbon neutral emissions will require progress on numerous fronts: from clean electricity production to electrification, from moderating energy demand growth to shifts in production processes, and transport modes. The transition pathways allow us to translate the massive undertaking 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 the 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 are 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 CO_2 emissions

2023 highlights

- The central government has released the *Opinions on Advancing the Transition from Dual Control of Energy Consumption to Dual Control of Carbon Emissions.*
- The development of the Carbon Emission MRV (Monitoring, Reporting, and Verification) and Accounting System is fundamental to the implementation of Dual Control of Carbon Emissions.
- *The Ecosystem Carbon Sink Enhancement Plan* was launched to assess China's ecosystem carbon storage baseline, identify potential for increased carbon sink, and establish an internationally-aligned carbon sink measurement system.
- Carbon trading is expected to expand beyond the power sector to include other industries and CCER is expected to be re-launched by the end of 2023.
- Strong support for low carbon and zero carbon technologies.

To be consistent with the 1.5°C degree target, even assuming very aggressive emissions reductions after 2030, China's CO_2 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[31], which assumes that CO_2 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

[31] 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* 9, 100134. https://www.sciencedirect.com/science/article/pii/S2666498421000582. Scientific article.

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 CO_2 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, 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, CO_2 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 CO_2 emissions to be achieved by 2050.

Table 3 | CO_2 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
CO_2 emissions, billion tCO_2	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 CO_2 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

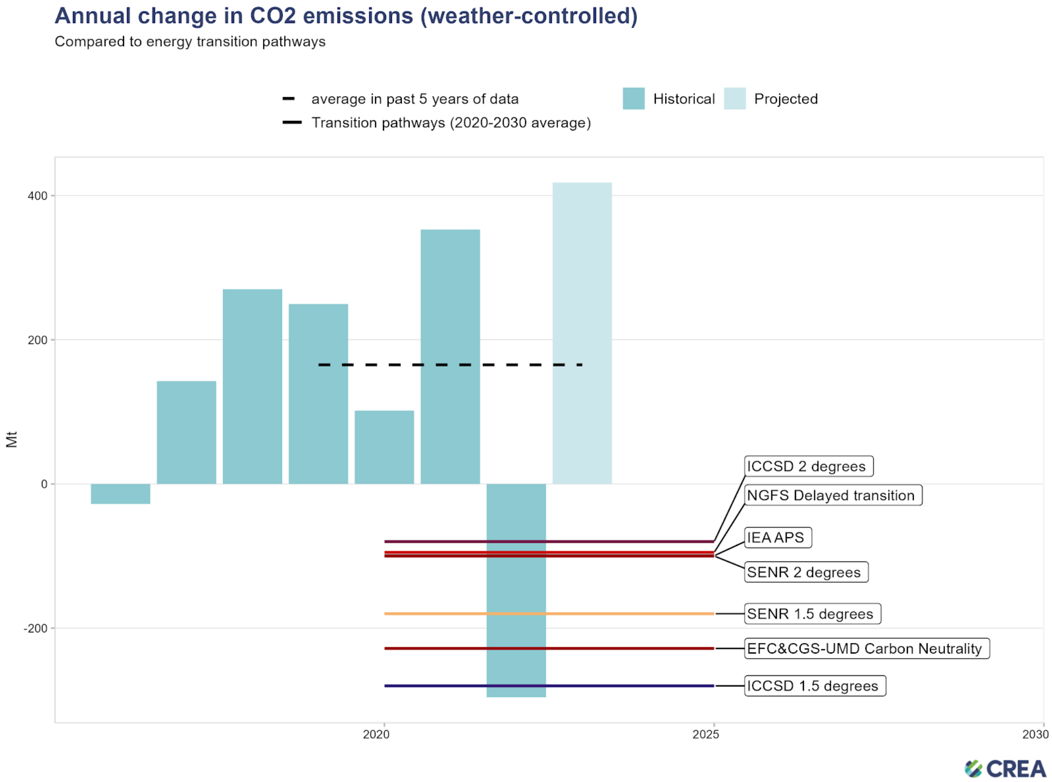

Figure 12 | Annual change in CO_2 emissions compared to energy transition pathways

China's CO_2 emissions grew every year from 2016 to 2021, albeit at a much slower pace than CO_2 emissions up to 2013. The increase in CO_2 emissions reversed in the summer of 2021, resulting in a fall in CO_2 emissions in 2022, although there is still uncertainty about the magnitude of the fall. There was another upswing in emissions in 2023 due to a drop in hydropower generation due to droughts and a rebound in emissions following COVID-19. All transition pathways require emissions to fall from 2020 to 2030, implying a peak well before 2030 and emissions reductions thereafter. In all transition pathways, emissions reductions need to accelerate significantly from the rates projected for 2020–2030 immediately after 2030 to meet their temperature targets.

Our projected CO_2 emissions growth rate for 2022 to 2023 is near-zero, making progress towards the annual reductions required in the Paris Agreement-aligned pathways.

4.1.2 Policies in place

The increase in CO_2 emissions is currently constrained by the CO_2 intensity and non-fossil energy targets for 2025 and 2030, the energy intensity target for 2025 and the commitment to peak CO_2 emissions before 2030. The targets, however, leave room for a substantial increase in CO_2 emissions from 2020 to 2030, of up to 15%, assuming a 5% average GDP growth rate in 2021–2030. 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. The absence of targets make 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.

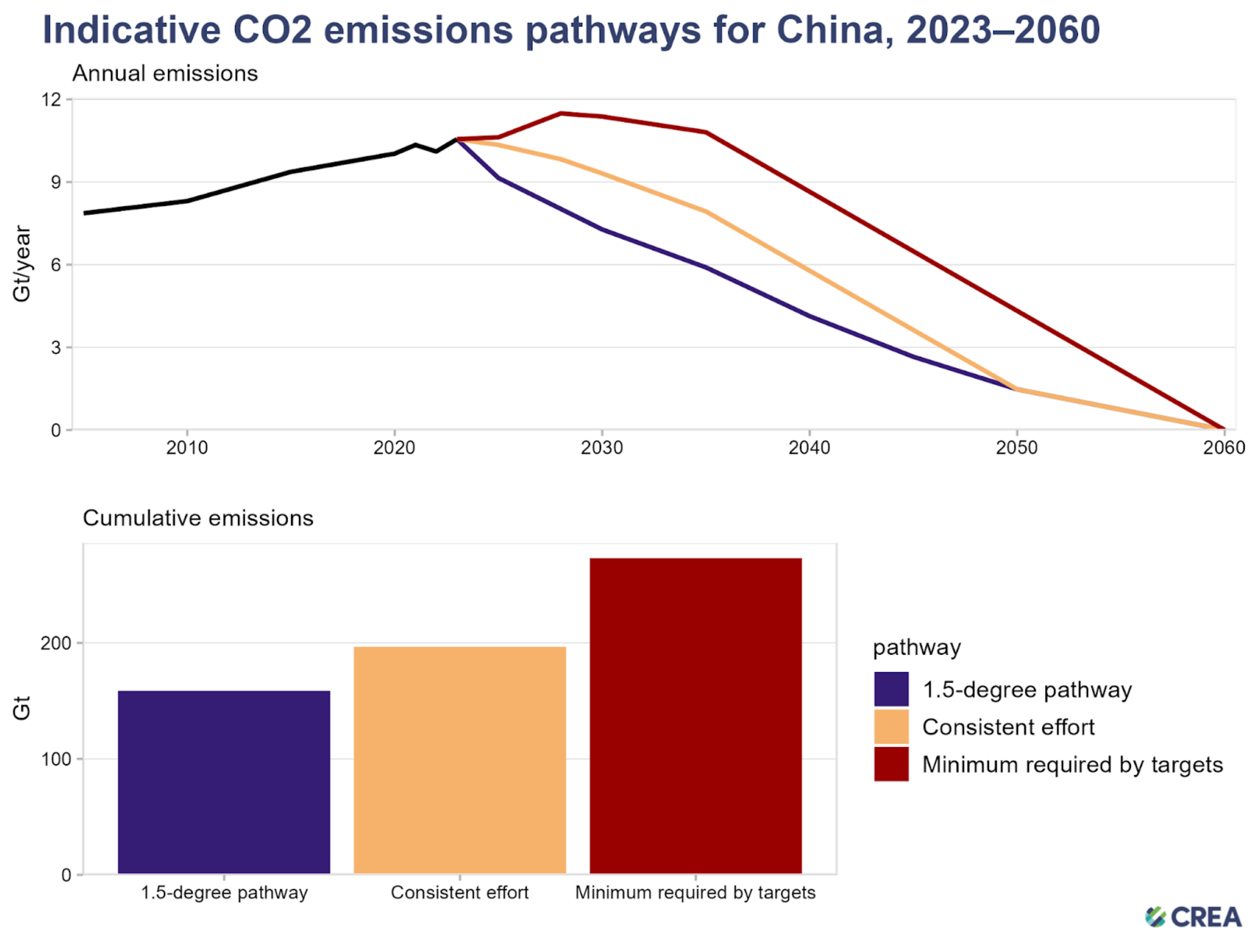

Figure 13 | Indicative emissions pathways for China

Data sources: CO_2 emissions until 2020 from BP Statistical Review of World's Energy; CREA analysis.

China's current climate commitments allow a wide range of CO_2 emissions outcomes. The pathway labelled "minimum required by targets" shows the highest possible emissions pathway that China could follow while meeting the 2025 and 2030 CO_2 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 large change in the amount of effort required in the following decades. The 1.5°C pathway would be extremely challenging to achieve, but it is what China and other countries should strive towards based on the Paris Agreement. China's cumulative CO2 emissions in 2023-2060 under the 1.5 degree pathway would be 160 Gt, 200 Gt in the "consistent" effort pathway and 270 Gt in the "minimum required by targets" pathway.

The remaining carbon budget for a 50% chance of keeping global warming below 1.5 degrees is estimated at 250 Gt as of January 2023. The budget for a 66% chance of limiting warming to 2 degrees is an estimated 940 Gt.[32] This means that under the "minimum required by targets" pathway China's emissions would use up the entire remaining 1.5-degree budget, and 29% of the 2-degree budget. Under the 1.5-degree pathway, China would emit 64% of the remaining global 1.5 degree budget and 17% of the 2-degree budget. The 17% share could be seen as China's fair share as it corresponds to China's share of the world population. The 1.5-degree pathway for China shown in the figure includes CO2 concentration overshoot and negative emissions, which is why China's share of the global emissions budget is implausibly large.

Carbon Emissions Control

In July 2023, the Central Committee for the Comprehensive Deepening of Reforms approved the *Opinions on Advancing the Transition from Dual Control of Energy Consumption to Dual Control of Carbon Emissions*[33] during its second meeting, although the content of this document has not been publicly disclosed. "Dual Control of Energy Consumption" manages total energy use and intensity. China has achieved progress in this regard, with a cumulative 26.4% decrease in energy consumption per unit of GDP from 2012 to 2021, although the energy intensity target for 2020 was missed. "Dual Control of Carbon Emissions" focuses on regulating both the total volume and intensity of carbon emissions. Both of these approaches place constraints on the use of fossil fuels. However, it's important to note that controlling total energy consumption extends beyond just fossil fuels. It also impacts the development of nuclear and renewable energy sources (exemptions for newly added renewable energy consumptions as of the end of 2022). Moreover, industries like petrochemicals have inflexible energy demands, and overly restrictive measures during the "dual control of energy consumption" may not be reasonable or conducive to economic development. In contrast, "dual control of carbon emissions" considers both the quantity and intensity of carbon emissions, allowing for greater flexibility in utilising renewable energy. To implement this approach, China needs to enhance the carbon emissions accounting capabilities, and allocate carbon emission targets to various administrative regions and key sectors. "Carbon emission dual control" empowers high-energy-consuming enterprises to effectively manage emissions, fostering room for growth and transformation. This aligns with the transition from fossil fuels to renewable energy sources, supporting both economic development and environmental sustainability.

Carbon sinks

Besides emissions control, China is also seeking to enhance its ecosystems' carbon sink capacity. In 2023, the Chinese government launched the *Ecosystem Carbon Sink Enhancement Plan*[34]. This plan aims to assess China's ecosystem carbon storage baseline, identify potential for increased carbon sink during the 14th FYP period, and establish an internationally-aligned carbon sink measurement system.

The plan also focuses on key actions, including enhancing forests and grassland carbon sinks, conserving and restoring marine and freshwater ecosystems, bolstering carbon sink capacity in urban

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[32] Lamboll, R.D., Nicholls, Z.R.J., Smith, C.J. et al. Assessing the size and uncertainty of remaining carbon budgets. Nat. Clim. Chang. (2023). https://doi.org/10.1038/s41558-023-01848-5

[33] CPC News. (2023) Constructing a New System for a Higher-Level Open Economy to Gradually Shift from Energy Consumption Dual Control to Carbon Emission Dual Control http://cpc.people.com.cn/n1/2023/0712/c64094-40033549.html

[34] Ministry of National Resources of China. (2023). Ecosystem Carbon Sink Enhancement Plan. https://www.forestry.gov.cn/c/www/zyxx/367743.jhtml

and agricultural areas, and rehabilitating degraded lands.

Afforestation programmes have managed to continuously increase China's forest coverage since 2012. By 2022, the national forest cover rate reached 24%, with a forest stock volume of 19.5 billion cubic metres[35].

With the context of a top-level goal set to reach a forest cover rate of 25% by 2030[36], 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 should have a significant increase by 2030[37]. Supporting tools such as *Guidelines for Validation and Verification of Forestry Carbon Projects* are also promulgated[38].

The 14th FYP stated that "ocean carbon sinks should be improved", although no further detailed policy has been released. In 2023, the industry standard *Ocean Carbon Sink Accounting Methods*[39] was officially adopted, offering a solution for quantifying ocean carbon sinks. While there is no national-level policy, coastal regions have made local policies. For example, Zhejiang Province has released the *Guidelines for Advancing Ocean Carbon Sink Capacity*[40], aiming to create a model for ocean carbon sink development. Key goals to achieve by 2025 include establishing a foundational research and monitoring system for ocean carbon sink, restoring 2,000 hectares of coastal wetlands, adding more than 200 hectares of mangroves, and rehabilitating 74 km of coastline. 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)*[41]. 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*[42].

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[35] State Council of China. (2021) By 2025 Continuous Improvement in Urban and Rural Living Environments in Our Country, Village Greening Coverage Rate Reaches 32.01%. https://www.forestry.gov.cn/main/586/20230313/091901658592486.html News.

[36] 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.

[37] National Greening Commission. (2022). National Land Greening Planning Outline. (2022-2030). http://www.gov.cn/xinwen/2022-09/13/content_5709591.htm. Policy.

[38] 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.

[39] CCTV. (2023) Experts on Ocean Carbon Sink Accounting Methods. https://eco.cctv.com/2023/01/17/ARTIwjUCbudMxobMJFHOyeKd230117.shtml

[40] Development and Reform Commission of Zhejiang. (2023) Guidelines for Advancing Ocean Carbon Sink Capacity. https://zrzyt.zj.gov.cn/art/2023/3/22/art_1289955_59015480.html

[41] Hainan Provincial Ministry of Natural Resources and Planning. (2022). Hainan Province Pilot Work Plan for Carbon Sinks in Marine Ecosystems (2022- 2024). http://www.gov.cn/xinwen/2022-07/30/content_5703578.htm. Policy.

[42] Shandong Provincial Leaders' Group for Addressing Climate Change. (2022). Shandong Province Plan for Combating Climate Change during 14th FYP. http://www.scio.gov.cn/xwfbh/gssxwfbh/xwfbh/shandong/Document/1722588/1722588.htm. Policy.

Carbon emissions trading

Since 2011, China has progressively launched carbon emissions trading pilot programmes in eight regions, including Beijing, Tianjin and Shanghai. In July 2021, the nationwide carbon emissions trading system began, covering the power sector. The trading system differs from the "cap and trade" approach used in the EU in that it's not designed to limit the total CO_2 emissions from the power sector but only to drive reductions in the emissions 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 of the scheme would therefore have to be revised significantly; this can however happen quite fast if the policymakers decide to do it.

To ensure a stable power supply, the Carbon Emission Quota Scheme[43] grants exemptions to companies with significant quota shortfalls. This year, companies with a shortfall rate of 10% or more, and those temporarily unable to comply due to operational difficulties, can apply for the pre-allocation of a portion of the 2023 quotas to meet their compliance obligations. It's unclear if the policy will continue.

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 supposed to be included in carbon emissions trading[44], namely those with annual emissions exceeding 26,000 tonnes of CO_2 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[45]. After more than six years of suspension, the national carbon credit programme (China Certified Emission Reduction, CCER) is about to relaunch by the end of 2023. In October 2023, the MEE released the *Management Measures for Voluntary Greenhouse Gas Emissions Trading (Trial)*[46], optimising the management approach for various aspects of voluntary greenhouse gas emissions reduction, including methodologies, projects, emission reductions, accrediting and verification bodies, and trading entities. These measures serve as the foundational regulations to ensure the orderly operation of the CCER. CCER refers to the quantified verification of greenhouse gas emissions reductions from projects like renewable energy, forestry carbon sinks, and methane utilisation. These reductions can be used by regulated entities to offset their carbon emissions.

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[43] Ministry of Ecology and Environment of China. (2023).Implementation Plan for the Total Allocation of Carbon Emission Trading Quotas for the Power Generation Industry in 2021 and 2022 Nationwide. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202303/W020230315687660073734.pdf

[44] Ministry of Ecology and Environment of China. (2022). Notice on the Management of Corporate Greenhouse Gas Emissions Reporting in 2022. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202203/t20220315_971468.html. Policy.

[45] Office of the Central Committee of the Communist Party of China, Office of State Council. (2021). Opinions on Establishing and Improving the Value Realisation Mechanism of Ecological Products. http://www.gov.cn/zhengce/2021-04/26/content_5602763.htm. Policy.

[46] Ministry of Ecology and Environment. (2023).Management Measures for Voluntary Greenhouse Gas Emissions Trading (Trial).https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202310/t20231020_1043694.html. Policy.

Carbon emissions monitoring, reporting, and verification and accounting system

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 emissions monitoring, reporting, and verification (MRV) systems that make up the foundation of an effective carbon trading system, and effective climate policy in general. The *Notice on Carrying Out Greenhouse Gas Emission Reporting and Verification for Selected Key Industries for the Years 2023-2025*[47] and the *Guidelines for the Verification of Corporate Greenhouse Gas Emissions Report*[48] 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)[49,50,51]. In the trading stage, *Measures for the Administration of Carbon Emissions Trading* is regulating the trading activity[52].

In April 2022, NDRC with other government departments jointly issued a plan[53] to create a standardised national and local carbon emissions accounting system. The National Bureau of Statistics was tasked with developing methods for this purpose. The plan also included annual carbon emission calculations, improving industry and enterprise carbon accounting and enhancing greenhouse gas inventory mechanisms. The goal was to establish a unified and standardised carbon emissions accounting system by 2023. In November 2022, the State Administration for Market Regulation issued a plan[54] to develop standards for carbon emissions monitoring, accounting and verification, essential for achieving carbon peak and neutrality. The plan aimed to establish the measurement system by 2025, covering major industries. In September 2023, MEE and NBS signed a framework agreement[55] to collaborate on carbon emissions accounting. This partnership aims to build a National Greenhouse Gas Emission Factor Database, strengthening China's foundational support for carbon accounting and enhancing transparency for compliance on carbon emissions.

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[47] Ministry of Ecology and Environment. (2023). The Notice on Carrying Out Greenhouse Gas Emission Reporting and Verification for Selected Key Industries for the Years 2023-2025. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202310/t20231018_1043427.html. Policy.
[48] Ministry of Ecology and Environment. (2022) Guidelines for the Verification of Corporate Greenhouse Gas Emission Report. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202212/t20221221_1008430.html
[49] 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.
[50] 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.
[51] 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.
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[53] National Development and Reform Commission. (2022). Implementation Plan for Accelerating the Establishment of a Unified and Standardised Carbon Emission Accounting System.https://www.ndrc.gov.cn/xxgk/zcfb/tz/202208/P020220819537055381532.pdf. Policy.
[54] State Administration for Market Regulation. (2022). Implementation Plan for Establishing and Improving the Carbon Peak and Carbon Neutrality Standard Measurement System. https://www.gov.cn/zhengce/zhengceku/2022-11/01/5723071/files/456978e8376e43fa80a0ce26ea6622c7.pdf. Policy.
[55]Ministry of Ecology and Environment. (2023) Ministry of Ecology and Environment and National Bureau of Statistics Sign Cooperation Framework Agreement on Carbon Emission Statistical Accounting Workhttps://www.mee.gov.cn/ywdt/hjywnews/202309/t20230926_1041974.shtml.News.

Low carbon and zero carbon technologies

The Ministry of Science and Technology, along with other departments, jointly released the *2022-2030 Implementation Plan for Technological Support for Carbon Peak and Carbon Neutrality*[56]. Following this, several local governments including Shanghai, Jiangsu and Hebei have introduced their own plans to achieve dual carbon goals with technological backing. The significance of industrial and technology policy in China's carbon peak and carbon neutrality strategy is growing. The evidence of this is a wave of investment in manufacturing clean energy technologies, especially in solar, wind (details in 4.5.2) and electric vehicles (details in 4.7.2). The NDRC also clearly specified in the *Implementation Plan for Further Enhancing the Market-Driven Green Technology Innovation System (2023-2025)*[57] that it intends to bolster financial and tax support for clean technologies.

Currently, China's efforts in carbon neutrality technology focus on key areas such as clean and efficient coal utilisation, renewable energy technologies, low-carbon utilisation, and carbon capture and storage (CCUS). "Clean coal utilisation" includes technologies that make at most a marginal contribution to reducing emissions, such as unabated coal power plants using ultra-supercritical steam cycles, as well as ones that paradoxically have higher carbon emissions than the technologies they replace, especially coal-based synfuels and chemicals production (coal-to-chemicals industry). However, these technologies are often emphasised by officials as a showcase of emissions reduction achievements, as an alternative to limiting new coal projects.

Technologies related to net zero carbon, such as CCUS, are currently in the industrial demonstration phase and are associated with relatively high costs. According to the *China Annual Report on CCUS 2023*, nearly 100 CCUS demonstration projects are operational or permitted. Among them, more than half have been constructed and put into construction, with a capacity to capture approximately 4 millions tons of CO_2 per year. The report suggests that it lays the foundation for achieving large-scale applications in the near future.

4.1.3 Data disclosure

The government currently reports on the improvement in CO_2 intensity every year, which can be used to calculate the change in CO_2 emissions based on reported GDP growth. However, this is a rudimentary and non-transparent way of reporting and doesn't include sinks or non-energy CO_2 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. Implementing dual control of carbon emissions(details in 4.1.2) hinges on building the necessary foundation capabilities, particularly in carbon emission data accounting.

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[56] Ministry of Science and Technology of China. (2022). Policy. 2022-2023 Implementation Plan for Technological Support for Carbon Peak and Carbon Neutrality. https://www.gov.cn/zhengce/zhengceku/2022-08/18/5705865/files/94318119b8464e2583a3d4284df9c855.pdf. Policy.

[57] National Development and Reform Commission. (2022). Implementation Plan for Further Enhancing the Market-Driven Green Technology Innovation System (2023-2025). https://www.ndrc.gov.cn/xxgk/zcfb/tz/202212/t20221228_1344205.html. Policy.

4.2 Non-CO_2 greenhouse gases

2023 highlights

- The Methane Emissions Control Action Plan was published, laying out China's approach to methane emission management and control.

Besides rapid reductions in CO_2 emissions, the transition pathways consistent with the 1.5°C target require more efforts to control other non-CO_2 greenhouse gases (NCGHGs). The total reductions in NCGHGs will reach 30% of the 2014 emissions level (2,000 $MtCO_2$-eq) in 2030 and 34% in 2050 in the 1.5°C pathway.

In the ICCSD 1.5°C pathway, non-CO_2 emissions peak and fall below the 2020 level before 2025. Emissions stand at 2.38 $GtCO_2$-eq in 2025 and fall to 1.2 $GtCO_2$-eq in 2050. The ICCSD's 2°C pathway projects that non-CO_2 GHG emissions will peak in 2025 at 2.51 billion tCO_2eq, with an average annual increase of 1.5% from 2020 to 2025, before falling to 1.76 $GtCO_2$-eq in 2050, an annual rate of reductions of 1.4%.

After CO_2, methane is the greenhouse gas that China emits the most in CO_2-equivalent terms. In the ICCSD 2°C pathway, methane emissions peak before 2025 at 1,220 $MtCO_2$-eq and fall to 1,180 $MtCO_2$-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 $MtCO_2$-eq by 2030.

The ICCSD 1.5°C pathway projects a peak in N_2O emissions around 2020 at 580 million tCO_2e, falling to 420 million tCO_2e in 2030. F-gases emissions peak in 2030 at 730 $MtCO_2$-eq and fall to 440 $MtCO_2$-eq in 2050. The ICCSD 2°C pathway sees N_2O emissions reaching a peak around 2020, but at 650 million tCO_2e and dropping to 570 million tCO_2e 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 tCO_2e in 2050.

4.2.1 Policies in place

China has long recognized the need to control non-CO_2 greenhouse gases, as shown by the inclusion of this area in the *Action Plan for the 13th FYP*, published in 2016. However, more specific policies were not issued. In the 14th FYP, this was specified as "strengthen controlling of methane, HFCs and PFCs". In the *China National Implementation Progress Report on NDC (2022)*[58] China outlined its commitment to develop and execute an action plan for managing non-CO_2 greenhouse gas emissions, and to improve monitoring and reporting techniques for these emissions. However, the action plan is yet to be published, and other policies have not included numerical targets. There is also no reporting on NCGHG emissions that would allow the assessment of emissions trends after 2014, the year covered by the latest official emissions inventory.

It's currently not clear whether the "carbon neutrality" target should be understood to cover all greenhouse gases or only CO_2. China's Special Envoy for Climate Change Affairs, Xie Zhenhua, has

[58] Ministry of Ecology and Environment of China. (2022). China National Implementation Progress Report on NDC (2022). https://www.mee.gov.cn/ywgz/ydqhbh/qhbhlf/202211/W020221111760730462299.pdf. Government document.

repeatedly stated[59] to the media that China's carbon peak refers to the peak of CO_2 emissions, and the carbon neutrality by 2060 refers to the neutrality of all greenhouse gases. China's NDC targets do not include emissions of greenhouse gases such as methane. However, the carbon neutrality goal encompasses emissions of greenhouse gases across the entire economy, not just CO_2. This includes methane, hydrofluorocarbons, and other non-CO_2 greenhouse gases. As of now, China has not officially documented these specifics in an official government document.

China's methane emissions account for more than 14% of the global total, making it the world's largest methane emitter. Methane accounted for 10.4% of China's total GHG emissions in 2014[60]. 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%[61]. The remaining emissions are restricted by an on-trial *Emission Standard for Coalbed Methane*[62], promulgated by the MEE. There is also a discharge standard that regulates methane emitted from municipal wastewater treatment plants[63].

At the 2021 COP26, the US and China agreed in *Joint Glasgow Declaration*[64] to enhance methane measurement and reduction, targeting fossil and waste sectors and introducing incentives to curb agricultural methane emissions.

In line with these commitments, November 2022 saw the MEE release *reference standards*[65] *for* climate investment, supporting projects that aim to reduce methane emissions. In October 2023, measures[66] were introduced for trading voluntary greenhouse gas emission reductions, including methane reduction initiatives.

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[59] Xie Zhenhua. (2021). http://www.ncsc.org.cn/xwdt/gnxw/202107/t20210727_851433.shtml. Speech.

[60] Ministry of Ecology and Environment of China. (2018). The People's Republic of China Second Biennial Update Report on Climate Change. https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/201907/P020190701765971866571.pdf. Report.

[61] National Energy Administration of China. (2020). Notice on Further Strengthening the Management of Environmental Impact Assessment of Coal Resources Development. http://www.nea.gov.cn/2020-12/03/c_139560035.htm. Policy.

[62] State Environmental Protection Administration and others. (2008). Emission Standard of Coalbed Methane/Coal Mine Gas (on trial). https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/dqhjbh/dqgdwrywrwpfbz/200804/t20080414_121137.shtml. National Standard.

[63] State Environmental Protection Administration and others. (2002). Discharge standard of pollutants for municipal wastewater treatment plant. https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/shjbh/swrwpfbz/200307/t20030701_66529.shtml. National Standard.

[64] US Department of State (2021) U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s. https://www.state.gov/u-s-china-joint-glasgow-declaration-on-enhancing-climate-action-in-the-2020s/. Government document.

[65] Ministry of Ecology and Environment of China. (2022). Reference Standards for Local Climate Investment and Financing Projects under the Climate Investment and Financing Pilot Program. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202211/W020221117316973946868.pdf. Standard.

[66] Ministry of Ecology and Environment of China. (2023). Management Measures for Voluntary Greenhouse Gas Emission Reduction Trading (Trial). https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202310/t20231020_1043694.html. Measures.

The latest development came in November 2023, when the MEE published the *Methane Emissions Control Action Plan*[67], setting out methane management strategies for the upcoming 14th and 15th FYP. The action plan sets an aim to develop policy, technology and standards, aiming to boost methane capture and utilisation, particularly in agriculture and waste management. It "seeks to establish" a monitoring , reporting and verification (MRV) system for methane and sets a direction for the oil and gas industry to end routine flaring. However, it lacks emissions reduction targets and firm timelines for the most important steps, such as regular reporting of methane emissions, only calling for "improvement" in emissions monitoring during the 14th and 15th Five-Year Plan periods.

Table 4 | Selected policies relating to non-CO2 greenhouse gases

Policy name	Release date	2025 Targets	Targets for 2030 and beyond
Methane Emission Control Action Plan (Ministry of Ecology and Environment)	2023-11-07	A policy, technology, and standards system for methane emissions control will be gradually established. The foundational capabilities for methane emissions monitoring, reporting and verification will be effectively enhanced, and positive progress in the utilisation of methane resources and emissions control efforts will be achieved. There will be a steady reduction in methane emissions intensity per unit of agricultural product in the planting and breeding industries, and a continuous increase in the resource utilisation rate of municipal solid waste and the harmless disposal rate of urban sewage sludge.	The policy, technology, and standards system for methane emissions control will be further perfected. The basic capabilities for methane emissions monitoring, reporting and verification will be significantly improved, and the control capacity and management level of methane emissions will be effectively elevated. The level of coal mine gas utilisation will be further enhanced, and methane emission intensity per unit of agricultural product in the planting and breeding sectors will be further reduced. Following this, the oil and natural gas extraction industry will strive to progressively achieve zero routine flaring in onshore oil and gas extraction.

4.2.2 Data disclosure

Emissions disclosure for non-CO_2 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.

[67] Ministry of Ecology and Environment.(2023). Methane Emissions Control Action Plan. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202311/W020231107750707766959.pdf

4.3 Total energy supply and demand

2023 highlights

- Additional consumption of renewable energy electricity is subtracted from the total energy consumption but is still included in the assessment of energy consumption intensity.

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 School of Environment and Natural Resources-Renmin University 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

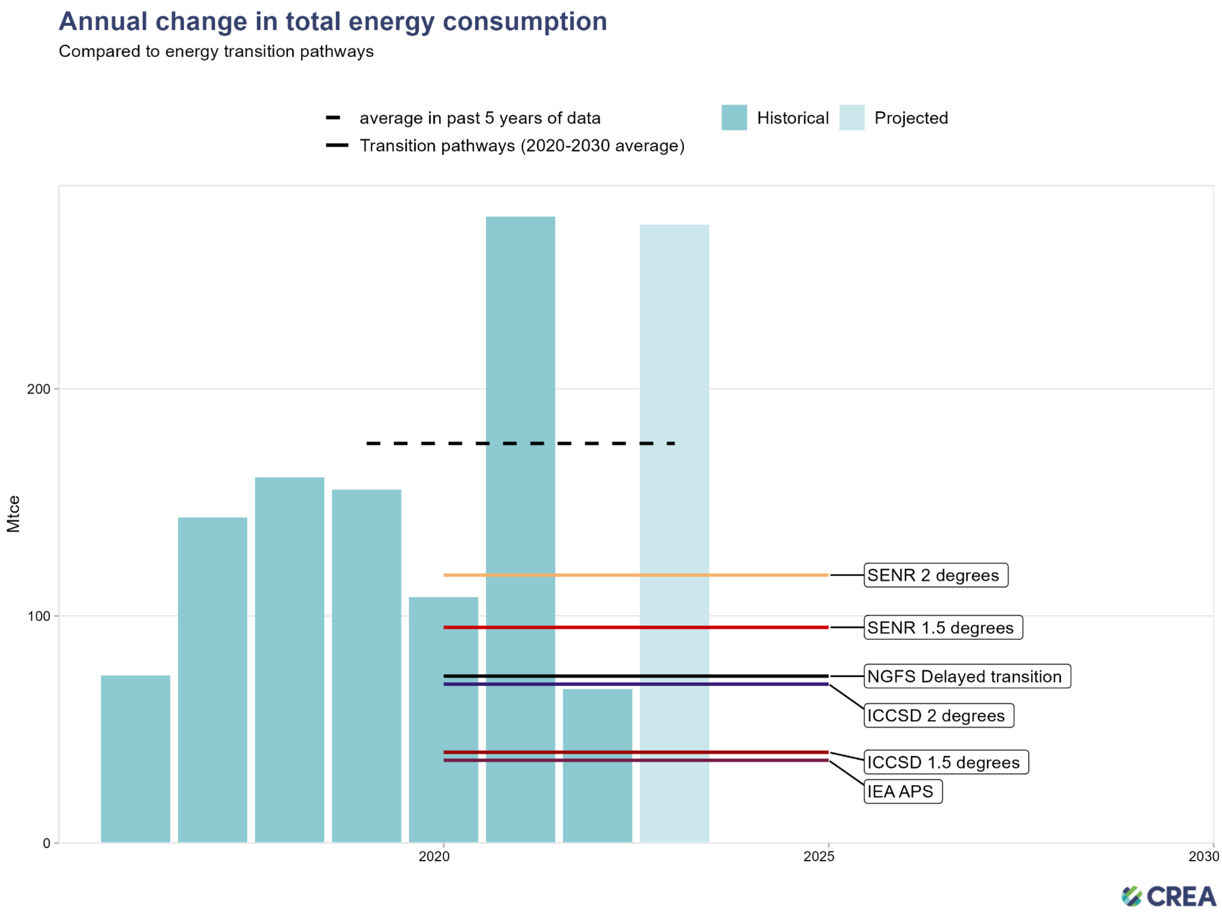

Figure 14 | Annual change in China's total energy consumption compared to energy transition pathways

China's total energy demand has been growing at an average of 3.3% 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 CO_2 emissions have kept increasing despite world-leading investment in clean energy. In 2022, growth slowed to approximately 1%, but accelerated in 2023, for projected 4% growth. 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 continues at current levels, much faster clean energy growth than projected in the transition scenarios will be required to peak and decline emissions.

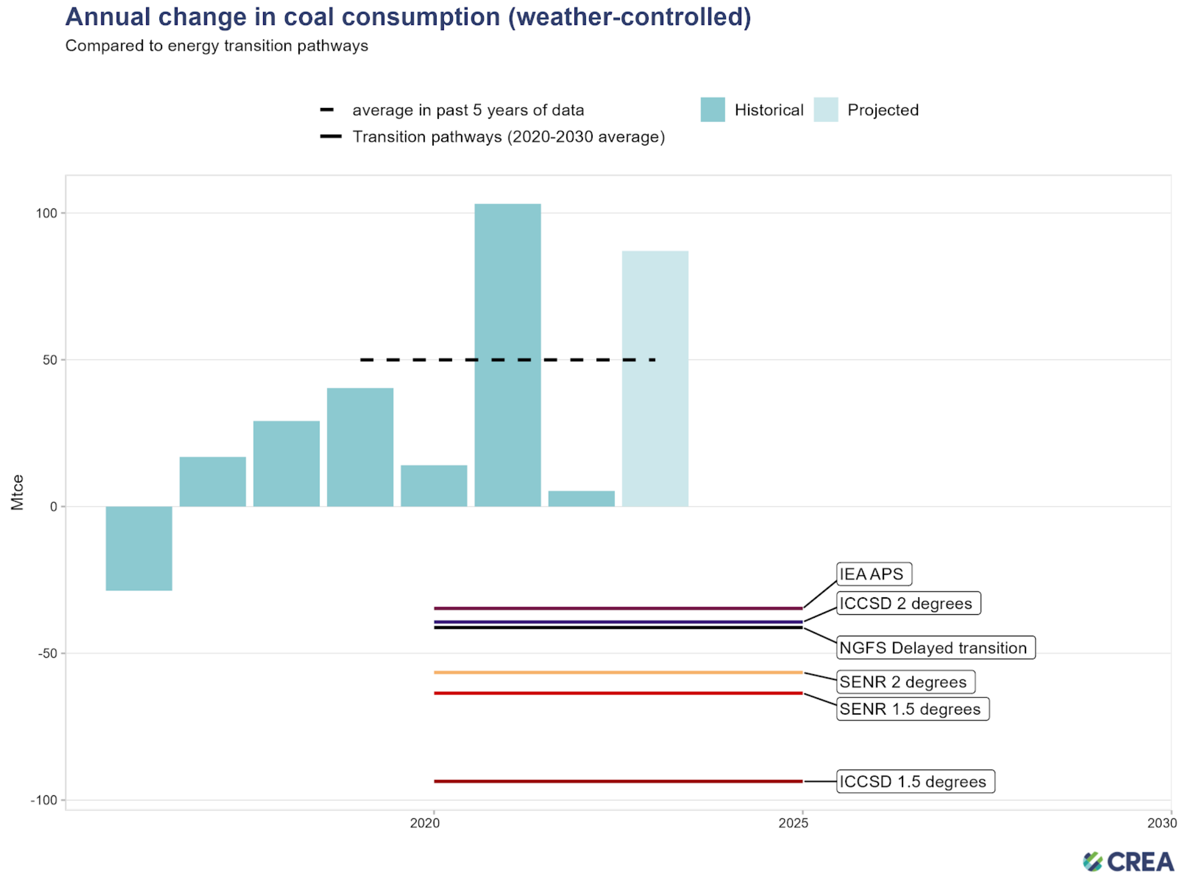

Figure 15 | Annual change in China's coal consumption compared to energy transition pathways

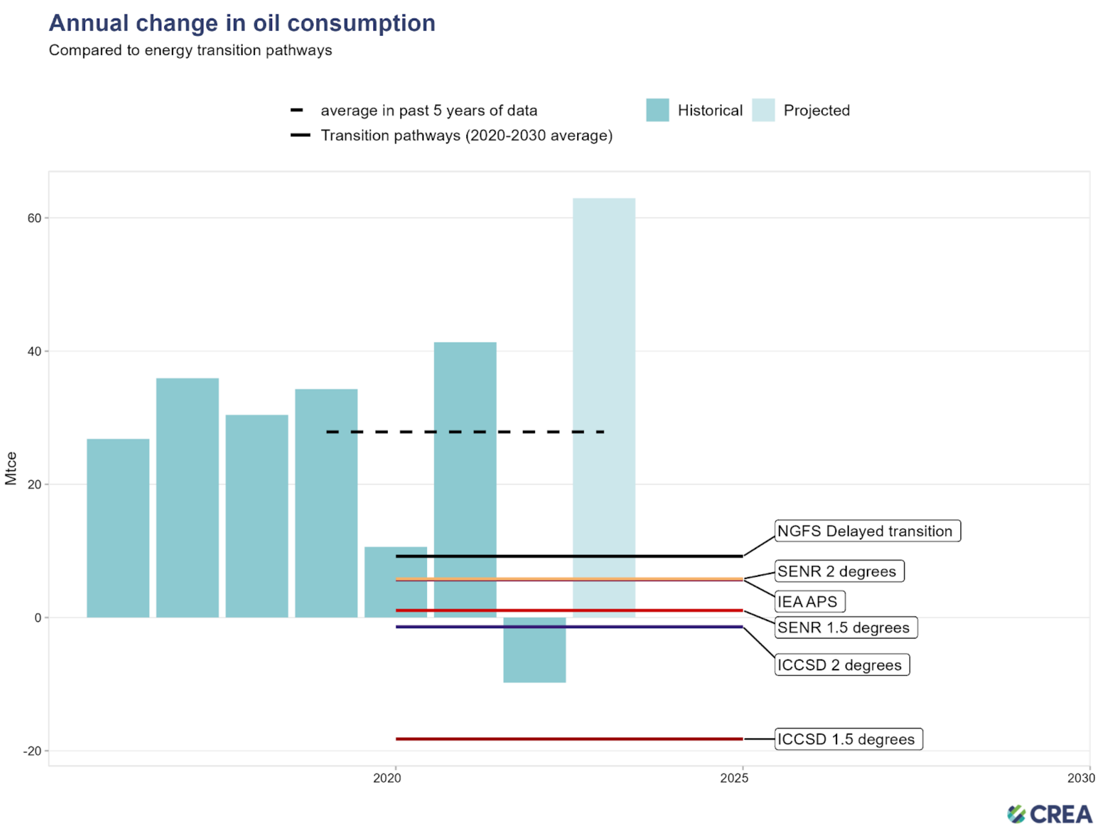

Figure 16 | Annual change in China's oil consumption compared to energy transition pathways

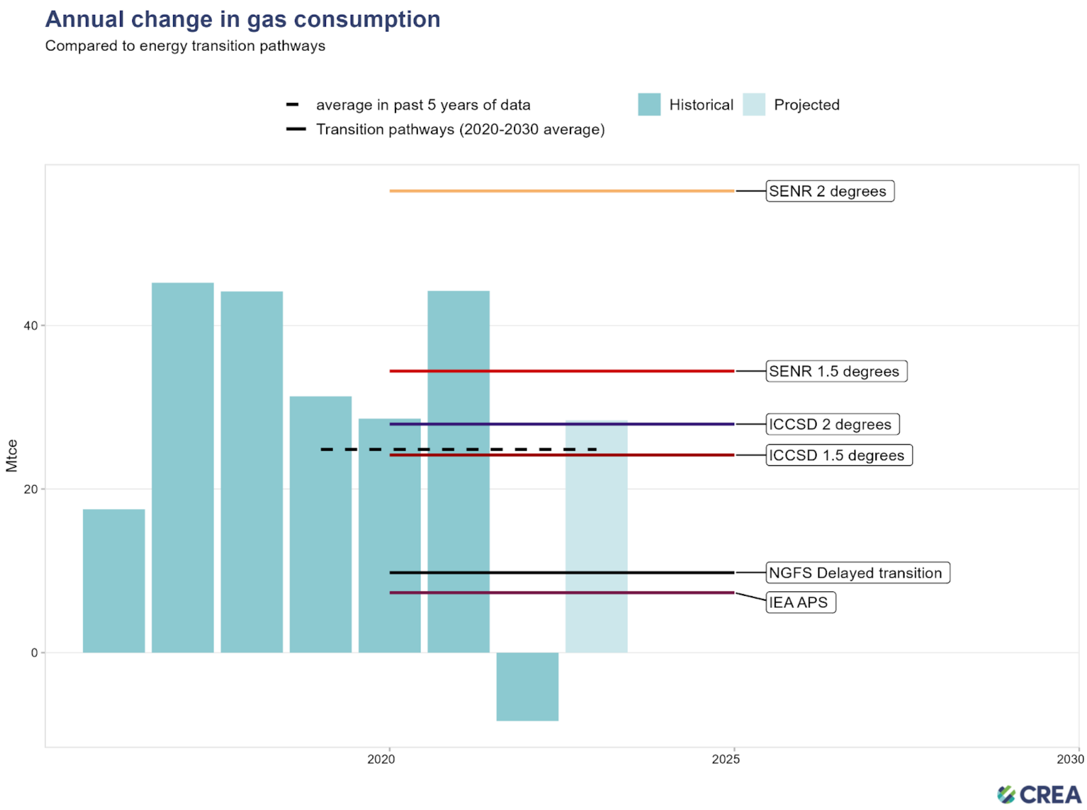

Figure 17 | Annual change in China's gas consumption compared to energy transition pathways

The transition pathways require a reduction in coal consumption throughout 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 scenarios require an absolute reduction from 2020 to 2030. However, China's oil consumption growth was faster than in the transition pathways every year from 2016 to 2021, including 2020, the first year of the COVID-19 pandemic. Oil consumption only fell in 2022 due to COVID-19 control measures, and rebounded in 2023.

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 growth appears to have slowed down in 2022–2023 due to high gas prices and reversal of policies favouring gas use over coal.

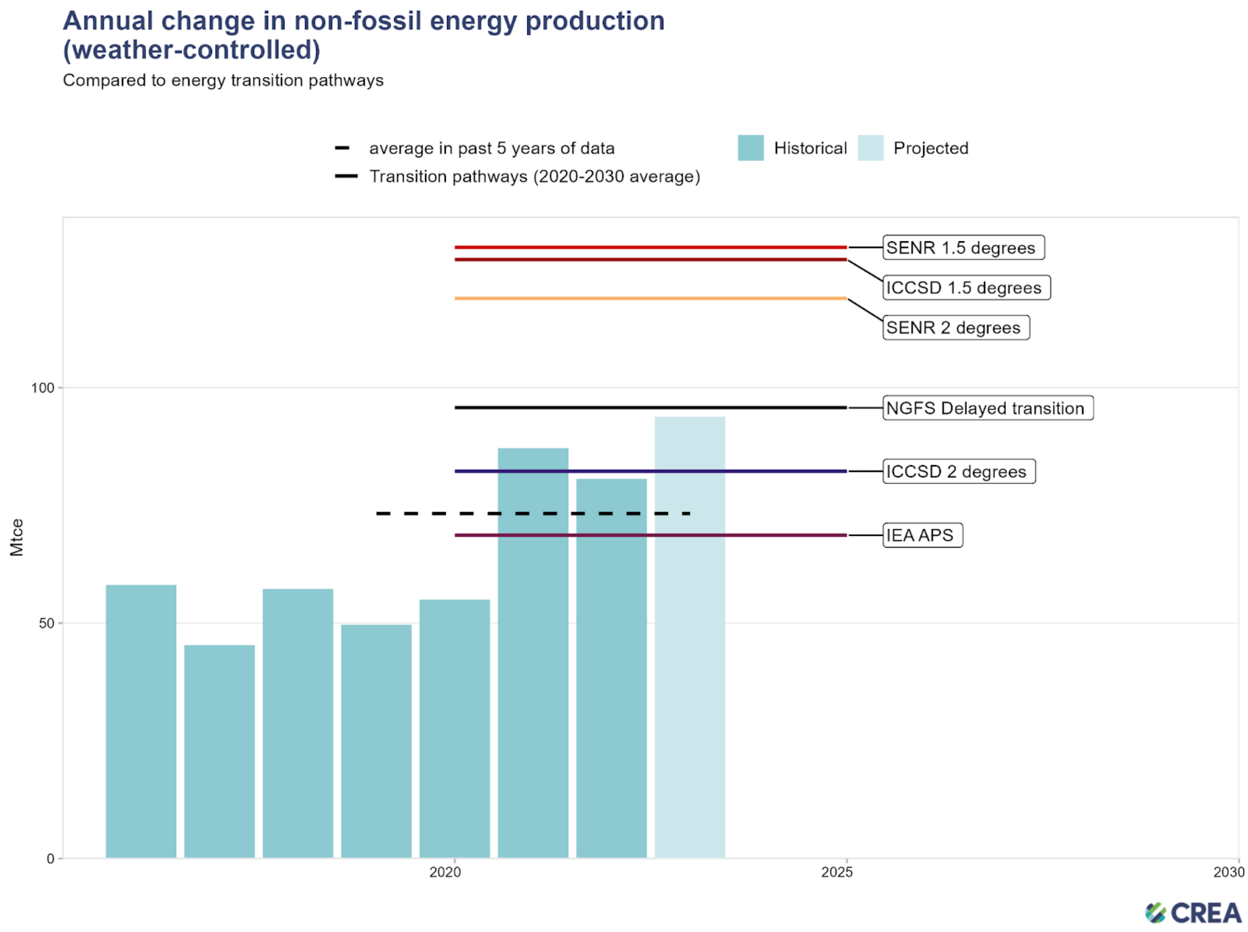

Figure 18 | Annual change in China's non-fossil energy production compared to energy transition pathways

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, the annual change in non-fossil energy production reached the low end of those pathways due to strong growth in wind and solar generation and strong hydropower contribution at times.

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 all of the examined pathways. To achieve peak carbon and decrease CO_2 emissions will require non-fossil energy growth rate and total energy demand growth rate to rise 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.

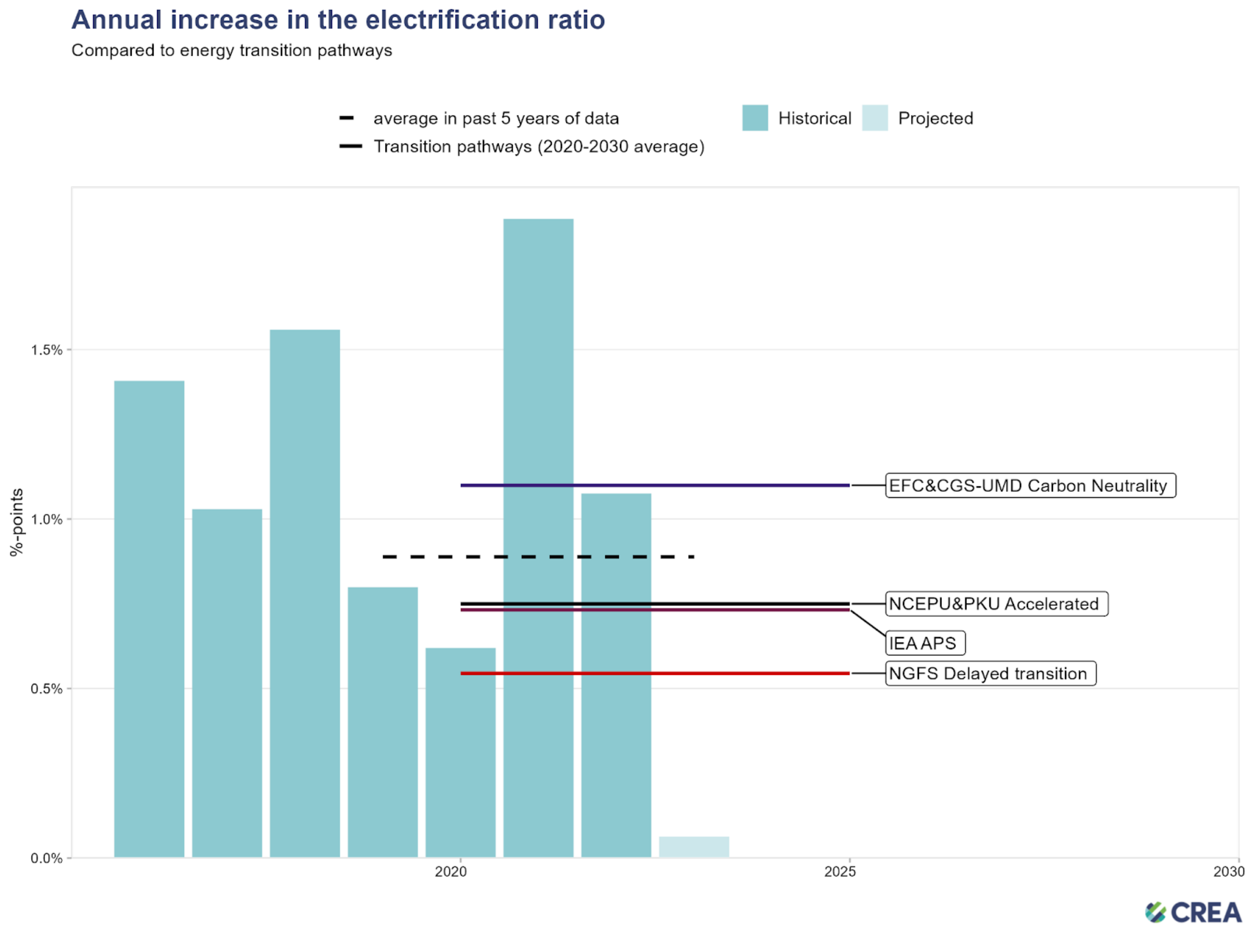

Figure 19 | Annual increase in the electrification ratio compared to energy transition pathways

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 faster than this in China, at more than 1% per year, creating the conditions for emissions reductions when the electricity is produced from clean sources. Currently, the increase in electricity demand has driven increases in power sector emissions because 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

The main reason that China's CO_2 emissions 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 2020–2022, 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.

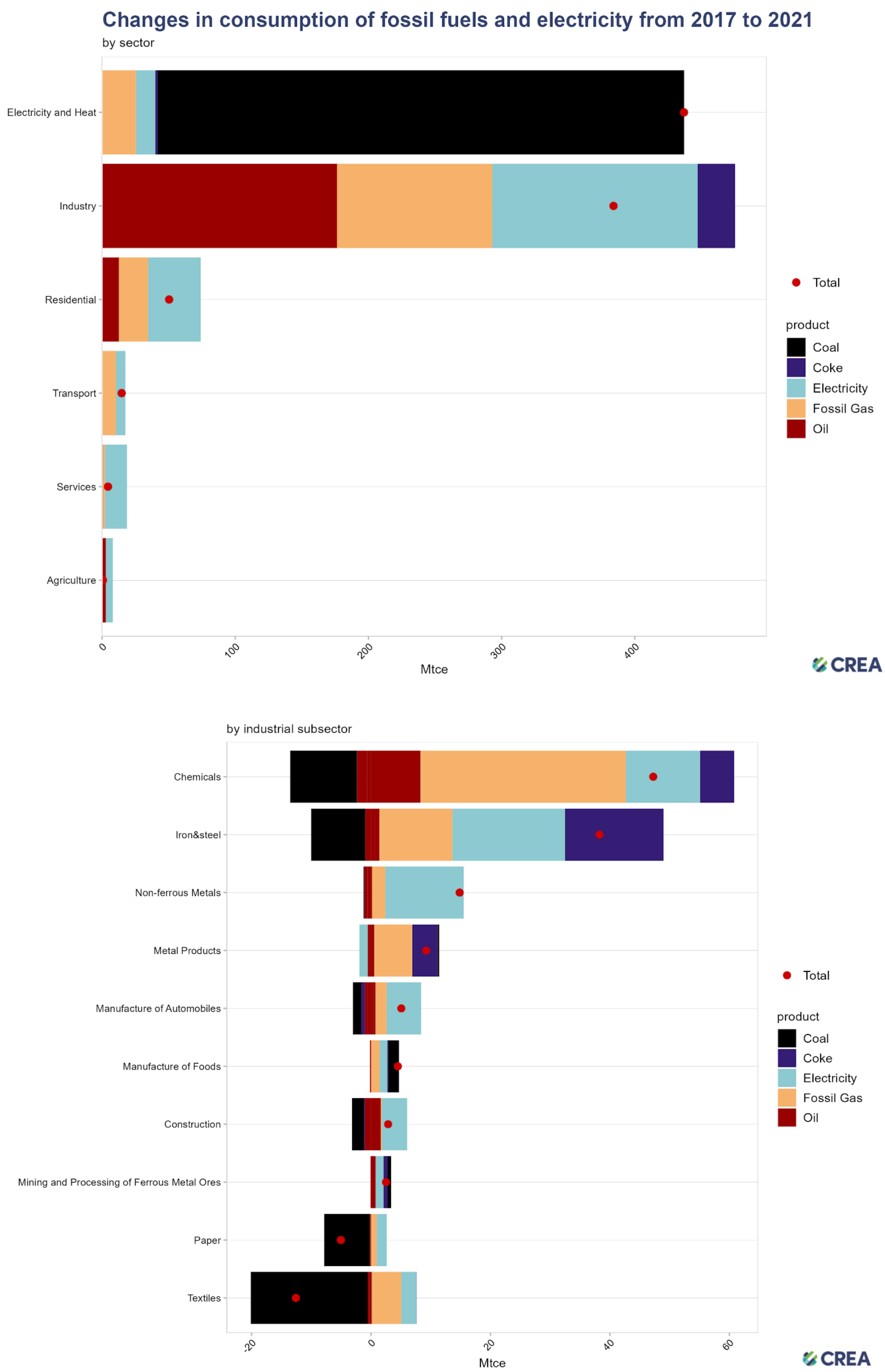

Figure 20 | Energy consumption growth by sector and fuel, from 2017 to 2021, and a decomposition of growth in industry by subsector

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*[68]. The overarching targets for the plan are set in the 14th FYP:

- Targets by 2025:
    - Energy consumption per unit of GDP will be lowered by 13.5% from the 2020 level;
    - Carbon dioxide (CO_2) 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:
    - CO_2 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, targets have trickled down and are being repeated in a variety of policies.

14th Five-Year Plan for Modern Energy System[69] is the overarching policy directing the development of the energy system. Besides adopting goals from the top-level objectives, it also established additional goals in the energy system (Table 4 shows only the energy efficiency and transition goals).

Guiding Opinions on High-Quality Development of the Coal Industry in 14th FYP[70] 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%. The *Benchmark of clean and efficient utilisation of coal (2022 edition)*[71] was

[68] 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.
[69] 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.
[70] 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.
[71] 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.

created in April 2022, based on the National level implementation plan (as outlined in the Industry section below)[72]. 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[73]. "Three Batches" refers to: 1) By 2023, amend binding standards for energy efficiency assessment, with the integration of current standards for general[74] and CHP[75] (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 emissions standards, the *Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants* will direct the retrofitting and upgrading of coal-fired fleets[76]. By 2025, the average coal consumption intensity of coal power generation should fall below 300 gce/kWh (grams coal equivalent per kilowatt-hour, equivalent to a thermal efficiency of 41% on a lower heating-value basis). Additionally, at least 350 GW of coal power plants need to be retrofitted for improved thermal efficiency, and 200 GW retrofitted to increase their flexibility. The average coal consumption rate had already fallen from 305.5 in 2020 to 301.5 in 2022, potentially achieving this target ahead of schedule.

In the *2023 Energy Work Guidance*[77], there is an emphasis on gradually raising coal washing rates. Coal washing and processing are essential for improving and stabilising coal quality, which, in return, boosts the efficiency of coal utilisation. By the end of 2022, China's raw coal washing rate had dropped from 74.1% in 2020 to 69.7%. The decline might be caused by two factors: 1) Part of the raw coal is shifted for direct burning in power plants per request by the government to ensure sufficient supply of electricity; 2) Gradual closure of the coal mines in middle-east and south-west areas, which lead to the shortage of raw coal supply for coal washing[78].

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[72] 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.
[73] 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.
[74] Standardization Administration of China. (2017). The norm of energy consumption per unit product of a general coal-fired power set. https://std.samr.gov.cn/gb/search/gbDetailed?id=71F772D817D5D3A7E05397BE0A0AB82A. National Standard.
[75] 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.
[76] 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.
[77] National Energy Administration. (2023). 2023 Energy Work Guidance. http://zfxxgk.nea.gov.cn/2023-04/06/c_1310710616.htm. Government document.
[78] Zhongtai Securities. (May 2023). Mid-term strategy for the coal industry in 2023. https://www.vzkoo.com/read/2023051298edc37d7524d4f2e04e7661.html. Sectoral analysis.

The development of non-fossil fuel energy is the other factor that determines the progress of the energy transition. The*14th Five-year plan for renewable energy development* is a promising blueprint that depicts the future vision for renewable energy development[79]. In November 2022, NDRC issued *Notice on Further Improving the Work Related to Excluding the Consumption of Newly Added Renewable Energy from the Total Energy Consumption Control*[80]*,* clarifying that the additional consumption of renewable energy electricity are subtracted from the total energy consumption in each region but are still included in the assessment of energy consumption intensity. Currently, renewable energy sources not considered in the total energy consumption primarily include wind power, solar power, hydropower, biomass power, and geothermal power. As technology advances and develops, additional measurable types of renewable energy sources will be progressively integrated.More details about renewable energy will be discussed in the Electricity section, below.

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 utilisation of coal (2022 edition), (National	2022-05-10	-	-

[79] 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.
[80] National Development and Reform Commision. (2022). Policy. Further Improving the Work Related to Excluding the Consumption of Newly Added Renewable Energy from the Total Energy Consumption Control. https://www.ndrc.gov.cn/xxgk/jd/jd/202211/t20221116_1341436.html

Policy name	Release date	2025 Targets	Targets for 2030 and beyond
Development and Reform Commission and others)			
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 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 1200 GW.
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.
Notice on Further Improving the Work Related to Excluding the Consumption of Newly Added Renewable Energy from the Total Energy Consumption Control (National Development and Reform Commission)	2022-11-16	-	-

Policy name	Release date	2025 Targets	Targets for 2030 and beyond
Action Plan for Accelerating the Integration of Oil and Gas Exploration and Development with New Energy Development (2023-2025) (National Energy Administration)	2023-03-23	Oil and gas are used to promote the efficient development of new energy sources, meet rising electricity demand in oil and gas fields, and replace self-consumed oil and gas in exploration and development. This has resulted in an additional 4.5 billion cubic meters of natural gas supply. Furthermore, measures like increased pressure and production have contributed to an additional 3 billion cubic meters of natural gas production. Establish "low-carbon" and "zero-carbon" oil and gas fields. Integrate onshore oil and gas operations with the consumption of wind and solar power, both onshore and offshore.	

4.3.3 Data disclosure

Data on total energy consumption and consumption of the 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 are 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 and disaggregated monthly or quarterly disclosure would greatly improve the timeliness of information about the development of China's energy sector's CO_2 emissions.

4.4 Electricity generation and capacity

2023 highlights

- The Whole County Distributed Solar Initiative and Large Scale Clean Energy Bases have made substantial contributions to the development of renewable energy electricity in China. Nevertheless, these two major projects also encounter various challenges during their implementation.
- China outlined a three-phase roadmap for its New Power System.
- In 2023, both Green Electricity Trading and Green Certificate Trading witnessed significant growth, thanks to the implementation of various policies designed to stimulate Green Electricity Consumption. The range of Green Certificate issuance has been expanded.
- The construction of the electricity spot market is progressing, with a capacity payment mechanism for coal power introduced in November 2023.

The energy sector is the largest emitter of CO_2, and electricity generation is the largest source of energy-related CO_2 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 substantial coal power fleet that 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 CO_2 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 China's 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 emissions 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 CO_2 captured in 2050. Deployment of BECCS will begin around 2040 and reach 48GW by 2050, with 280 million tonnes of CO_2 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

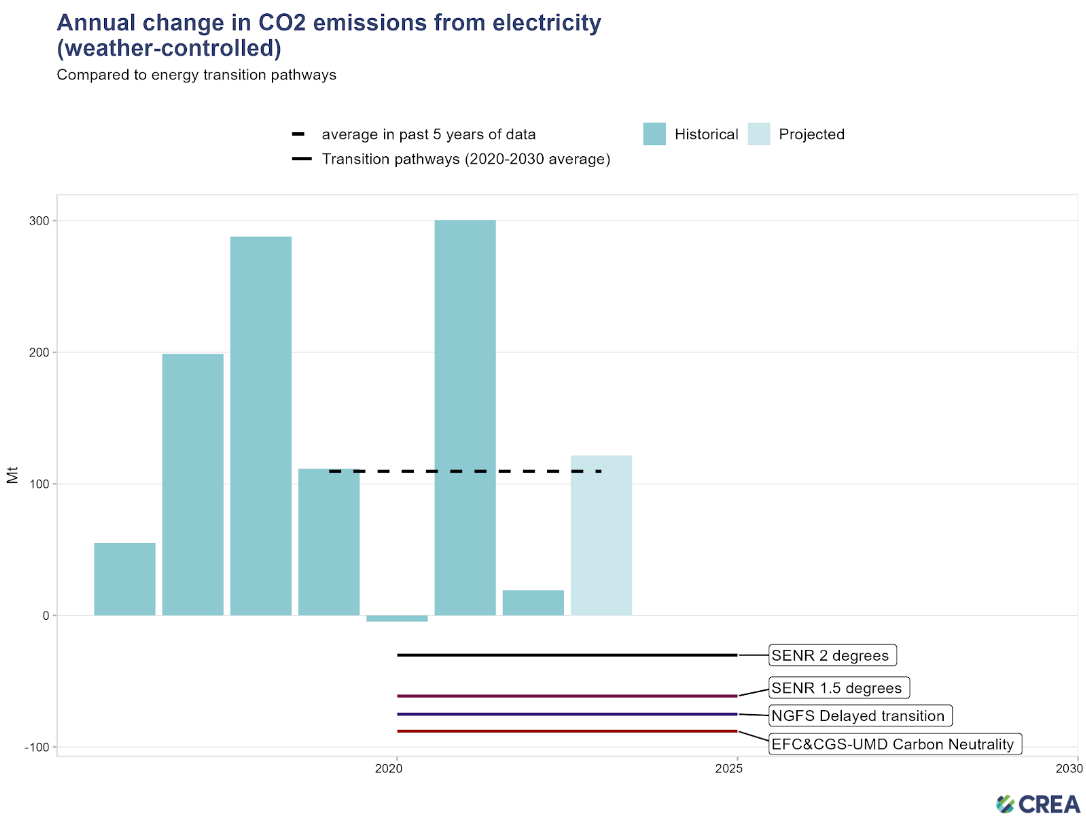

Figure 21 | Annual change in CO_2 emissions from electricity compared to energy transition pathways

Power generation from coal grew by an average of 4.0% 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. Year-to-year changes have been volatile, especially since the beginning of the COVID-19 pandemic in 2020. Coal-fired power generation increased 8% from January to August 2023 in comparison to the same period in 2022, a very sharp increase. This jump was, however, mainly due to the severe droughts that affected hydropower output from August 2022 to July 2023. When the information on coal-fired power generation is corrected for weather variations affecting hydropower, wind and solar power output, there appears to be a slowing trend in 2022–2023. When hydropower generation returns to typical levels and the increase in clean power generation from the record solar power installations of 2023 is realised, power generation from coal is likely to fall.

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.

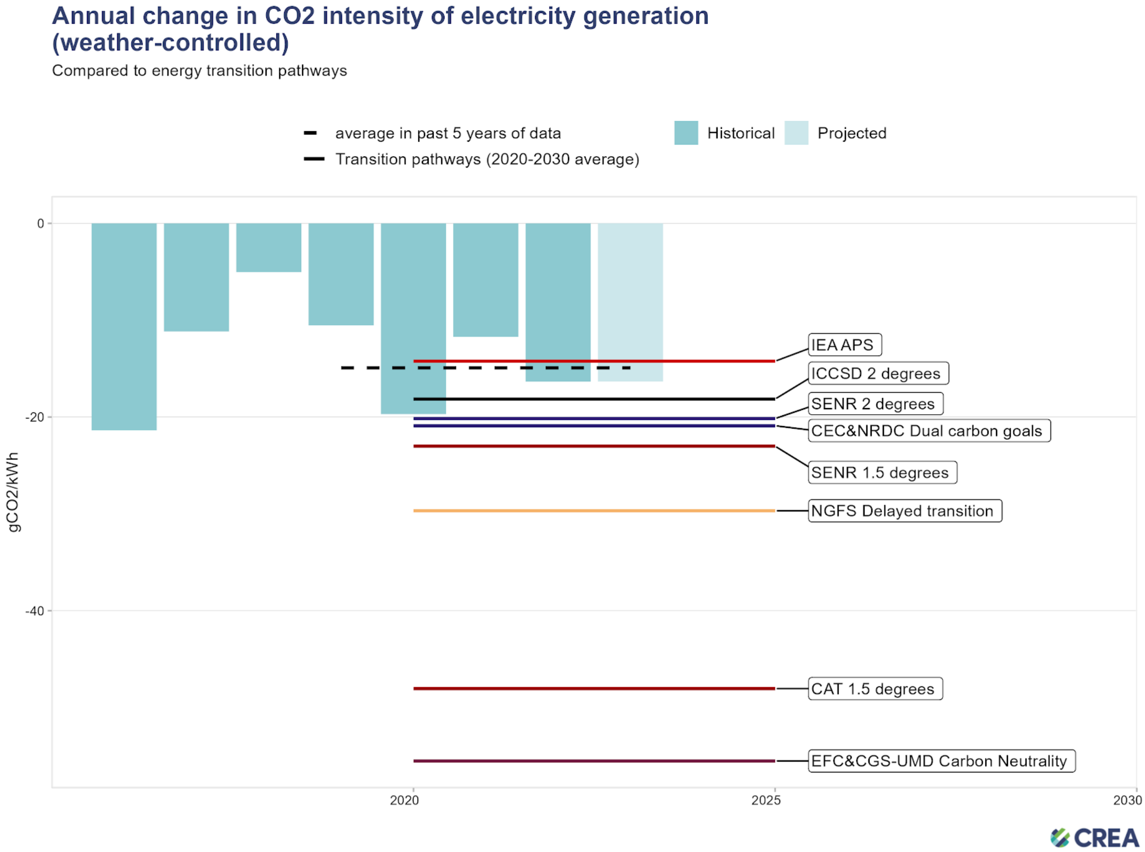

Figure 22 | Annual change in CO_2 intensity of electricity generation compared to energy transition pathways

The CO_2 intensity of power generation in China fell by an average of 13 g/kWh per year, from 570 g/kWh in 2018 to 520 g/kWh in 2023. In 2023, CO_2 intensity improvement slowed down to the lowest rate since 2015, but this was due to the collapse of hydropower generation. On a weather-corrected basis, steady improvements continued. The transition pathways require CO_2 intensity to fall to 300–400 g/kWh by 2030, or two to three times as fast as the average of the past five years. CO_2 intensity has fallen slightly faster in 2020–2023 than in 2017–2019, but further acceleration is needed to align with the majority of the transition pathways.

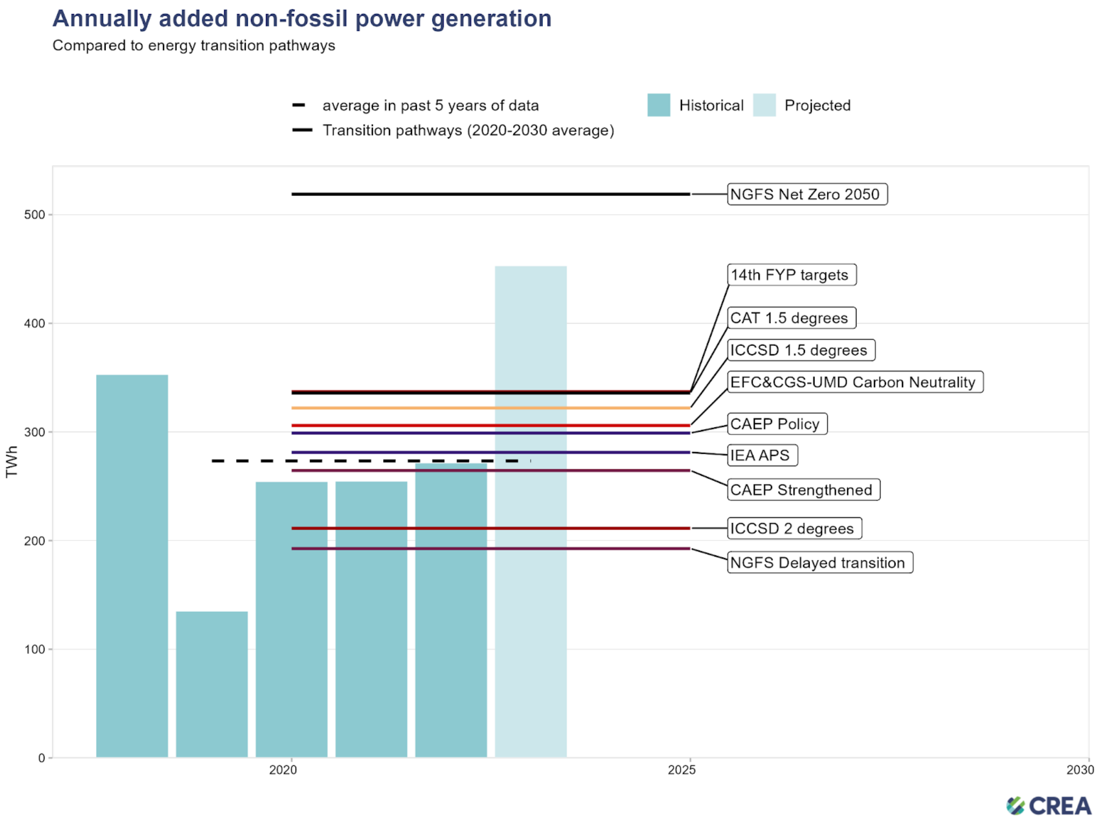

Figure 23 | Annual added non-fossil power generation compared to energy transition pathways, with wind, solar, nuclear and hydropower capacity added each year converted to annual electricity output using average capacity factors for each technology

The additions of clean electricity generating capacity are going to reach a new record in 2023, with over 200 GW of solar power installations expected. The previous annual solar power installations record was 87 GW in 2022.

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.

On this basis, the added annual non-fossil power generation in 2023 will reach over 400 TWh, and exceed the average annual growth in total electricity generation. This means that if clean energy growth is maintained and electricity consumption growth is at or below the historical average, power sector emissions will peak in the next few years.

Added non-fossil generation has been in the range projected in the transition pathways during the past five years, and in 2023, additions are likely to rise to the upper end of 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[81], taking combined wind and solar installed capacity in 2025 to 1400 GW. This addition is far ahead

[81] 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.

of China's headline target of 1200 GW wind and solar by 2030. Combined with the national FYP target for nuclear power and expected expansion of hydropower, the added total non-fossil power generation will meet the range of capacity additions in almost all transition scenarios, with the exception of the NGFS Net Zero 2050 scenario, the one with the most ambitious overall emission pathway.

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 half of additional power generation in 2017–2022, with the rest provided by fossil fuels.

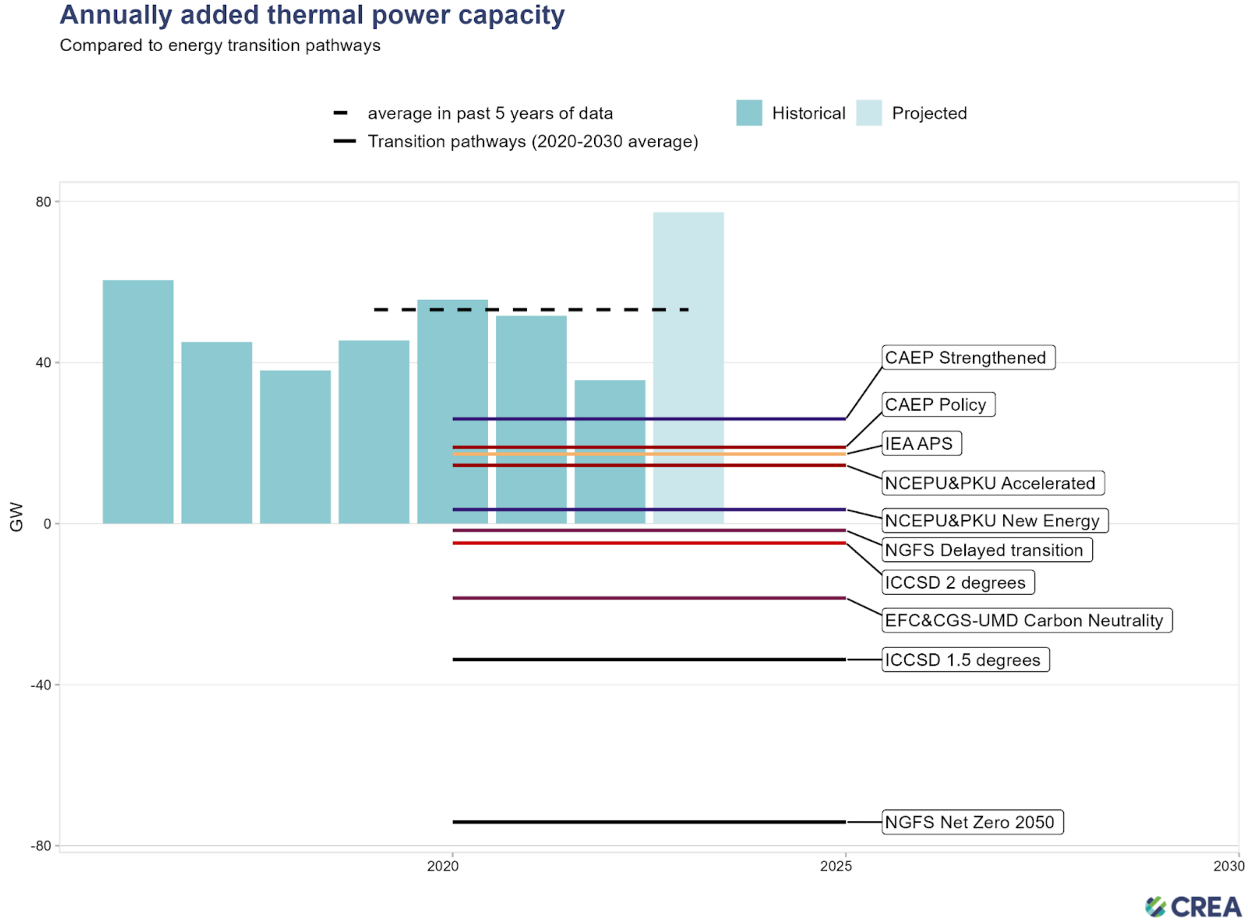

Figure 24 | Annually added thermal power capacity compared to energy transition pathways

Until 2022, China's net additions of thermal power capacity, mainly coal and fossil gas, 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. Yet, 2023 saw a sharp acceleration in new coal capacity as a result of permits and restarts of previously suspended projects that started in 2020.

Permitting new coal-fired power plants accelerated further in 2022 and 2023.

In 2020, China became one of the first major developing countries to commit to become carbon neutral. Since the announcement, one of Xi Jinping's central messages[82] was "strictly controlling high-energy, high-emissions projects", and in April 2021 he pledged specifically that China would "strictly control" new coal projects[83] at the Leaders Summit on Climate[84].

4.4.2 Focus on: China's Coal Power Surge

How did China go from pledging "strict control" in 2021 to a major surge in new coal projects in 2022? The turning point were concerns over electricity shortages in the autumn of 2021 and summer of 2022 which led to a policy reversal. The focus of energy policy has since shifted from discouraging and controlling new coal power projects to pushing for acceleration, with the regulators setting[85] a target in September 2022 to sharply accelerate construction starts, and pushing[86] profitable coal mining firms to invest in coal power generation.

While the power crunches have been the trigger of the recent coal spree, the shift in government policies on coal have changed the expectations of utilities and provincial officials, and there are several contextual and systemic drivers:

- **Inflexible grid operation:** coal power is far from the inevitable option to respond to power shortages in China. A flexible electricity system would make better use of existing power plants and transmission infrastructure. This will facilitate inter-province transmission, demand-side response and electricity storage, which reduce or eliminate the need for new coal power plants altogether. Yet reforms have been slow and patchy at best.
- **Self-reinforcing "coal rush" spiral:** The Chinese government's propensity for abrupt shifts in policy, best manifested by the hasty dismantling of the zero-COVID-19 policy, has prompted officials and companies alike to engage in an "enjoy while it lasts" mindset. When a large number of permits are handed out, market participants expect that the government will clamp down on the excesses, which becomes a reason to secure as many permits as possible. This dynamic played out during the coal plant permitting wave of 2015–2016, which was promptly followed by a clampdown first on new permits and then on already permitted projects in 2017.
- **Entrepreneurial instincts of state-owned enterprises and provincial officials:** On one hand, state-owned enterprises see the loosening scrutiny on coal as an opportunity to obtain market share by building capacity; on the other hand, provinces are seizing the opportunity to boost their power capacity. Coastal provinces prefer to generate power

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[82] Ministry of Ecological Environment. (2021). Guiding Opinions on Strengthening Ecological Environmental Management in High Energy-Consumption and High-Emission Projects. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202105/t20210531_835511.html. Government document.
[83] Xinhua News. (April 2021). Remarks by Chinese President Xi Jinping at Leaders Summit on Climate. http://www.xinhuanet.com/english/2021-04/22/c_139899289.htm. News.
[84] The White House. (April 2021). Leaders Summit on Climate Summary of Proceedings. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/23/leaders-summit-on-climate-summary-of-proceedings/. Government document.
[85] Jiemian News. (Oct 2022). China accelerates the approval process for coal-fired power plants. https://news.sina.cn/gn/2022-10-13/detail-imqqsmrp2477197.d.html. News report.
[86] Beijixing News. (Jan 2023). In 2022, the National Development and Reform Commission promoted the co-operation of coal and coal-fired power, as well as coal-fired power and new energy. https://m.bjx.com.cn/mnews/20230118/1283977.shtml. News report.

locally instead of relying on imports from inland, while inland provinces are counting on power exports to coastal provinces to justify their coal power investment. Big energy projects are a tried and tested way to boost local economic activity.

After the commitment to “strictly control” new coal power projects, the National Energy Administration (NEA) introduced a policy[87] that set strict conditions for new coal power projects. New plants will not be allowed for the purpose of “bulk power generation”, but only for “supporting” roles: supporting grid stability and integration of variable renewable energy into the grid.

However, there is no effective enforcement of the NEA policy that is meant to implement the pledge to “strictly control new coal power”. CREA assessment of coal power projects approved in 2022–2023 shows that the majority of the projects did not meet the requirements of the NEA policy and found that:

- The provinces building most new coal are not using it to “support” a correspondingly large buildout of clean energy.
- The majority of projects are in provinces that have no shortage of generating capacity to meet demand peaks.
- Most new project locations already have more than enough coal power to “support” existing and planned wind and solar capacity.

Between January 2022 and June 2023, China permitted 152 gigawatts (GW) and started construction on 92 GW of new coal power capacity. This is eight times the amount of capacity entering construction, and more than ten times the capacity permitted, in the rest of the world during the same period. Another 25 GW, at least, was permitted in China July to September 2023[88].

The situation highlights the need to reform China’s grid operation. 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. An analysis by Draworld Environment Research Center and CREA[89] 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 30 GW of coal-fired capacity in the East China grid alone.

[87] National Energy Administration. (2021).Summary of the Reply to Proposal No. 0481 of the Fourth Session of the 13th National Committee of the Chinese People's Political Consultative Conference (CPPCC). http://zfxxgk.nea.gov.cn/2021-08/27/c_1310486070.htm

[88] Announcements compiled from Polaris Network reporting, which is not a complete listing https://huodian.bjx.com.cn/yw/

[89] 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.

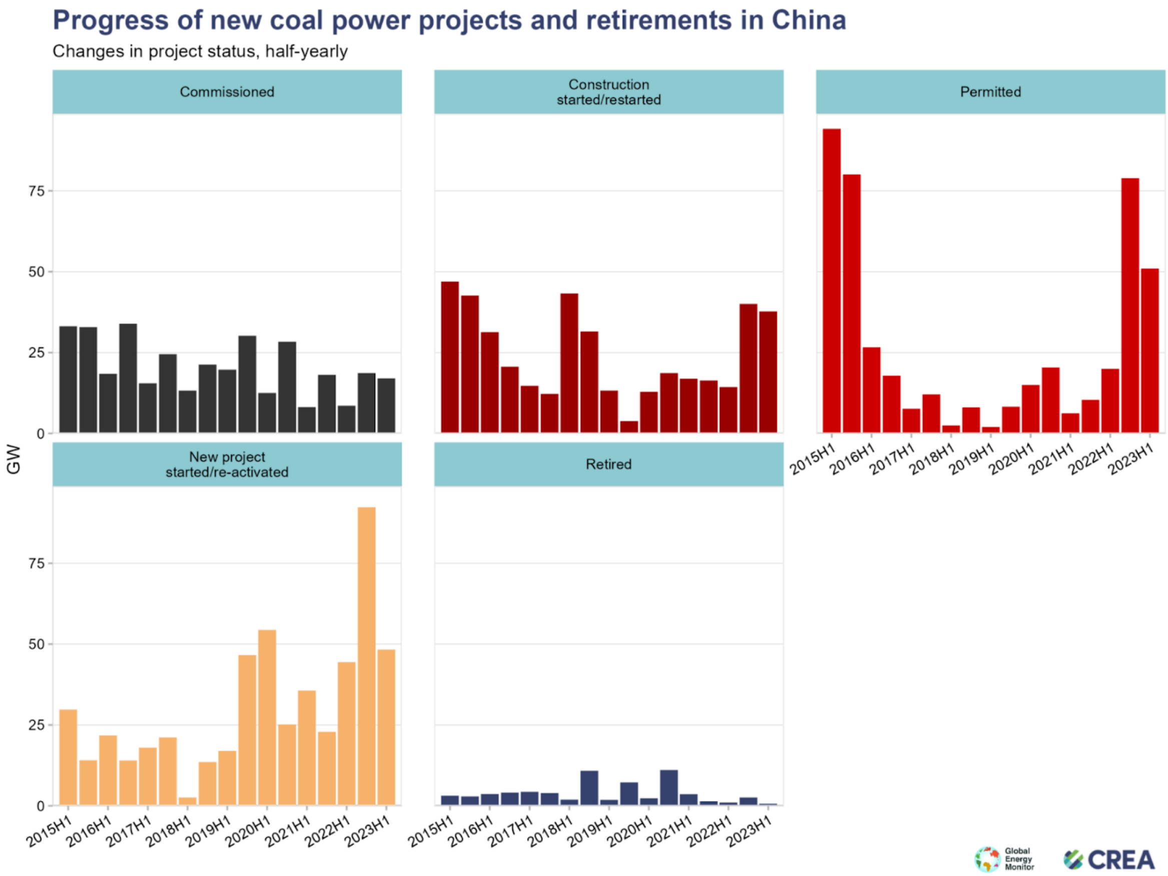

Figure 25 | Coal power pipeline in China; changes in project status, half-yearly

Source: CREA analysis of Global Coal Plant Tracker data.

4.4.3 Policies in place

Renewable energy and nuclear power

The *14th Five-Year Plan for renewable energy development*[90] is the overarching policy that comprehensively envisions the development of renewable energy in this decade. It sets multiple generation and consumption targets by 2025:

- The consumption of renewable energy is expected to grow to 1 Gtce, covering more than 50% of the growth in primary energy consumption.
- Annual electricity generated from renewable energy should reach 3300 TWh. The addition of renewables should make up more than half of newly added capacity, and solar and wind capacity should double during the 14th FYP period.
- The quotas for renewable electricity consumption should be raised to 33% of total electricity use, with the non-hydro consumption quota reaching 18%.
- Non-electricity usage such as geothermal, biomass heating and fuel, and solar energy heating should grow above 60 Mtce.

[90] 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.

The *14th Five-Year Plan for the 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. The China Nuclear Energy Development Report (2023)[91] predicts that China is poised to become the world's leading country in terms of operational nuclear power capacity by 2030. Additionally, it forecasts that by 2035, nuclear energy will make up approximately 10% of China's total electricity generation.

In terms of more specific policies, *Opinions on Promoting the Development of Non-Hydro Renewable Energy Power Generation,* provides guidance on the non-hydro renewable energy subsidies[92]. It also initiated work on a shift from tariff subsidies ramp-down mechanism to the Green Electricity Certificate for electricity trading as the instrument supporting renewable electricity buildout.

Meanwhile, the *Medium and Long-term Plan for the Development of the Hydrogen Energy Industry (2021-2035)*[93] draws the roadmap with 2025, 2030, and 2035 targets for the hydrogen industry. In August 2023, national guidelines[94] for the hydrogen energy industry were released, aiming to create a comprehensive standard system. Over 30 provinces and cities have included hydrogen energy development in their 14th FYPs, with detailed implementation plans in places like Beijing, Hebei, Sichuan and Inner Mongolia. According to the *2023 China Hydrogen Energy Industry Development Blue Book*[95], in 2022, China had a hydrogen production capacity of 41 million tons/year, yielding 37.81 million tons/year. By 2023, in line with carbon peak goals, China aims to surpass 50 million tons/year in hydrogen production.

The Development Plan for Biological Economy also highlighted biomass energy as one of the "example projects" and encouraged subsidising biomass[96].

Consumption of Renewable Energy Electricity

In 2019, the NDRC and the NEA jointly issued the *Notice on Establishing and Enhancing the Mechanism to Ensure the Consumption of Renewable Energy Electricity*[97], outlining the establishment of the consumption quota mechanism of renewable energy electricity in various provincial-level regions. These quotas represent the target proportion of renewable energy electricity in the total electricity

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[91] China Nuclear Energy Association. (2023). China Nuclear Energy Development Report (2023). https://www.china-nea.cn/site/content/43211.html

[92] 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.

[93] 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.

[94] National Standardization Administration of China. (2023). Guidelines for the Construction of the Hydrogen Energy Industry Standard System (2023 Edition) https://www.gov.cn/zhengce/zhengceku/202308/content_6897986.htm

[95] Beijing Kingzone General Oil & Gas Consulting Co.(2023). China Hydrogen Energy Industry Development Blue Book (2023) https://3cst.cn/mobile/information/yNUz0BNkITGS11ea8d6300163e0473d8

[96] 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.

[97] National Development and Reform Commission of China. (2019). Notice on Establishing and Enhancing the Mechanism to Ensure the Consumption of Renewable Energy Electricity. https://www.gov.cn/xinwen/2019-05/16/content_5392082.htm

consumption of each province. The notice clearly specifies that power suppliers and power consuming companies are jointly responsible for renewable energy electricity consumption requirements. In practice, however, most provinces currently rely on grid companies to ensure the fulfilment of these consumption quotas. Starting in 2020, the NDRC and NEA have annually released documents specifying these quotas for each province for the current year and expected targets for the following year.

In 2023[98] Sichuan, Qinghai, and Yunnan stand out with the highest quota at 70%, and they are also major hydropower producers. For non-hydropower, Qinghai (27.2%), Ningxia (24.5%), and Jilin (23.5%) have the highest quota, and they are prominent in solar and wind power generation.

Whole County Distributed Solar Initiative

In June 2021, the National Energy Administration launched the "whole county distributed solar[99]" pilot programme for rooftop solar installations at the county (city, district) level. By 2023, distributed solar constituted half of the unprecedented increase in solar power capacity, highlighting the success of the model. Central to this initiative is the leadership of county governments, which spearhead the implementation process in their jurisdictions. They oversee the entire lifecycle of distributed solar projects, including investment, financing, construction, operation and maintenance. This approach of county-led "centralised development of distributed solar" has enabled rooftop solar at a vast scale.

Initially, 676 areas were selected for this initiative, with specific installation targets for government buildings (50%), public buildings (40%), industrial and commercial facilities (30%), and residential rooftops (20%) in the pilot counties. The programme aimed to be completed in each province by the end of 2023.

This initiative has dramatically boosted distributed solar development, with distributed installations accounting for 53% national solar capacity in 2021, surpassing centralised solar power stations. By 2022, this proportion had grown to 58% and remained above 50% in the first half of 2023 even as overall solar capacity additions increased by 150%. The programme has therefore been an essential driver of China's rapid scale-up of solar installations. However, as of April 2023, progress has been uneven. Only 22% of the planned capacity had been achieved nationwide, with some provinces like Henan and Shandong exceeding 30% while others lagged below 15%. The entry of large state-owned enterprises into the market crowded out private enterprises but faced challenges in dealing with local governments, commerce, and residents, causing delays in project implementation[100].

Large-scale Clean Energy Bases

China is pursuing both distributed and centralised renewable energy development. The 14th FYP for the Modern Energy System emphasises the need to accelerate large wind and solar power projects in desert areas and other regions, as well as build clean energy bases in areas like the upper Yellow River,

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[98] National Development and Reform Commission. (2023). Notice on the Consumption Responsibility Weights for Renewable Energy Electricity in 2023 and Related Matters. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202308/t20230804_1359101.html

[99] National Energy Administration. (2021). Notice Regarding the Submission of Pilot Schemes for Distributed Solar Power on the Roofs of Whole Counties (Cities, Districts). https://www.gov.cn/zhengce/zhengceku/2021-09/15/content_5637323.htm

[100] China Power. (2022). Latest Development of Whole Country Distributed Solar Initiative. http://mm.chinapower.com.cn/zx/hyfx/20220819/163598.html

Xinjiang, and northern Hebei.

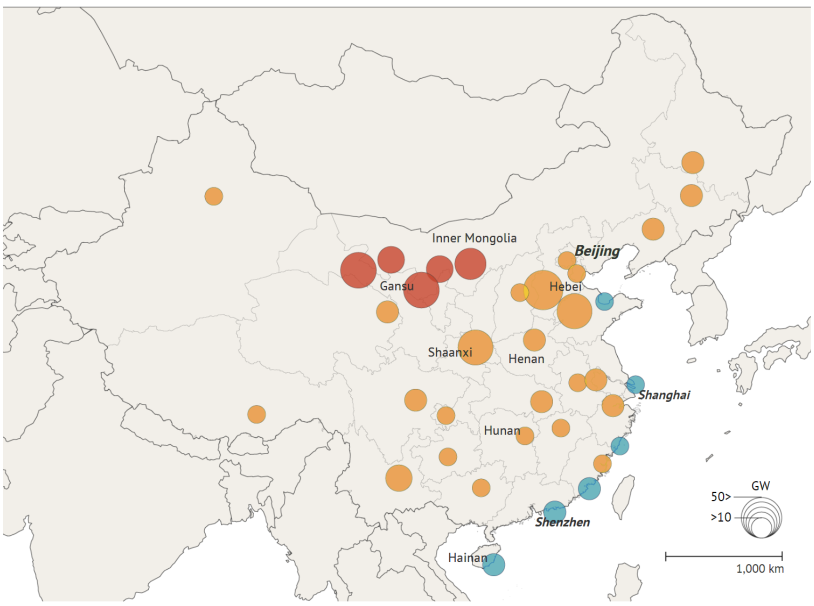
In February 2022, the NDRC and the NEA issued the *Plan for Large Wind and Solar Power Bases in Desert Areas*. This ambitious plan sets a target of 455 GW of wind and solar capacity by 2030. The first 97 GW of projects are underway, but progress is slower due to grid integration and unclear policy frameworks. As of July 2023, only 30 GW are operational.

These large-scale clean energy bases face challenges in balancing clean energy with coal power. They typically require thermal power backup, but the low utilisation hours of such backup can lead to losses, especially when coal prices are high. This has led to a lack of enthusiasm among power generation groups to provide supportive power sources for new energy projects. Paradoxically, despite the intention to reduce coal power's share, the prevailing approach has not significantly reduced the reliance on thermal power.

Furthermore, in the first batch of the large-scale clean energy base projects, the balance between consumption within the province and transmission to other provinces is roughly equal, while the second batch of projects focuses more on external power transmission. However, the costs associated with building power sources and equipping them with thermal power and energy storage, along with the high cost of ultra-high-voltage transmission lines, make it uncertain whether the electricity sent to eastern regions can compete with local coal power prices and local renewable energy prices.

China's clean energy bases' will help double its wind and solar capacity in five years

Desert base · Offshore base · Provincial plans and other bases



Clean energy bases and provincial clean energy installation plans with targeted installed wind and solar capacity by 2025 indicated by the size of the circles. The desert bases (red circles) in western Inner Mongolia and Gansu, offshore wind bases across the coast (blue) and provinces' own clean energy expansion (yellow) will all provide electricity to the demand centres in the east. Source: Authors' compilation of targets from policy documents. Map by Tom Prater for Carbon Brief.

Figure 26 | China's clean energy bases envisioned in the central and provincial Five-Year Plans[101]. Map by Tom Prater for Carbon Brief

[101] 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/

Energy storage

As confirmed by NDRC and NEA's *Guiding Opinions on Accelerating the Development of New Energy Storage*[102]*,* energy storage takes a "key supporting role" in carbon peaking and carbon neutrality in the energy sector. It encourages a development of energy storage on multiple levels, including making national and provincial level development plans, promoting energy storage projects integrated with electricity generation (generation-side) and electricity distribution (grid-side), as well as supporting building-level (behind the metre) storage. In February 2023, the NEA released guidelines to gradually establish a new energy storage standard system in line with China's context and international standards.

As the capacity of variable renewable energy sources like wind and solar power grows, the need for extended energy storage capacity has become critical. Nearly 30 provinces in China have introduced plans to promote "renewable energy combined with energy storage" to alleviate peak power supply challenges. These policies mandate that renewable energy sources be accompanied by energy storage systems, typically accounting for 10% to 20% of the installed capacity and requiring at least four hours of energy storage duration while keeping costs low. However, these mandatory requirements have also imposed financial burdens on renewable energy generation companies. And energy storage technology applications on the user side often offer better value.

New Power System

In June 2023, NEA released the *Blue Book on the Development of the New Power System*[103]. It outlines a three-phase roadmap (Figure 27) for the new power system.

- Acceleration Transformation Phase (present to 2030): This phase accelerates the transition to a new power system, promoting low-carbon energy adoption across industries with a goal of achieving a 25% non-fossil energy consumption share. It also fosters centralised and distributed renewable energy sources while encouraging industries to move from the east to the central and western regions.
- General Formation Phase (2030 to 2045): During this period, the new power system takes shape, with evolving infrastructure and technology, establishing the foundations of the new energy landscape.
- Consolidation and Improvement Phase (2045 to 2060): This final phase focuses on refining and stabilising the new power system.

[102] National Development and Reform Commission. (2021). Guiding Opinions on Accelerating the Development of New Energy Storage. https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/202107/t20210723_1291321.html. Policy.
[103] National Energy Administration(2023) Blue Book on the Development of the New Power System. http://www.nea.gov.cn/download/xxdlxtfzlpsgk.pdf. Research report.

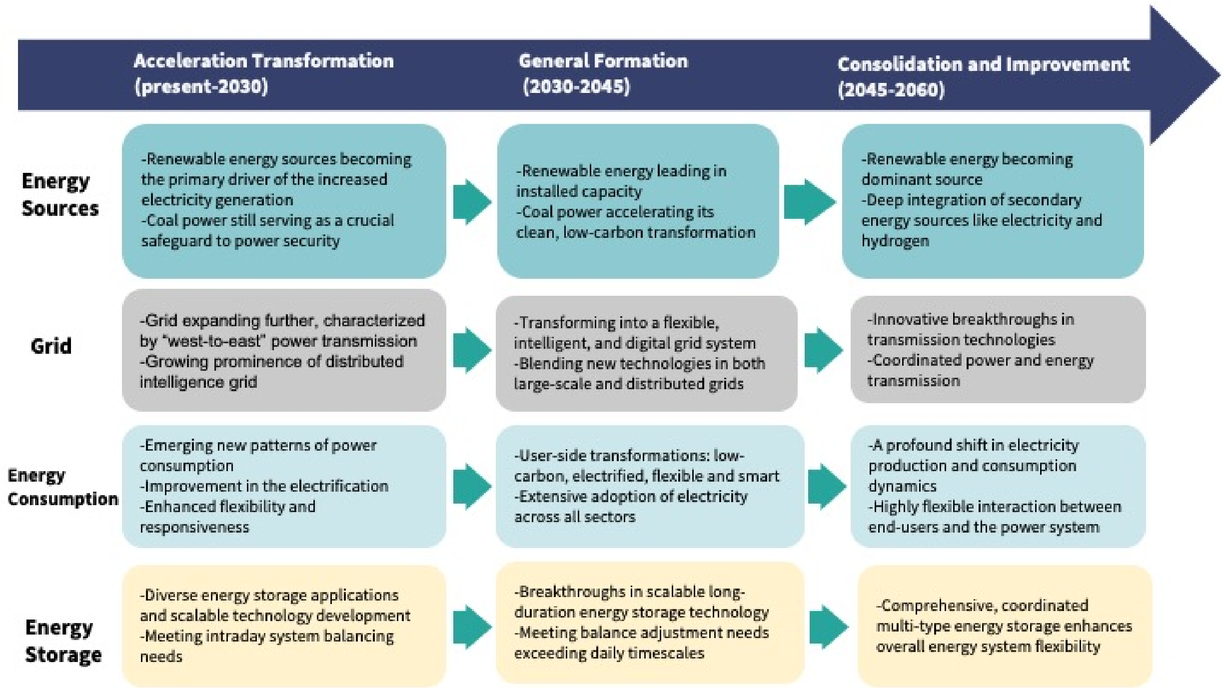


Figure 27 | China's New Power System Roadmap, from *Blue Book on the Development of the New Power System*

The *Blue Book* also outlines the development role of coal power. It clearly states that in the near to medium future, there remains potential for growth in both coal power capacity and electricity generation. The expansion of coal power is primarily intended to address peak electricity demand and provide emergency backup capacity.

Green Electricity Trading and Green Certificates

To promote the use of clean energy in China, a green certificate system[104] was established in 2017. Under this system, renewable energy companies can earn and sell green certificates based on their electricity generation. However, due to the voluntary nature of the system and the inability to convey the environmental benefits to end-users, green certificate trading was inactive.

To address this issue and encourage green energy adoption, in August 2021, the NDRC and NEA launched a pilot programme for Green Electricity Trading[105]. It 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 agreements, and also encourages long-term power purchase agreements.
- Priority principle: green electricity should be prioritised in each stage of the trading, covering organising, execution and settlement.

[104] National Development and Reform Commission of China. (2017). Notice on the Trial Implementation of the Renewable Energy Green Power Certificate Issuance and Voluntary Subscription Trading System https://www.ndrc.gov.cn/xxgk/zcfb/tz/201702/t20170203_962895.html
[105] 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. News.

- 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.

"Green electricity priority" is a fundamental principle of the pilot programme. In January 2022, NDRC and NEA issued guidance[106] emphasising the importance of determining the environmental value of green electricity through market mechanisms, encouraging users to directly purchase green electricity and urging grid companies to prioritise direct green electricity transactions. In May 2022, the State Council released an implementation plan[107] highlighting the need to prioritise green electricity in trading organisation, grid management and price-setting mechanisms. Later, NDRC and NEA issued a notice[108] regarding the signing and performances of long-term electricity contracts in 2023, and said green electricity priorities in the above fields "must be a given".

Furthermore, the government has issued multiple documents to boost demand for green electricity trading and expand the market. In January 2022, the Green Consumption Implementation Plan[109] was released to encourage industry leaders, large state-owned enterprises, and multinational corporations to lead in consuming green electricity. It enforces mandatory requirements for high-energy-consuming enterprises to use green electricity, with local authorities setting minimum proportions. It also establishes a mechanism linking green electricity trading with renewable energy consumption quotas, allowing power consuming companies to fulfil their renewable energy consumption quota by purchasing green power or green certificate. February 2023, government departments issued a notice[110], promoting comprehensive participation of subsidised projects in green electricity trading. In September 2023, Electricity Demand-Side Management Measures (2023 Edition)[111] was jointly issued by various government departments, promoting green electricity usage, particularly within new infrastructure, and encouraging local green electricity consumption. Additionally, there's an emphasis on key regions and enterprises increasing their green electricity consumption share.

Green certificates serve as indirect evidence of green energy consumption, while green electricity transactions offer direct proof. Initially, the green certificate trading market had very low trading volumes, but it became more active in early 2022. In August 2023, government departments jointly

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[106] National Development and Reform Commission of China.(2022).Guidance on Accelerating the Construction of a Unified National Electricity Market System. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202201/t20220128_1313653.html

[107] State Council of China. (2022). Implementation Plan for Promoting High-Quality Development of New Energy in the New Era. https://www.gov.cn/zhengce/content/2022-05/30/content_5693013.htm

[108] National Development and Reform Commission of China. (2022). Contract Signing and Performance in the Long-term Electricity Market for 2023.https://www.ndrc.gov.cn/xwdt/tzgg/202212/t20221222_1343757.html

[109] National Development and Reform Commission of China. (2022). Green Consumption Implementation Plan. https://www.ndrc.gov.cn/xwdt/tzgg/202201/t20220121_1312525.html

[110] Idea Carbon (2023). Surplus from Green Electricity Trading to Offset National Subsidies or to Be Owned by the State https://www.ideacarbon.org/news_free/59010/?pc=pc News.

[111] National Development and Reform Commission of China. (2023). Electricity Demand-side Management Measures(2023 Edition). https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/202309/t20230927_1360902.html

issued a notice[112], clarifying that green certificates are the sole proof of environmental attributes for China's renewable energy electricity volume. The issue of green certificates has expanded to encompass all registered and approved renewable energy generation projects, achieving full coverage. Tradable green certificates can serve as proof of renewable energy consumption and can be transferred between power generation companies and users through various means, including green certificate trading and green electricity transactions. Under current policies, it's important to note that green certificates can only be traded once, and purchasers are not permitted to resell them. This restriction significantly limits the transferability of green certificates.

Green Electricity Trading and CCERs both can help carbon-emitting companies meet compliance obligations. Under the current market rules, renewable energy projects with CCER registrations can simultaneously sell green certificates and CCERs to generate additional revenue.

Electricity Spot Market

China's electricity market development differs from many global markets because it prioritises medium- to long-term trading before spot markets. This approach is aimed at providing price stability and risk mitigation. Currently, medium- to long-term markets dominate China's electricity trade.

In 2015, the Implementation Opinions on Promoting the Construction of Electricity Markets[113] proposed gradually establishing market-based mechanisms for quantity-based electricity trading, with a focus on medium- to long-term trading and supplemented by spot trading. The objective was to create a risk-hedging platform in the medium to long term while discovering prices in the spot market and offering a comprehensive range of electricity market products and services, including day-ahead, real-time trading, and ancillary services.

In 2017 and 2021, pilot provinces and cities were chosen for spot markets. In 2022, national guidelines[114] were introduced to establish a unified electricity market system by 2025, integrating medium- to long-term, spot, and ancillary services markets.

Spot markets are categorised as provincial, inter-provincial, and national. Provincial spot markets are operating continuously, while inter-provincial markets are developing. The aim is to create a unified national spot market by 2030. In September 2023, the *Basic Rules for the Electricity Spot Market (Trial)* were introduced, providing unified national guidelines for provincial and inter-provincial spot markets, and potentially paving the way for an eventual national market.

The Basic Rules stress inter-provincial and provincial/regional spot market integration. They aim to include various market participants in inter-provincial markets, fostering participation from power generators, users, and retailers. Inter-provincial spot trading has played a role during peak electricity demand in 2023.

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[112] National Development and Reform Commission of China, Ministry of Finance, and National Energy Administration on Achieving Full Coverage of Green Power Certificates for Renewable Energy and Promoting Renewable Energy Electricity Consumption.
https://www.ndrc.gov.cn/xwdt/tzgg/202308/t20230803_1359093.html

[113] National Energy Administration. (2015). Implementation Opinions on Promoting the Construction of Electricity Markets.
https://www.gov.cn/xinwen/2015-11/30/5018221/files/87556b7e1f4f4aaab86ac7c99f5acf3f.pdf

[114] National Development and Reform Commission. (2022). Guiding Opinions of the Central Committee of the Communist Party of China and the State Council on Accelerating the Construction of a Nationwide Unified Electricity Market System https://www.ndrc.gov.cn/xxgk/zcfb/tz/202201/t20220128_1313653.html

These rules also focus on renewable energy participation, designing market mechanisms aligned with their characteristics, and encouraging involvement from distributed generation, load aggregators, energy storage, and virtual power plants in electricity trading.

In October 2023, the NDRC and the NEA issued new directives[115] for the development of electricity spot markets. They require most provinces to be ready for spot market trials by year-end 2023 and set specific timelines for market development. For example, Zhejiang is tasked with launching continuous settlement trials by June 2024, and Fujian must conduct long-term settlement trials by late 2023. The directives also outline criteria for full spot market operation, with most initial pilot provinces meeting these criteria after a year of continuous operation.

In terms of regional markets, South China's spot market is slated to begin settlement trials by end-2023, while the Beijing-Tianjin-Hebei market aims for simulated trials by June 2024.

The directives emphasise opening up spot markets to diverse power sources, aligning with the 2030 goal of comprehensive participation of new energy sources. They also encourage greater participation of distributed energy sources.

Capacity payment mechanism

As large-scale renewable energy generation is integrated into the power grid, coal power units are supposed to shift from primary sources of generation to backup and system regulation roles[116]. However, coal power units in China have faced challenges in recovering their costs. Despite central government pressure to ensure power supply, some coal generators have been hesitant to operate as their fuel and operating costs often surpass the revenue generated from electricity sales. The absence of a cost recovery mechanism for generating capacity has raised concerns about the reliability of coal power's contribution to peak load regulation, potentially leading to underutilised coal power assets. Recognizing these challenges, the *Guiding Opinions on Accelerating the Construction of a National Unified Electricity Market System*[117] , released in January 2022, advised regions to explore various methods, including scarcity pricing, capacity payment, and capacity markets to establish cost recovery mechanisms for generating capacity tailored to their needs.
In line with this guidance, China has now expanded the capacity payment mechanism. As of November 2023, a coal power capacity payment mechanism[118] has been introduced. Provincial-level coal capacity electricity prices have been announced, with implementation scheduled for 1 January, 2024. The mechanism will provide an additional incentive for power companies to complete the newly permitted coal power plants, as well as an incentive to delay the retirement of existing coal power capacity. At the same time, the payments could make the transition of coal power to a supporting role in the grid, involving lower utilisation hours, more palatable politically and financially. It also transfers some of the cost of maintaining China's very large coal power capacity from state-owned power

[115] National Development and Reform Commission. (2023). Notice on Further Accelerating the Construction of the Electricity Spot Market https://www.ndrc.gov.cn/xxgk/zcfb/tz/202311/t20231101_1361704.html
[116] National Energy Administration. (2021). Response to the Proposal on High-Quality Development of the Coal Power Industry Under the Carbon Neutrality Goal http://zfxxgk.nea.gov.cn/2021-08/27/c_1310486070.htm
[117] National Development and Reform Commission. (2022). Guiding Opinions on Accelerating the Construction of a National Unified Electricity Market System.
https://www.ndrc.gov.cn/xxgk/zcfb/tz/202201/t20220128_1313653.html. Policy.
[118] National Development and Reform Commission. (2023). Notice Regarding the Establishment of a Coal Power Capacity Payment Mechanism. https://www.ndrc.gov.cn/xwdt/tzgg/202311/t20231110_1361899.html. Policy.

companies to industrial and commercial electricity consumers in each province, which could encourage provincial officials to avoid excess capacity. Prior to this, China had implemented capacity payment for pumped storage power stations[119] and certain natural gas power generation stations in specific regions.

Incremental Distribution

In September 2023, China's NDRC issued a public notice seeking feedback on the *Draft of Division of Incremental Distribution Business Distribution Areas*[120]. Incremental distribution, a product of the 2015 power system reform, is a vital pathway for private investment in the grid sector, balancing against traditional power grid enterprises, mitigating monopolies, optimising grid costs, and enhancing service quality. The proposed changes in the draft mainly focus on clarifying the division principles, specifying that the primary recipients of incremental distribution networks are renewable energy resources, simplifying area division criteria, and further defining the rights and responsibilities of distribution businesses.

Table 7 | Selected policies relating to the electricity sector

Policy name	Release date	Targets and Highlights
14th Five-Year Plan for Modern Energy System, (National Development and Reform Commission and others)	2022-03	• 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	• 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.
Implementation Plan for the Retrofitting and Upgrading of Coal-fired Power Plants, (National Development and Reform Commission and others)	2021-11	• By 2025, the average 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.

[119] National Development and Reform Commission. (2023). Notice Regarding Capacity Pricing for Pumped Storage Power Stations and Related Matters. https://www.ndrc.gov.cn/xwdt/tzgg/202305/t20230515_1355745.html

[120] National Development and Reform Commission of China. (2023). Draft of Division of Incremental Distribution Business Distribution Areas. https://www.ndrc.gov.cn/hdjl/yjzq/202309/P020230925404913402231.pdf

Policy name	Release date	Targets and Highlights
Guiding Opinions on High-Quality Development of the Coal Industry in the "14th Five-Year Plan", (China Coal Industry Association)	2021-06	• 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	• 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	• 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	• State Grid Corporation and Southern Grid Corporation Launch Green Electricity Trading Pilot • Market participants involved in green electricity trading are required to obtain approval from the relevant local government authorities. This primarily includes grid companies, wind and solar power generation companies, electricity users, and electricity retail companies
Guiding Opinions on Accelerating the Development of New Energy Storage, (National Development and Reform Commission and others)	2021-07	• 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.
Blue Book on the Development of New Power Systems,(National Energy Administration)	2023-06	• Acceleration Transformation Phase (Present to 2030): This phase accelerates the transition to a new power system, promoting low-carbon energy adoption across industries with a goal of achieving a 25% non-fossil energy consumption share. It also fosters centralised and distributed renewable energy sources while encouraging industries to move from the east to the central and western regions. • General Formation Phase (2030 to 2045): During this period, the new power system takes shape, with evolving infrastructure and technology, establishing the foundations of the new energy landscape. • Consolidation and Improvement Phase (2045 to 2060): This final phase focuses on refining and stabilising the new power system.
Plan for Large Wind and Solar Power Bases in Desert Areas, (National Development and Reform Commission and others)	2022-02	• By 2030, the planned construction of wind and solar power bases will have a total installed capacity of approximately 455 GW

4.4.4 Data disclosure

The 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

2023 Highlights

- **Emission:** Industrial energy consumption growth increased at a high rate, reflecting the consistency of an energy-intensive pattern of economic growth. Despite that, electrification has progressed faster in the industrial sector, and direct coal consumption in the industry has been falling quite rapidly, largely driven by air pollution policies requiring the replacement of coal with gas and electricity.

- **Sectoral development:** Progress on clean technology manufacturing has been rapid since the carbon neutrality announcement in 2020, and has accelerated further in 2022–2023, as a result of an unprecedented boom in investment. On the other hand, the development of coal-based steelmaking capacity continued at a high rate in 2023, remaining out of step with the prospect of emissions peaking and a shift to more steel production from scrap.

- **Policymaking:** MEE started to request seven energy-intensive industrial sectors to report and verify emissions in 2022. Building on that, a more detailed action plan of emissions reporting for key industrial sectors 2023–2025 was released in Oct 2023. It is seen as an important step to steadily expand ETS by 2025, embracing other emissions-intensive industries – cement, steel, and aluminium.

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 CO_2 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 CO_2 emissions will peak before industrial energy demand, between 2020 and 2025.

Under the ICCSD's 2°C and 1.5°C scenarios, total industrial CO_2 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 tCO_2), total industrial CO_2 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.

Clean energy manufacturing as the economic bright spot of 2023

Besides emissions reductions, the industrial sector also needs to deliver the equipment for the low carbon transition: everything from wind turbines and rail engines to batteries and heat pumps. Progress on this front has been rapid since the carbon neutrality announcement in 2020, and has accelerated further in 2022–2023, as a result of an unprecedented boom in investment.

We estimate that 10% of all fixed asset investment in 2023 will go into clean power generation, energy storage, electric vehicles, rail transportation and electricity transmission. This investment grew approximately 40% on year and contributed all of the growth in investment year-on-year: without it, fixed asset investment would see zero growth.

The manufacturing of solar panels, EVs and batteries alone will be responsible for 3% of China's CO_2 emissions in 2023, with the combined emissions from those sectors increasing by an estimated 60% year-on-year. These emissions will be offset many times over by emissions reductions from all the solar panels, wind, EVs, batteries, railways and so on once they're in use in China and the rest of the world, but the manufacturing still represents an upfront emissions cost to the transition.

4.5.1 Trends compared to benchmarks

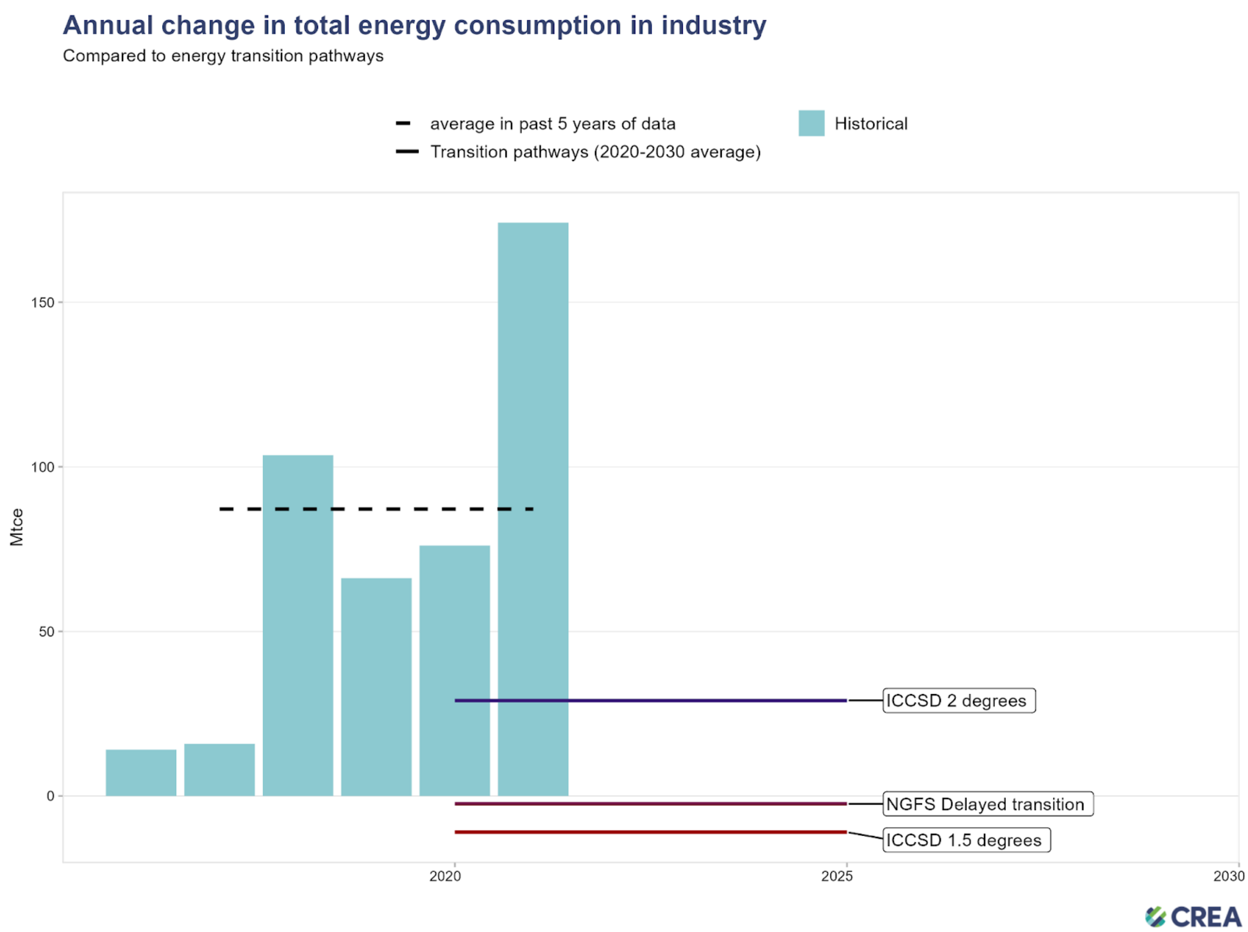

Figure 28 | Annual change in total energy consumption in industry compared to energy transition pathways

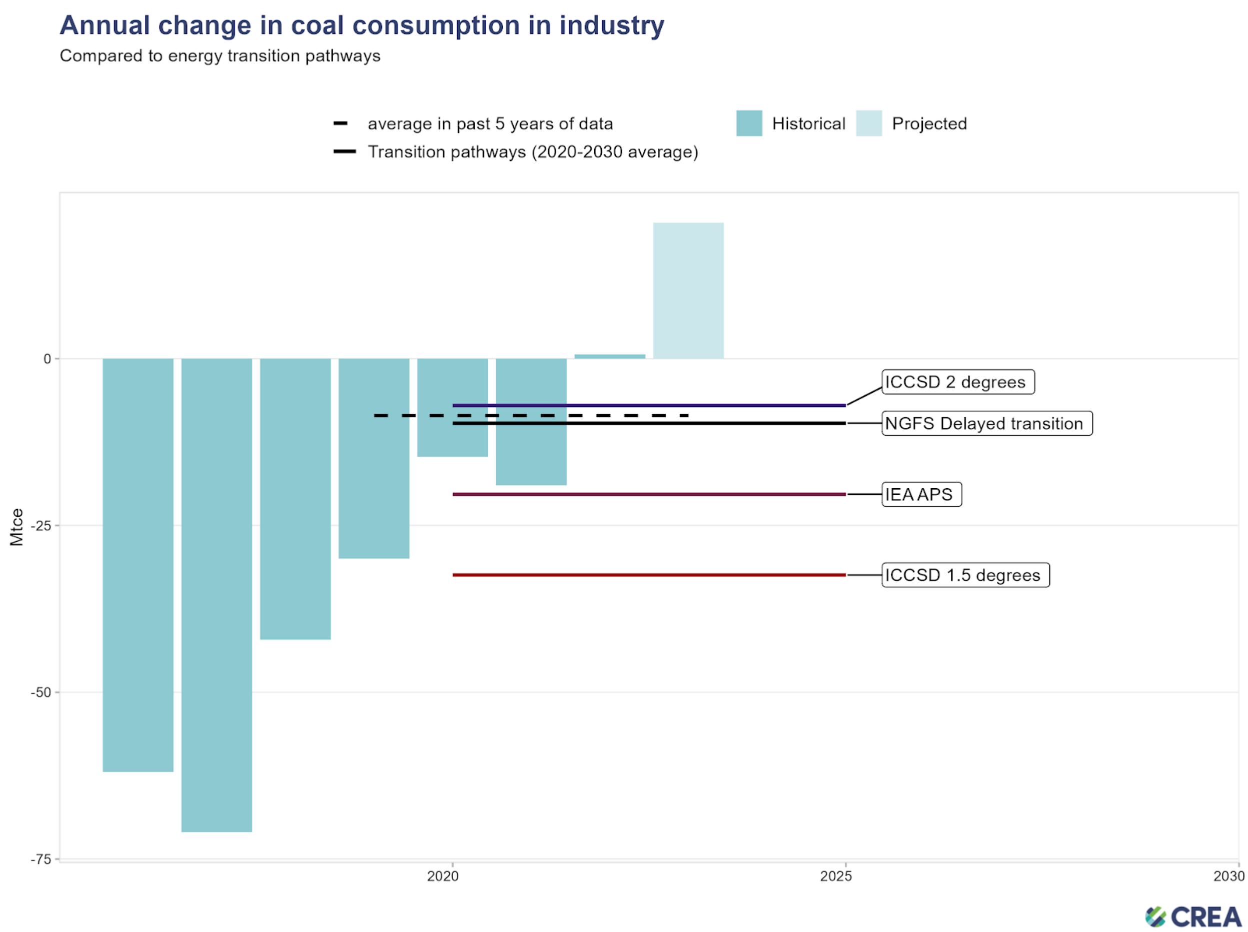

Figure 29 | Annual change in coal consumption in industry sector compared to energy transition pathways

Industrial energy consumption growth was much faster than in the transition pathways from 2017–2021, with growth accelerating from 2018. This reflects the energy-intensive pattern of economic growth after President Trump's tariffs and the onset of the COVID-19 pandemic.

The sector in which 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 that 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.

After falling in 2015–2021, coal consumption in industry has increased in 2022–2023. The overall trend is from rapid reductions during the industrial slowdown and air pollution campaigns of 2015–2017 to first slower reductions and then outright increases.

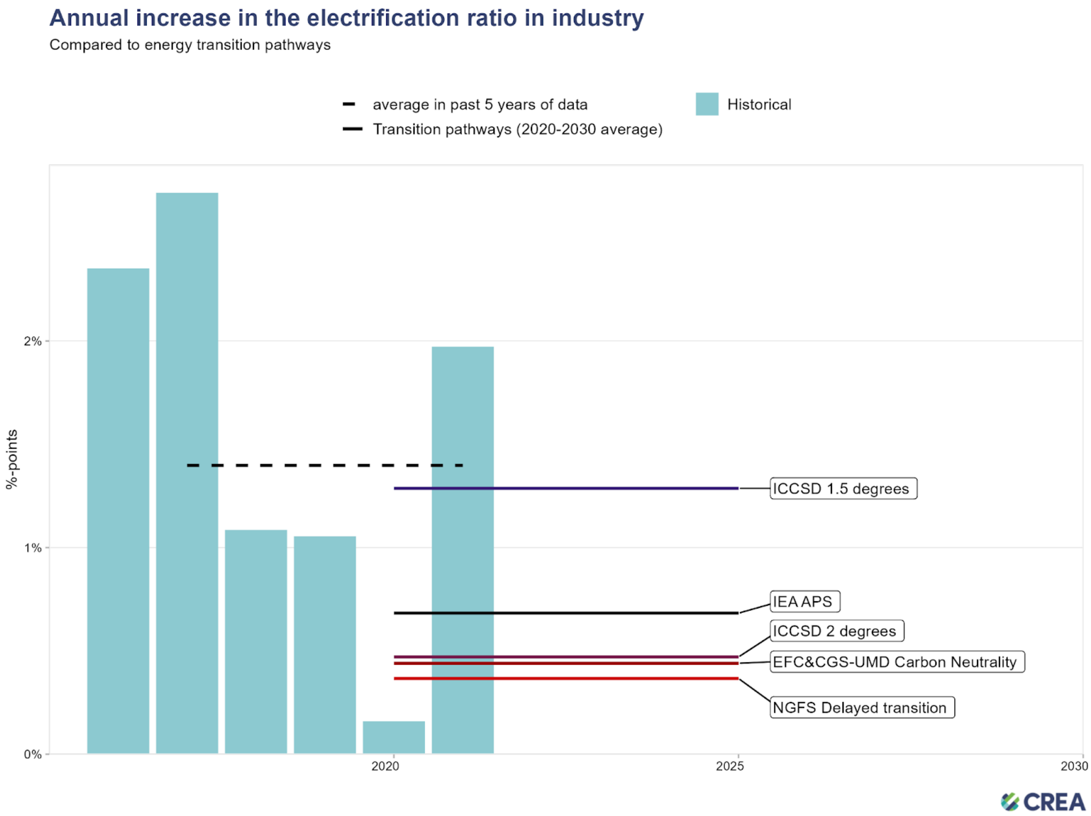

Figure 30 | Annual increase in the electrification ratio in industry compared to energy transition pathways

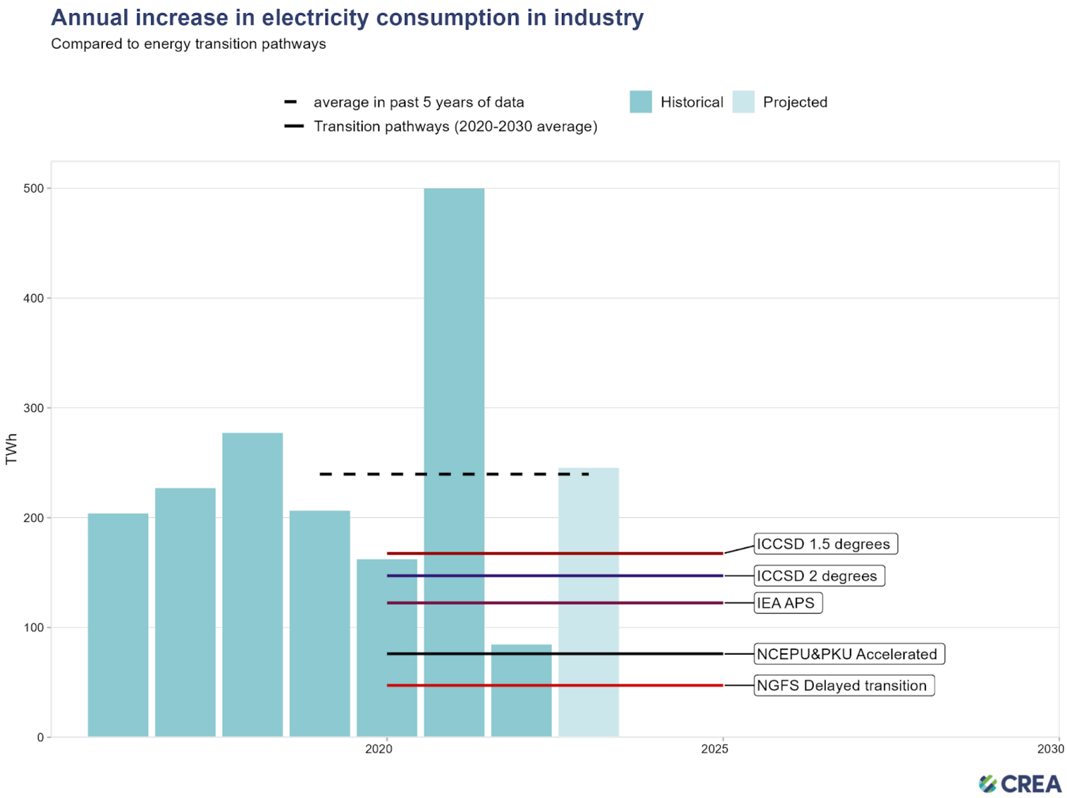

Figure 31 | Annual increase in electricity consumption in industry compared to energy transition pathways

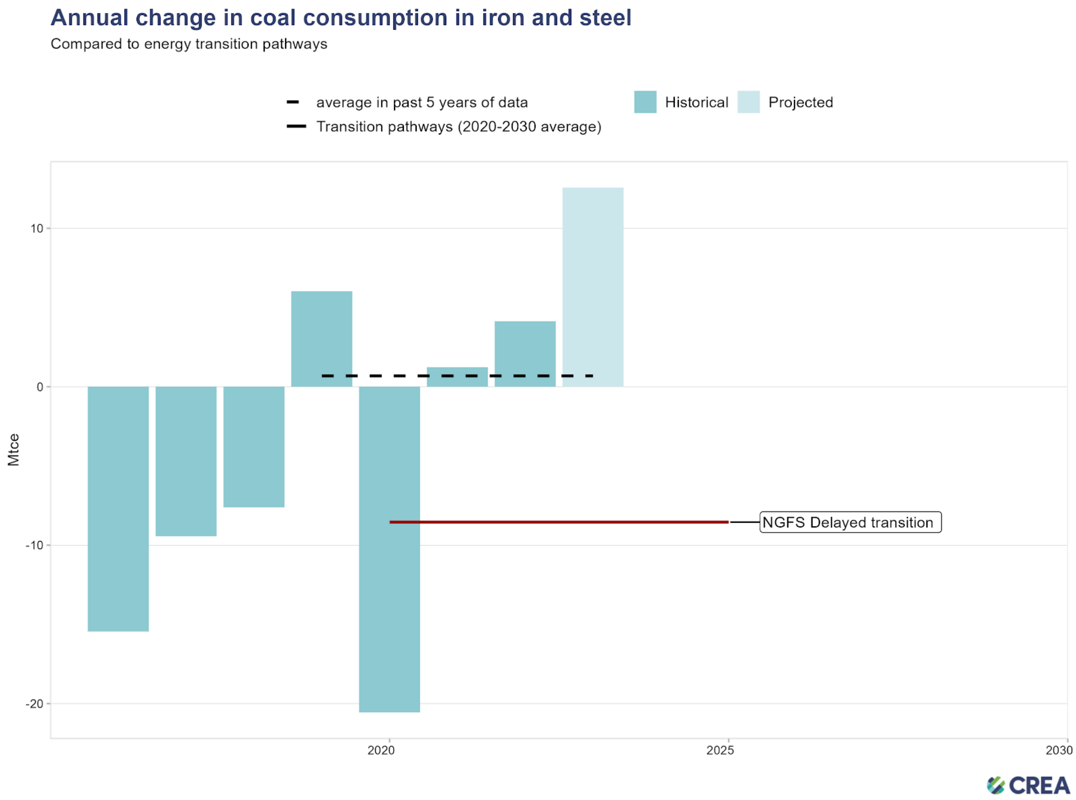

Figure 32 | Annual change in coal consumption in iron and steel compared to energy transition pathways

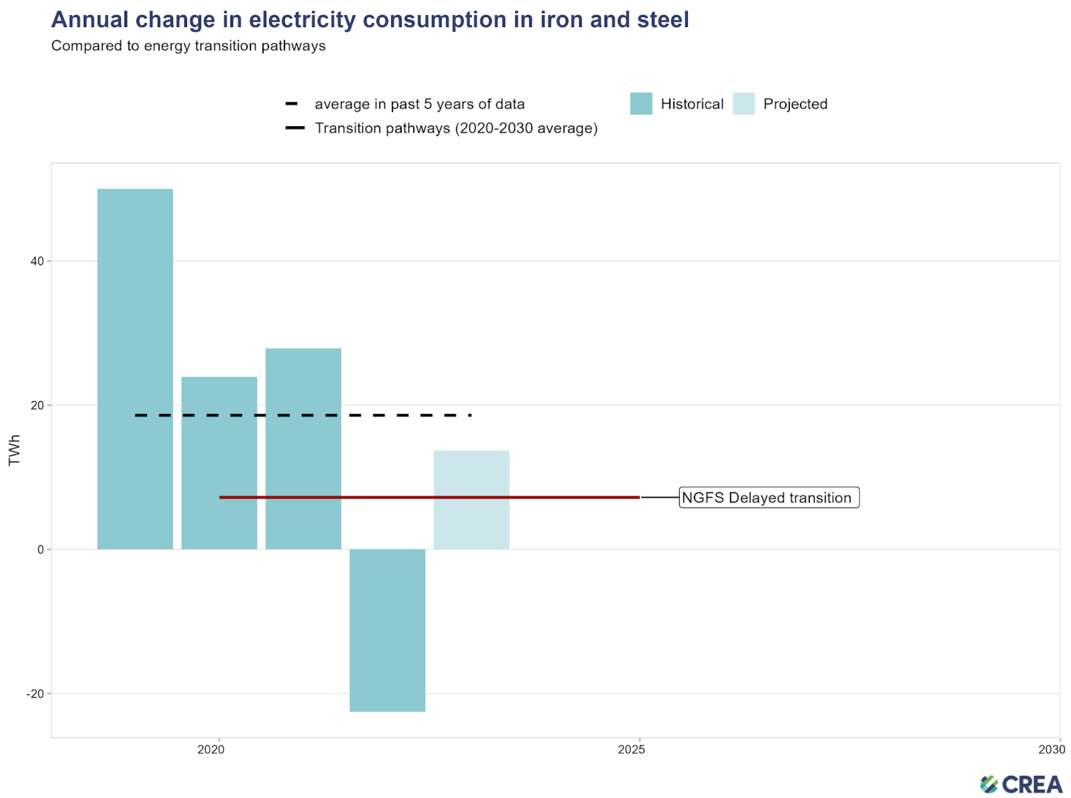

Figure 33 | Annual change in electricity consumption in iron and steel compared to energy transition pathways

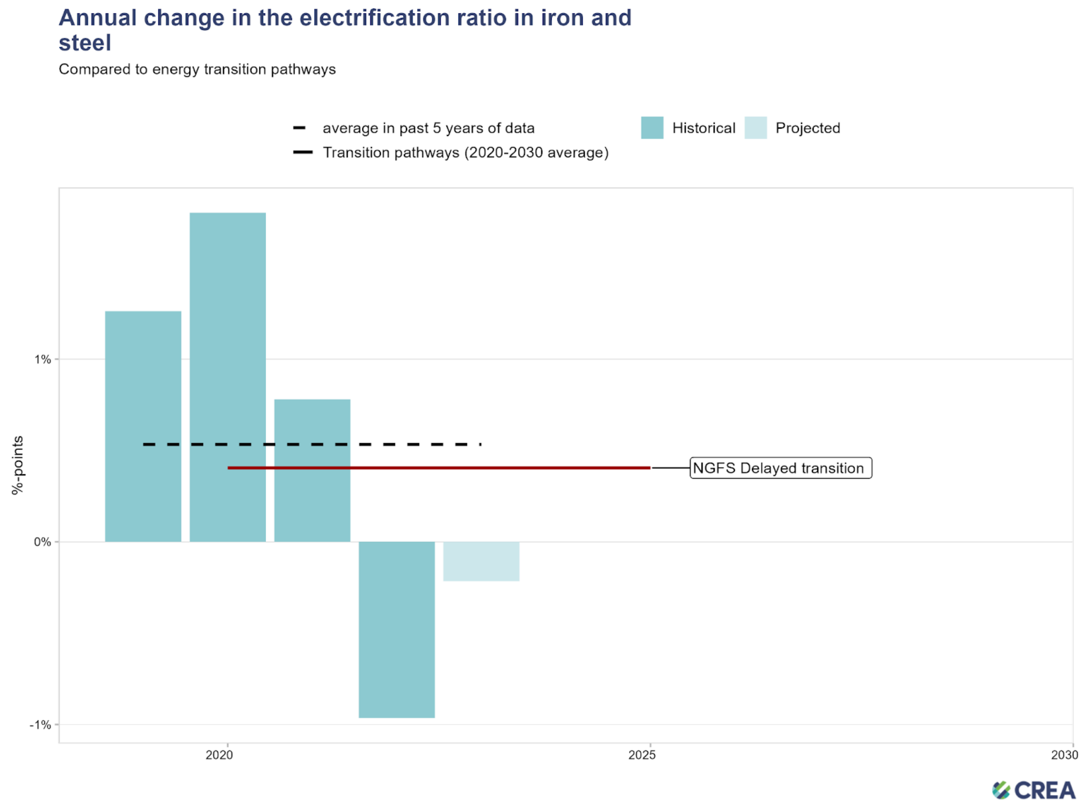

Figure 34 | Annual change in the electrification ratio in iron and steel compared to energy transition pathways

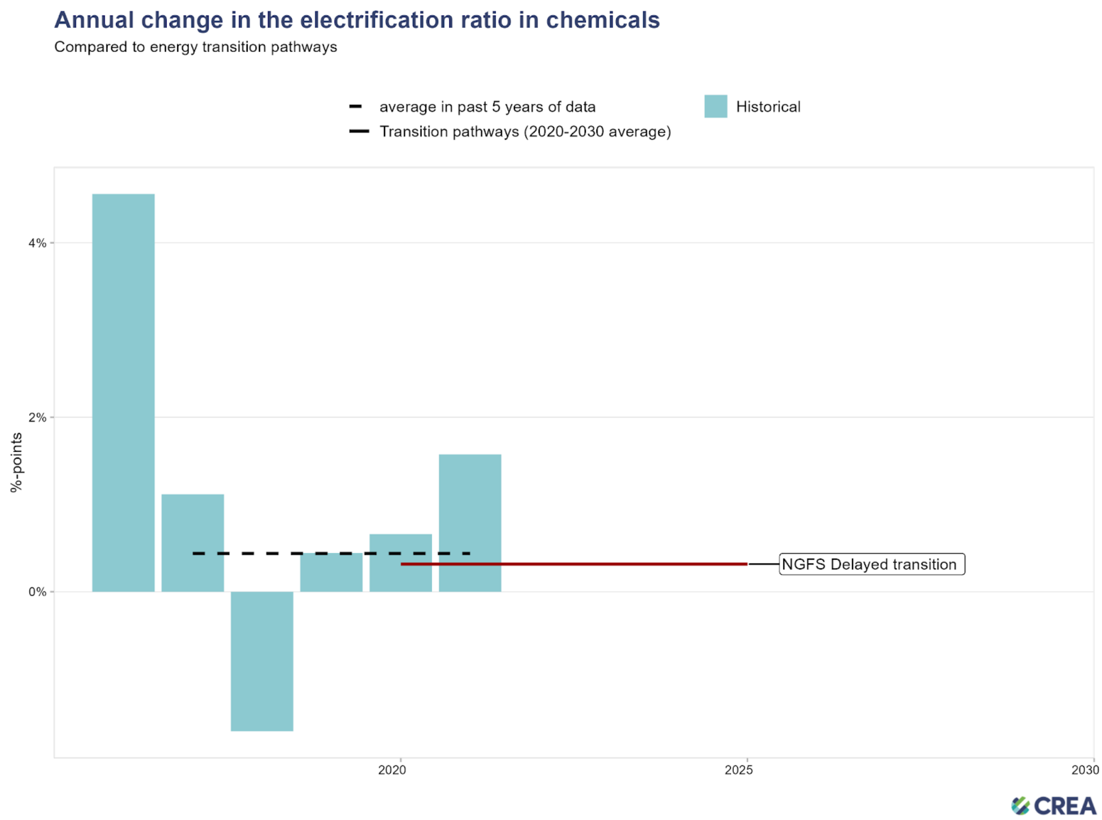

Figure 35 | Annual change in the electrification ratio in chemicals compared to energy transition pathways

4.5.2 Policies in place: Peaking carbon dioxide emissions in industry

China's plan to peak carbon dioxide emissions in industry is divided into two stages, corresponding to the two five-year periods, namely the 14th FYP (2021-2025) and 15th FYP (2026-2030).

MIIT released the *14th Five-Year Plan for Industrial Green Development* in December 2021, laying out detailed targets and action plans by 2025, with the aim to establish a foundation for the goal of carbon peaking before 2030.

Building on that, MIIT released the *Implementation Plan for Carbon Peaking in the Industrial Sectors* in July 2022. This serves as the top guidance for the various industrial sectors' carbon peaking work throughout 2030, with six key tasks and two key actions. The six key tasks apply to all industrial sectors, and the two key actions are targeted at production and goods supply end for each sector. MIIT also led the work to make specific policy and plan for each task and action, as well as the integration with existing early policies.

Due to its dominant share in China's CO_2 emissions, the industrial sector is heavily regulated by an abundance of policies, action plans, and emission standards. Here we listed selected relevant policies below.

Table 8 | Selected policies relating to industry

Policy name	Release date	Targets and Highlights
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)	2021-12-03	• 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.

Policy name	Release date	Targets and Highlights
The 14th Five-Year Plan for Circular Economy Development, (National Development and Reform Commission)	2021-7-7	• 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, 11.5 million tonnes, and 2.9 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)	NA	• 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.

Policy name	Release date	Targets and Highlights
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 Industry, (Ministry of Industry and Information Technology and others)	2022-06-19	• By 2025, the efficiency of resource utilisation will be greatly improved, and the energy consumption per unit 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.
Notice on the exclusion of new renewable energy consumption from total energy consumption control (National Development and Reform Commission)	2022-11-16	• Exclude renewable energy consumption in the total energy consumption cap, including wind power, solar power, hydropower, biomass power generation, geothermal power generation and other renewable energy sources.
Notice on the exclusion of non-energy use of fossil fuels from total energy consumption control (National Development and Reform Commission)	2022-11-01	• Coal, petroleum, natural gas and their products used to produce olefins, aromatics, alkynes, alcohols, synthetic ammonia and other products for non-energy purposes belong to the category of raw material energy consumption.

Policy name	Release date	Targets and Highlights
Updated Guidance on Environmental Impact Assessment Projects in the Four Industries: Steel/Coking, Modern Coal Chemicals, Petrochemicals, and Thermal Power, (Ministry of Ecology and Environment)	2022-12-14	• Include the control of greenhouse gases emissions in the EIA. Encourage the development of EAF scrap steelmaking, non-blast furnace ironmaking, CCUS, green hydrogen etc.
Action Plan of MRV reporting for key industrial sectors 2023–2025 (Ministry of Ecology and Environment)	2023-10-18	• MEE started to request seven energy-intensive industrial sectors, including petrochemical, chemical, building materials, steel, nonferrous metals, paper and civil aviation industries, to report and verify emissions in a regular base annually.
Plan for Steady Growth of Power Equipment Manufacturing (2023-2024) (Ministry of Industry and Information Technology and others)	2023-09-04	• Ensure a steady growth of the power equipment manufacturing, aiming for an annual 9% growth of the total revenue between 2023 and 2024.
Guiding Opinions on Promoting Green Innovation and High-quality Development of the Refining Industry (National Development and Reform Commission)	2023-10-25	• By 2025, the domestic primary crude oil processing capacity will be controlled within 1 billion tons, and the 10-million-ton refining capacity will account for about 55% of the total capacity..

EIA and "dual control" of energy for energy and carbon intensive industries

MEE updated environmental impact assessment (EIA) guidance for four energy and carbon intensive industries – steel/coking, coal chemicals, petrochemicals, and thermal power at the end of 2022, with the aim to curb the blind investment in energy and carbon intensive industries. Besides strengthening pollution control in the EIA process, the new guidance requires greenhouse gases emissions assessment for new projects, and promotes low carbon projects such as secondary steelmaking using electric arc furnaces, non-blast furnace ironmaking, hydrogen metallurgy technology, CCUS, and green hydrogen.

The aggressive investments in heavy industries have been a hindrance to meet the goal of "dual control" of energy for the majority of the provinces. The National Energy Plan for 14th FYP (2021-2025) targets a 13.5% reduction in energy intensity, with the national target broken down to provincial targets. Meeting this target is proving to be very difficult, as economic growth during the zero-COVID-19 period has been driven largely by the more energy intensive sectors of the economy. An assessment released by NDRC in August 2021 shows the poor performance of the provinces on meeting their dual control targets[121]. Tellingly, the NDRC has not released updated assessments since

[121] National Development and Reform Commission. Evaluation of the "dual control" of energy consumption by provinces.(Aug, 2021) https://www.ndrc.gov.cn/xwdt/tzgg/202108/t20210817_1293836.html. Government

then, but national-level data indicates that energy intensity only fell 3.1% from 2020 to the first half of 2023, a far cry from the 7% reduction needed to put the country on track to meet the target in 2025.

The “dual control” of energy consumption has put limits on the growth in energy consumption for each province, as well as on developing new projects with high energy intensity. Despite the effort of exploring low-carbon development models, it has been difficult for provincial governments to move away from the old energy intensive economic model. With the economy picking up following the removal of zero-COVID-19 policies, 2023 has seen year-on-year growth in investment and output in the energy- and carbon-intensive chemical, steel, power and fossil fuel-processing sectors[122].

MRV reporting for industrial sectors

China’s national emissions trading system (ETS) came into operation in 2021[123]. Initially covering the power sector, which accounts for over 40% of China’s energy-related CO_2 emissions, the ETS is set to subsequently be expanded to other energy-intensive industrial sectors. The annual procedure for monitoring, reporting and verifying (MRV), together with all the associated processes, is known as the ETS compliance cycle.

In addition to the power sector, MEE started to request seven energy-intensive industrial sectors, including petrochemical, chemical, building materials, steel, nonferrous metals, paper and civil aviation industries, to report and verify emissions in 2022. A more detailed *Action Plan of MRV reporting for key industrial sectors 2023–2025* was released in October 2023. It is seen as an important step to steadily expand ETS by 2025, embracing other emissions-intensive industries – cement, steel, and aluminium.

Peak industrial carbon emissions

Steel, building materials (cement and glass) and non-ferrous metals (aluminium) are among the top industrial carbon emitters in China. MIIT has made action plans for each of them with the goal to peak their emission before 2030.

New technologies, such as hydrogen, and renewable energy in these sectors will play an important role in decarbonisation. *The Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035)* has set three-stage targets: 1) 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. 2) By 2030, a relatively complete hydrogen energy industry technology innovation system, clean energy hydrogen production, and supply system will be formed. 3) By 2035, a hydrogen based industry system will be formed, and a diversified hydrogen application system covering transportation, energy storage, industry, and other fields will be built.

Moreover, recycling will reduce emissions from production of primary materials. The *14th Five-Year Plan for Circular Economy Development* set goals for recycling important industrial materials by 2025. The utilisation of scrap steel should reach 320 million tonnes, and the output of secondary non-ferrous

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document.

[122] China Dialogue. Analysis: Carbon-intensive industries are worsening China’s ozone pollution. (Sep, 2023) https://chinadialogue.net/en/pollution/carbon-intensive-industries-worsen-chinas-ozone-pollution/. Analytic article.

[123] People’s Daily. National Emission Trade Scheme launched, starting from the power sector. (July 2021). https://www.gov.cn/zhengce/2021-07/16/content_5625373.htm. News report.

metals should reach 20 million tonnes, of which the output of secondary copper, secondary aluminium, and the secondary lead should reach 4 million tonnes, 11.5 million tonnes, and 2.9 million tones respectively.

Specifically for the steel industry — the biggest industrial emitter, its carbon peaking plan sets a target to increase the share of EAF-based secondary steel to 15% by 2025, from 10% in 2020. Its upstream sector, the coking industry, aims to peak its CO_2 emissions by 2025, as crude steel production is expected to peak by then.

Clean-tech manufacturing

Chinese industrial and innovation policies focused on industries with high-tech and high-value, which are named as emerging industries of strategic importance, and include renewable energy, new energy automobiles, energy conservation, environmental protection and other nine industries in total.

The expanding solar panel and wind turbine production and markets in the past decade have helped solar and wind power become the most affordable electricity generation technology in many parts of the world. Between 2010 and 2022, the global weighted-average levelized cost of electricity (LCOE) of newly commissioned utility-scale solar PV projects declined 89%. For onshore wind projects, the global weighted-average cost of electricity fell by 69% in the same period[124].

The polysilicon, solar, battery and EV industries are rapidly expanding production capacity in 2023. It is estimated that by the end of 2023, China's manufacturing capacity of solar PV will be close to 1000 GW, doubling from the end of 2022[125]. Reportedly, in the first half of 2023, there were 42 energy storage projects worth over 10 billion yuan each, of which 28 projects have already been contracted[126].

Amid economic challenges and a declining real estate sector, renewable energy is regarded as a promising industry with clear growth prospects under the "dual carbon" goal. The MIIT issued the *Plan for Steady Growth of Power Equipment Manufacturing (2023-2024)* in September 2023.

The announcement of the 2060 carbon neutrality target provided the political signal, but the reason the magnitude of the growth has exceeded policymakers' targets and expectations is macroeconomic.

Environmental goals made cleantech one of the only acceptable sectors for investment for local governments at a time when their investment spending was under scrutiny due to debt concerns, income was under pressure due to the contraction in the real estate sector, and they were eager to attract investment and economic activity.

As a part of the measures to stimulate the economy during the pandemic, the government made it easier for private sector companies to raise money on the financial markets and from banks[127]. The clean energy sector, in contrast with the fossil fuel and traditional heavy industries, is largely made up

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[124] IRENA. (2023). Renewable Power Generation Costs in 2022. https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022. Report.
[125] Caixin. (Sep 2023).China's Solar Profits Surge as Oversupply Looms. https://database.caixin.com/2023-09-02/102099625.html. News report.
[126] Energy Magazine. (July 2023). Half-Year Review of Energy Storage Industry's Investment Projects Exceeding 10 Billion Yuan. https://www.inengyuan.com/kuaixun/11232.html. News report.
[127] State Council of China. (2023). Opinions of the CCCPC and the State Council on Promoting the Development and Growth of the Private Economy. https://www.gov.cn/zhengce/202307/content_6893055.htm. Government document.

of private companies. Access to credit had earlier been a major bottleneck for them in a financial system that has heavily favoured state-owned firms. Data show that in the first half of 2023, 60 solar PV companies raised over 200 billion yuan in total from the capital market, double size of the sectoral yearly financing of 2022[128].

The hunger of local governments for investments resulted in sizable subsidies. Reportedly, it's common for local governments to cover 30% of the capital costs through low price land, tax reduction and various subsidies[129], even including building the entire factory premises. Local governments also set the construction of local manufacturing capacity as a precondition for lucrative power generation projects.

It is clear that the wave of manufacturing investment has resulted in significant overcapacity, even though how much depends on the pace of the global energy transition.

Provincial governments have set ambitious goals for renewable manufacturing by 2025. Zhejiang on the east coast is targeting a manufacturing capacity of 150 GW solar PV, 5 GW wind power and 100 GWh energy storage. Zhejiang is the second largest solar PV manufacturer in China, with a total manufacturing capacity of 40 GW in 2020, after Jiangsu. Shanxi province, in the north of China and a leading coal producer, also approved a mega solar PV manufacturing project developed by JinkoSolar, and provided about 20-30 billion yuan in investment through government backed investment funds.

4.5.3 Focus: Iron and steel

China currently produces in excess of 1 billion tons of crude steel annually, accounting for more than half of the world's steel production. The dominance of coal-based[130] blast furnace–basic oxygen furnace (BF–BOF) method in the Chinese steel sector, along with its large scale, presents significant challenges for decarbonisation. The sector is the second-largest emitter of CO_2 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.

Another challenge for China's steel sector is that it has been trapped in overcapacity for years. The central government set the target to reduce steelmaking capacity below 1 billion tonnes by 2020, a net reduction of 150 million tonnes steelmaking capacity from 1.13 billion tonnes in 2015[131]. However, China's crude steel production climbed to a record high of 1,065 million tonnes in 2020[132], the highest output on record. While official numbers for steelmaking capacity in 2020 were never published, presumably due to the fact that they would have shown the target being missed, the reported steel production and plant utilisation indicate that there must have been more than 1.2 billion tonnes of capacity in place in 2020, implying that the capacity control target was missed by well over 200 million

[128] China Energy News. (Oct 2023). Photovoltaic "financing heat" inflection point has come.http://paper.people.com.cn/zgnyb/html/2023-10/16/content_26022909.htm. News report.
[129] Caixin. (Sep 2023).China's Solar Profits Surge as Oversupply Looms. https://database.caixin.com/2023-09-02/102099625.html. News report.
[130] Coal is used as a reductant to strip oxygen from the iron ore and this process generates substantial carbon emissions.
[131] National Development and Reform Commission. Iron and Steel Industry Adjustment and Upgrading Plan (2016-2020). (July 2017). https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201706/t20170621_1196816.html. Policy.
[132] National Bureau of Statistics. (2022). https://data.stats.gov.cn/easyquery.htm?cn=C01. Statistics.

tonnes[133].

Based on the failure of tackling the overcapacity issue, and following the announcement of China's dual carbon goals in September 2020, the central government stepped up efforts to cut steel output to reduce pollutant and greenhouse gas emissions in the steel sector in 2021 and 2022[134, 135]. China's crude steel production fell by 2.8% and 1.7% year-on-year in 2021 and 2022, respectively[136].

In 2023, the central government hasn't announced an output control target publicly, but it is widely discussed that the government might set a goal to keep it below the 2022 level[137]. Crude steel output increased 2.6% year–on-year in January–August 2023[138]. If the government aims to limit full-year crude steel output below 2022 level, it will require a 6% reduction in September–December 2023[139].

Output reduction might be an effective way to peak carbon emissions in the short-term, while deep decarbonisation in the long term will require the deployment of low carbon technologies, energy efficiency improvements, and recycling of resources.

In contrast to the steel production staying at high levels in the past three years, the profitability of the sector has plummeted after the peak in 2021, with total profits falling by 91.3% in 2022 year-on-year[140], and a further 57.1% in January–August 2023[141]. The profitability decline once again reveals the excess capacity in the steel sector, and the weak growth of downstream demand, with the ongoing deflation of the real estate sector the main burden on steel prices[142].

Given the massive scale of China's steel consumption over the past 20 years, there is a huge potential pool of domestic scrap steel from demolished buildings and infrastructure, as well as from scrapped cars and machinery, that can be recycled as part of a move towards the circular economy. 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

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[133] Lauri Myllyvirta. Carbon Brief. Analysis: Surge in China's steel production helps to fuel record-high CO2 emissions. (March 2020). https://www.carbonbrief.org/analysis-surge-in-chinas-steel-production-helps-to-fuel-record-high-co2-emissions/. Article.

[134] 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.

[135] National Development and Reform Commission. Plan on steel output reduction. (April 2022). https://www.ndrc.gov.cn/xwdt/xwfb/202204/t20220419_1322416.html. News.

[136] National Bureau of Statistics. (2022). https://data.stats.gov.cn/easyquery.htm?cn=C01. Statistics.

[137] Xinhua Finance. The uncertainty of China's steel output control goal. (Aug 2023). https://www.cnfin.com/yw-lb/detail/20230821/3917937_1.html. News report.

[138] National Bureau of Statistics. (2023). Statistics. https://data.stats.gov.cn/easyquery.htm?cn=A01

[139] Lauri Myllyvirta, Centre for Research on Energy and Clean Air. (Sep 2023). https://energyandcleanair.org/china-energy-and-emissions-trends-september-2023-snapshot/. Analysis.

[140] National Bureau of Statistics. (2022). http://www.stats.gov.cn/xxgk/sjfb/zxfb2020/202301/t20230131_1892601.html. Statistics.

[141] National Bureau of Statistics. (2023). http://www.stats.gov.cn/sj/zxfb/202309/t20230927_1943230.html. Statistics.

[142] Bloomberg News. (2023). China's Property Woes to Weigh on Steel Prices Through Next Year. https://www.bloomberg.com/news/articles/2023-08-30/china-s-property-woes-to-weigh-on-steel-prices-through-next-year. News.

scrap steel to more than 300 million tonnes per year by 2025[143], up from 233 million in 2020[144], and an increase in the share of electric arc furnace-based steel (EAF-steel) from the current 10% to 15% of steel production by 2025.

The huge potential scrap resource and policy targets have not, however, translated into a boom of EAF-steel production. The share of EAF-steel in total crude steel production was 9.7% in 2022, lower than that of the past four years (Figure 36). The cost to produce steel using scrap through EAF is higher than that of using iron ore through the BF-BOF process in the current Chinese market, and there is also still a lack of incentives for low carbon steel products. The lack of economic competitiveness of EAF-steel over BOF steel will require more policy support and a growing market for low carbon products to pave the way for the growth of EAF capacity and production, and to meet the 15% goal by 2025.

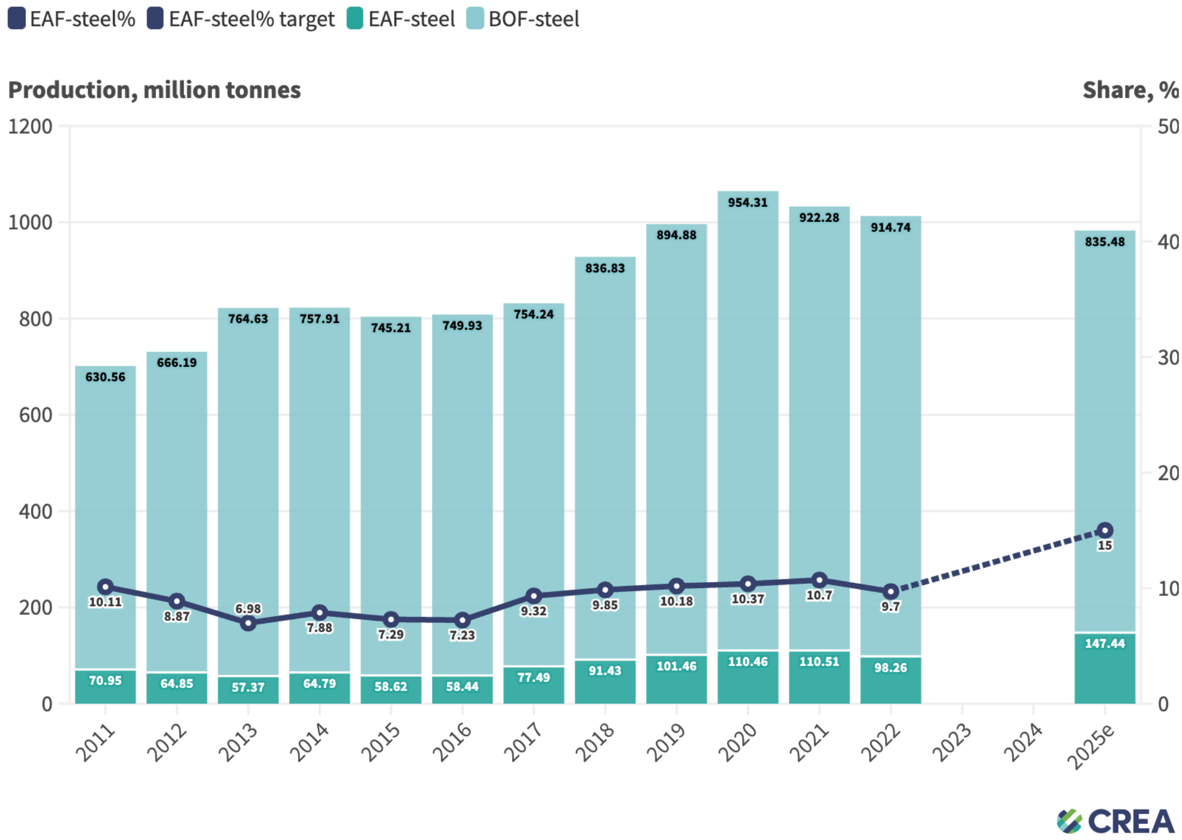

Figure 36 | China's steel production share and EAF-steel output target by 2025

Source: CREA analysis, China Iron and Steel Industry Yearbook 2022. Note: BOF is basic oxygen furnace, EAF is electric arc furnace, e is estimation. 2025 steel production is estimated by an annual reduction of 1% based on 2022 data.

If the government continues the steel output control throughout the following years, CO_2 emissions from the steel sector will not only peak but fall substantially by 2030, as the increased supply of scrap

[143] 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.
[144] China Scrap Steel Application Association. (2021). "14th Five-Year" Development Plan for Steel Scrap Industry. http://www.csteelnews.com/xwzx/jrrd/202109/t20210917_55000.html. Document.

allows pig iron to be replaced with scrap as an input. This makes it relatively easy for China to peak the CO_2 emissions of the steel sector by 2030. What is essential now is to guide the investment in low carbon production facilities to realise the carbon neutrality goal by 2060. New iron and steelmaking projects should follow the capacity replacement policy, which requires a larger quantity of existing capacity to be retired for all new capacity that is added. MIIT has used this measure since 2014 to alleviate the overcapacity of steel, aluminium, cement and glass in China.

New iron and steelmaking capacity

Based on available data from 2017 to the first half of 2023 (2023 H1), CREA has mapped the trends in the development of new iron and steelmaking projects[145]. Specifically, the data show that:

- Chinese steel firms are making significant investments in new, coal-based steelmaking capacity. Companies received approvals from provincial governments for 384.3 million tonnes per annum (Mtpa) of new ironmaking capacity, and 425.9 Mtpa new steelmaking capacity from 2017 until the first half of 2023. On average, approximately 30 Mtpa steelmaking capacity was approved every six months, which is almost equal to the total steel capacity of Germany.
- New iron and steel capacity is continuously dominated by the BF–BOF route. BF accounts for 99% of the new ironmaking capacity and BOF accounts for 70% of the new steelmaking capacity approved in 2017–2023 H1. That is to say, at least one-quarter of China's existing steelmaking capacity is being replaced with new units, further locking in carbon intensive production during its lifespan.
- In spite of the 'dual carbon' pledge announced in 2020, during 2021–2023 H1 there was a total 119.8 Mtpa BF and 76.6 Mtpa BOF approved. To meet the 2060 carbon neutrality goal requires early retirement of carbon-intensive steelmaking facilities. Therefore, the new BF–BOF capacity approved after 2020 alone would result in nearly USD 100 billion (CNY 700 billion) in stranded assets.
- There has been some promising progress on shifting investments into facilities that are less carbon-intensive. New proposed EAF projects significantly increased in 2021–2023 H1, with a total capacity of 52.5 Mtpa approved. EAF steelmaking is promoted under the latest capacity replacement policy. The share of EAF in newly announced steelmaking capacity grew to 30–40% during the period. Several non-BF projects with a total capacity of 4.7 Mtpa, applying incremental technology or zero-emission technology in the ironmaking process, also received approvals.
- By 2025, nearly all new permitted iron and steel projects will commence operations. Through these replacements, approximately 40% of China's iron and steelmaking capacity will be renewed.

[145] Centre for Research on Energy and Clean Air. China's steel sector invests USD 100 billion in coal-based steel plants, despite low profitability, overcapacity and carbon commitments. (2023). https://energyandcleanair.org/publication/chinas-steel-sector-invests-usd-100-bn-in-coal-based-steel-plants-despite-low-profitability-overcapacity-and-carbon-commitments/. Report.

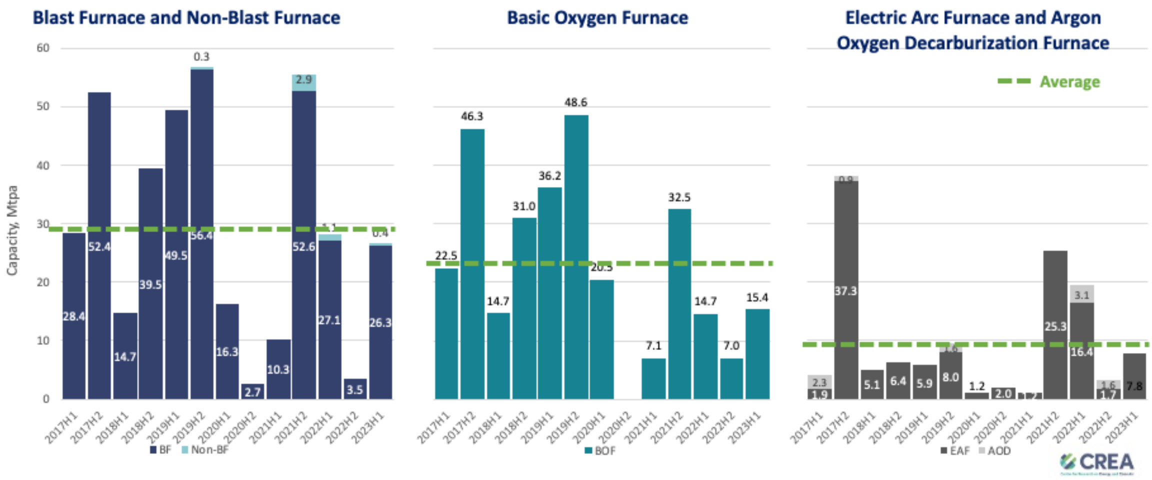

Figure 37 | Newly proposed iron and steelmaking capacity announced through capacity replacement on a half-yearly basis, 2017–2023 H1

Source: CREA analysis, provincial government websites. Note: BF is blast furnace, Non-BF is non-blast furnace (here includes hydrogen-based direct reduction plant, Hydrogen plasma smelting reduction plant and HIsmelt plant), BOF is basic oxygen furnace, EAF is electric arc furnace, AOD is argon oxygen decarburization furnace.

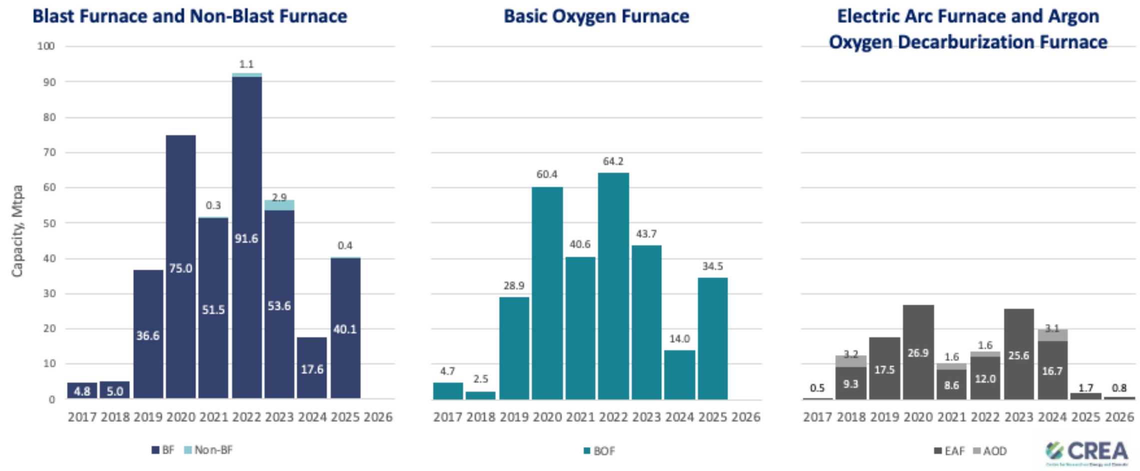

Figure 38 | New iron and steelmaking capacity additions by their estimated commision year

Source: CREA analysis, provincial government websites. Data include announcements made during 2017-2023 Jan-June. Note: BF is blast furnace, Non-BF is non-blast furnace (here includes COREX, hydrogen-based direct reduction plant, Hydrogen plasma smelting reduction plant and HIsmelt plant), BOF is basic oxygen furnace, EAF is electric arc furnace, AOD is argon oxygen decarburization furnace.

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 CO_2 emissions from industry has only been published twice, with the latest data covering the year 2014.

4.6 Buildings

2023 Highlights

- **Emission:** Energy consumption in buildings increased faster with most growth in electricity consumption in 2022–2023, due to heatwaves and increased prevalence of air conditioning. It then resulted in increased coal use in the power sector as clean power generation additions were insufficient to meet increased demand.
- **Sectoral development:** 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.
- **Policymaking:** Replacing residential coal stoves in north China continues to be one of the policy-driven focuses for both air pollution control and carbon reduction, as well as energy efficiency retrofits of existing buildings, and promoting renewable energy.

Electricity use in buildings increased sharply in 2022–2023 in comparison to previous years due to heatwaves and increased prevalence of air conditioning. This drove increases in emissions from power generation and emphasised the significance of building energy efficiency.

The building sector (residential and commercial) was responsible for 16% of China's CO_2 emissions from the energy sector in 2021, 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 and rising rapidly. 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[146], 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 fell by 18% from 2015 to 2020, because fuel use in buildings was replaced by district heating and electricity. Direct emissions increased by 5% in 2021 due to an increase in the use of gas, while the use of coal continued to fall.

When including the emissions from the consumption of electricity and heat, emissions associated with buildings have increased rapidly. Electricity consumption in buildings grew more than 50% from 2018 to 2023. Increases in the use of air conditioning, prompted in part by recent extreme heatwaves, is an important contributor.

In the transition pathways, the total emissions of the sector, including the emissions from the production of electricity and heat used in buildings, begin to fall sharply from 2030 to 2045 and reach

[146] 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.

80 $MtCO_2$ in 2050.

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 hydrofluorocarbons (HFCs), air conditioning units for buildings are a major source of fluorinated gases that will need to be controlled as a part of China's policymaking on non-CO_2 greenhouse gases[147].

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 projected 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. As the construction of new buildings slows down in China, the energy efficiency of existing buildings could be an important focus area.

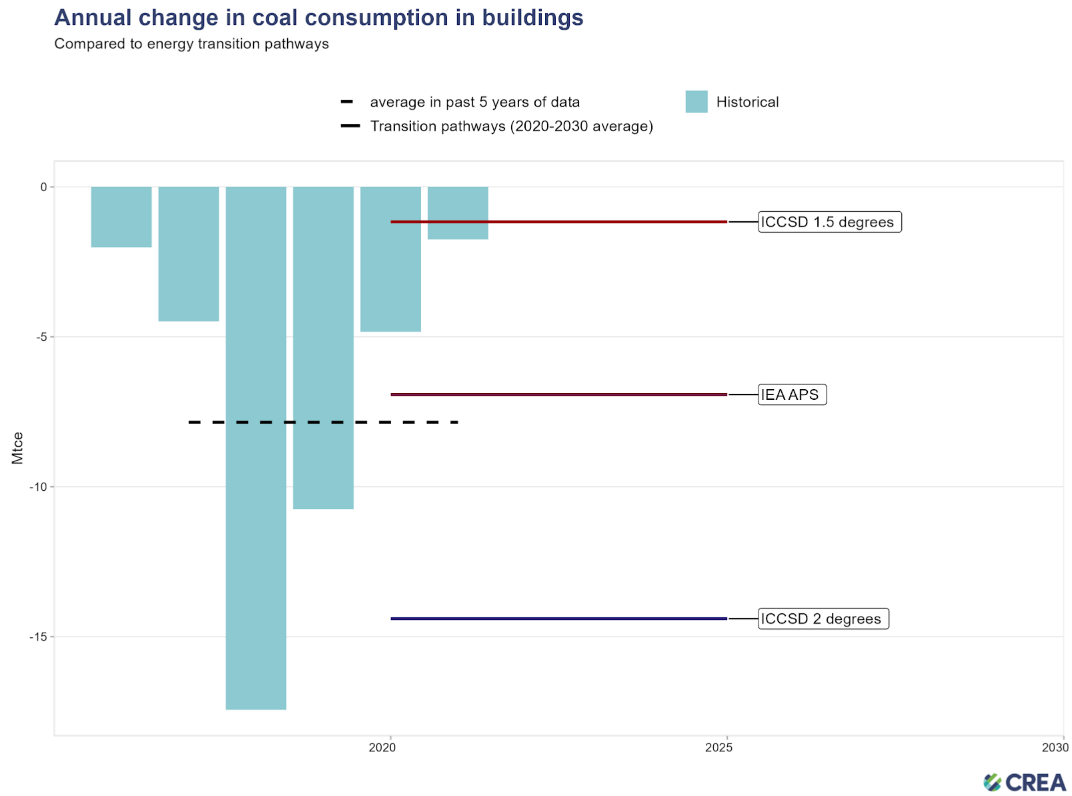

Figure 39 | Annual change in coal consumption in buildings compared to energy transition pathways

[147] 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. Policy.

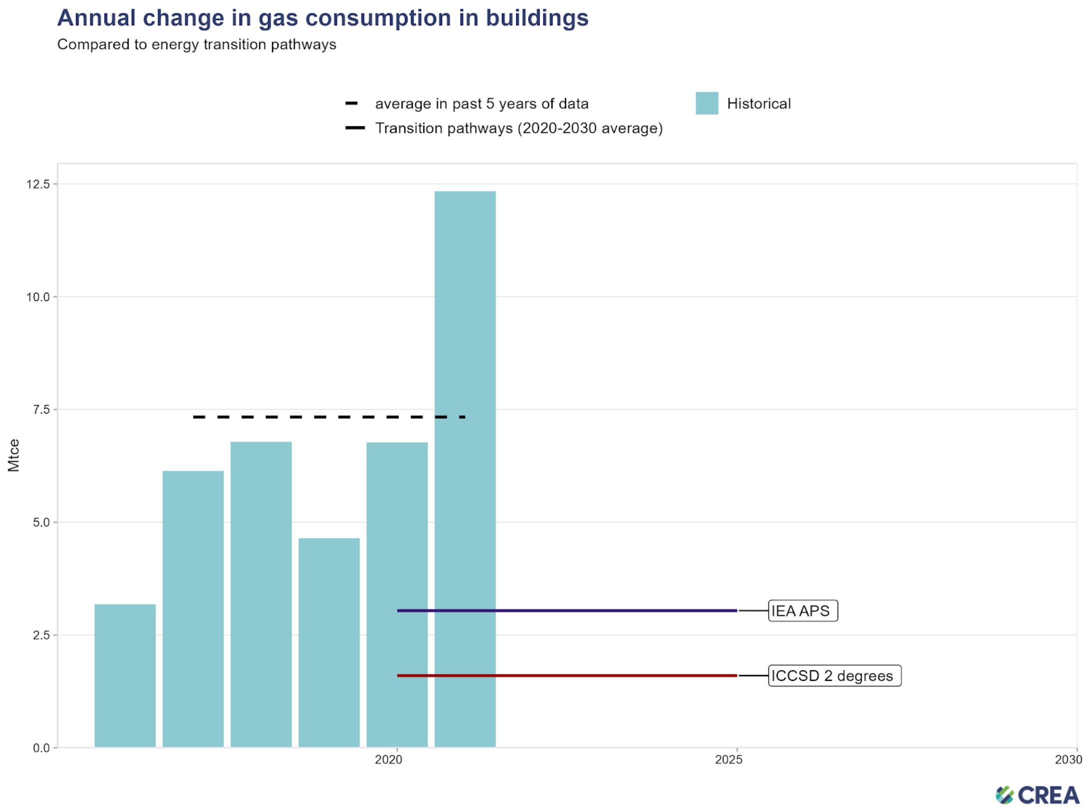

Figure 40 | Annual change in gas consumption in buildings compared to energy transition pathways

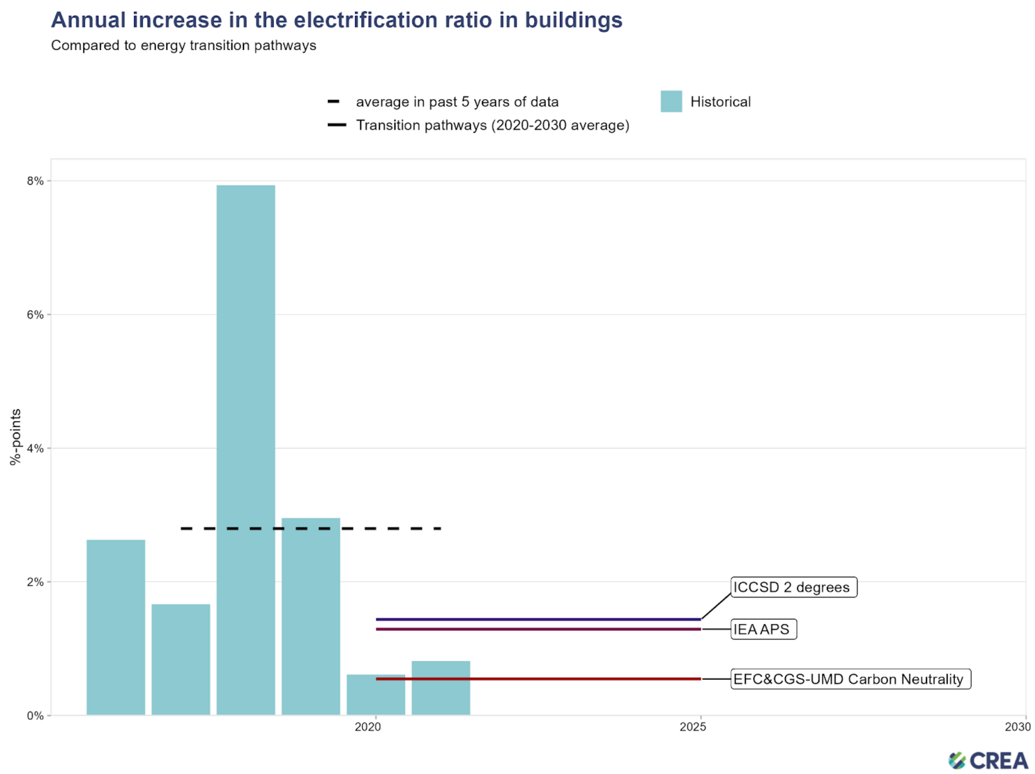

Figure 41 | Annual increase in the electrification ratio in buildings compared to energy transition pathways

In the IEA Sustainable Development Scenario, coal use in buildings falls by 75% from 2020 to 2030. This is a 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 not replacing coal and gas.

4.6.2 Policies in place: Peaking carbon dioxide emissions in the residential sector

The building sector is covered in China's CO_2 peaking action plan under "urban and rural development". Besides the implementation of earlier policies, highlights for the latest policies are in the reduction of bulk coal use and promoting renewable energy in rural areas.

Residential coal heating

Replacing residential coal stoves in north China became one of the policy-driven focuses for both air pollution control and carbon reduction in 2017. According to research by the Energy Research Institute of Peking University, 36.3 million households switched from coal to electricity or gas-based heating during 2017–2022, reducing residential consumption of coal by 38%[148]. The research also estimated that another 21 million households will switch from coal to electricity or gas-based heating in 2022–2025, cutting residential coal consumption by 60% compared to 2017.

The type of coal traditionally used in household stoves is sanmei (散煤), meaning "loose coal". The targets and policies aiming to reduce residential coal use have targeted this coal specifically. Recently, cleaner-burning coal varieties have been used to replace loose coal, instead of eliminating coal use, due to the high cost of gas and concerns about energy security. This entails no reduction in CO_2 and much smaller reductions in air pollutant emissions than shifting from coal to electricity, or even gas.

In the *Action Plan for Comprehensive Air Pollution Control in the Autumn and Winter of 2023-2024 in the Beijing-Tianjin-Hebei and Surrounding Areas and Fenwei Plain (Draft for Comments)*[149], MEE targets 787,000 households to phase out loose coal use in the coming winter. Financial support from central government is the key driver in this large scale loose coal phase-out. Market-based instruments are essential for the continuity of this work. With the reduction of government subsidies and the compromised way to replace loose coal with cleaner-burning coal varieties, it is not clear how many will actually be shifted from coal.

Green building and building energy efficiency

China is currently working both to raise energy consumption standards for new buildings and to retrofit existing buildings for energy efficiency.

The *14th Five-Year Plan for Building Energy Efficiency and Green Building Development* has introduced non-binding targets for the building sector by 2025: 1) Cap the total energy consumption of buildings,

[148] China Dispersed Coal Management Report 2023. Peking University. (Sep 2023). https://www.ccetp.cn/newsinfo/6390799.html. Research report.
[149] Ministry of Ecology and Environment. (Sep 2023). Action Plan for Comprehensive Air Pollution Control in the Autumn and Winter of 2023-2024 in the Beijing-Tianjin-Hebei and Surrounding Areas and Fenwei Plain (Draft for Comments). https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202309/t20230922_1041574.html. Policy.

including upstream energy use, at 1.15 Gtce; 2) Increase the energy efficiency of newly-built urban private residential buildings by 30%; 3) Increase the energy efficiency of urban public residential buildings by 20%; 4) Complete energy efficiency retrofits on 350 million square metres of existing buildings, including 100 million square metres of private existing buildings, and 250 million square metres of public existing buildings. This is only half of the retrofitted area during the 13th FYP period (2016–2020), showing that this effort is being downscaled.

Renewable energy in urban and rural buildings

Given that increasing the share of renewable energy supplied to buildings requires transforming China's overall energy system, and the negotiations for the renewable energy installations in residential buildings involve multiple stakeholders, a more practical pathway for buildings in urban areas is to bring down energy consumption within buildings. The above mentioned "*Green Building Plan*" targets a share of 8% for renewable energy consumption in the total energy consumption for urban buildings by 2025, just two percentage points higher than the 6% target for the end of the 13th FYP period (2016-2020). However, in practice, the whole-county solar programme has resulted in greatly accelerated progress.

Meanwhile, the NEA called for applications for "energy transition pilot counties" in March 2023[150], with the aim to promote renewable energy in rural areas. These energy transition pilot counties are required to meet two goals: 1) increase the share of renewable energy to 30% in their total primary energy consumption; 2) covering 60% in their primary energy consumption growth with renewable energy.

Table 9 | Selected policies relating to the buildings sector.

Policy name	Release date	Targets and Highlights
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	• Set a coal consumption cap, 1.15 billion tonnes of standard coal, for building maintenance by 2025; • Increase the energy efficiency of newly built private buildings by 30% by 2025; • Increase the energy efficiency of newly built public buildings by 20% by 2025.
The 14th Five-Year Plan to Promote the Modernization of Agriculture and Rural Areas, (State Council)	2022-02-11	• Promote carbon emission reduction and carbon sequestration in agriculture and rural areas.

[150]National Energy Administration. (March 2023). Notice on organising the construction of pilot counties for rural energy transition. https://www.gov.cn/zhengce/zhengceku/2023-03/24/content_5748120.htm. Government document.

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 CO_2 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

2023 Highlights

- **Emission:** China's oil consumption was almost stable from 2019 to 2022, largely due to the reduction in mobility caused by COVID-19 control measures. The removal of pandemic control measures resulted in a significant rebound in 2023. For road vehicles, electrification represents the main thrust of emission reductions. The share of electricity in transport energy use rose from 3.4% in 2018 to 4.7% in 2023.
- **Sectoral development:** Electric vehicle production and sales have been skyrocketing, with the share of EVs out of all vehicles produced increasing from 5% in 2019 to 30% in the 12 months up to August 2023. The decarbonisation and electrification of transport are supported by a highly developed network of high-speed rail connections between cities, as well as urban rail and bus transport.
- **Policymaking:** Despite the end of the national purchase subsidies for new energy vehicles at the end of 2022, they have been replaced by subsidies from provincial governments. Additionally, the Ministry of Finance extended the vehicle purchase tax reduction for new energy vehicles from 2024 to 2027.

If China's economic development and urbanisation continue at a fast pace, the demand for passenger and freight transportation is expected to rise sharply until around 2040. Limiting the increase in CO_2 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 synthetic fuels and/or biofuels in aviation. In both the ICCSD 1.5°C and 2°C pathways, total CO_2 emissions from the transportation sector peak around 2030, at 1.04 and 1.08 billion tonnes, respectively, up from 991 million tonnes in 2020, before a 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[151], 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[152] 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 share of road transport falls from 34% to 26.5%. The share of aviation will fall slightly from 33% in 2021 to 29% in 2050.

For road vehicles, electrification represents the main thrust of emissions 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.

[151] 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

[152] 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.

4.7.1 Trends compared to benchmarks

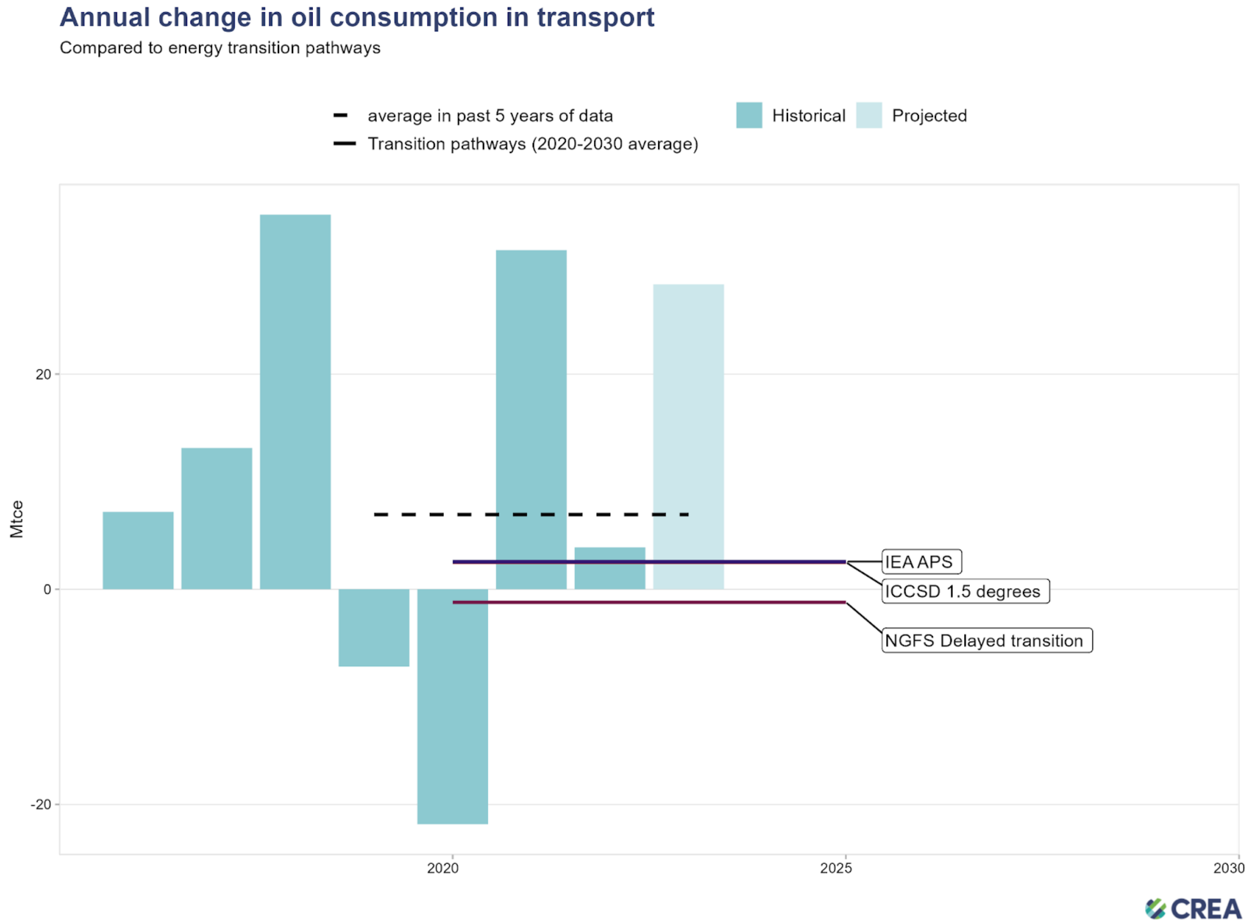

Figure 42 | Annual change in oil consumption in transport compared to energy transition pathways

China's oil consumption was almost stable from 2019 to 2022, but this was largely due to the reduction in mobility caused by COVID-19 control measures. The removal of pandemic control measures resulted in a significant rebound in 2023, and the longer-term trend is difficult to discern from data.

The transition pathways consistent with 1.5 degrees project near-zero growth in transport oil demand from 2020 to 2030.

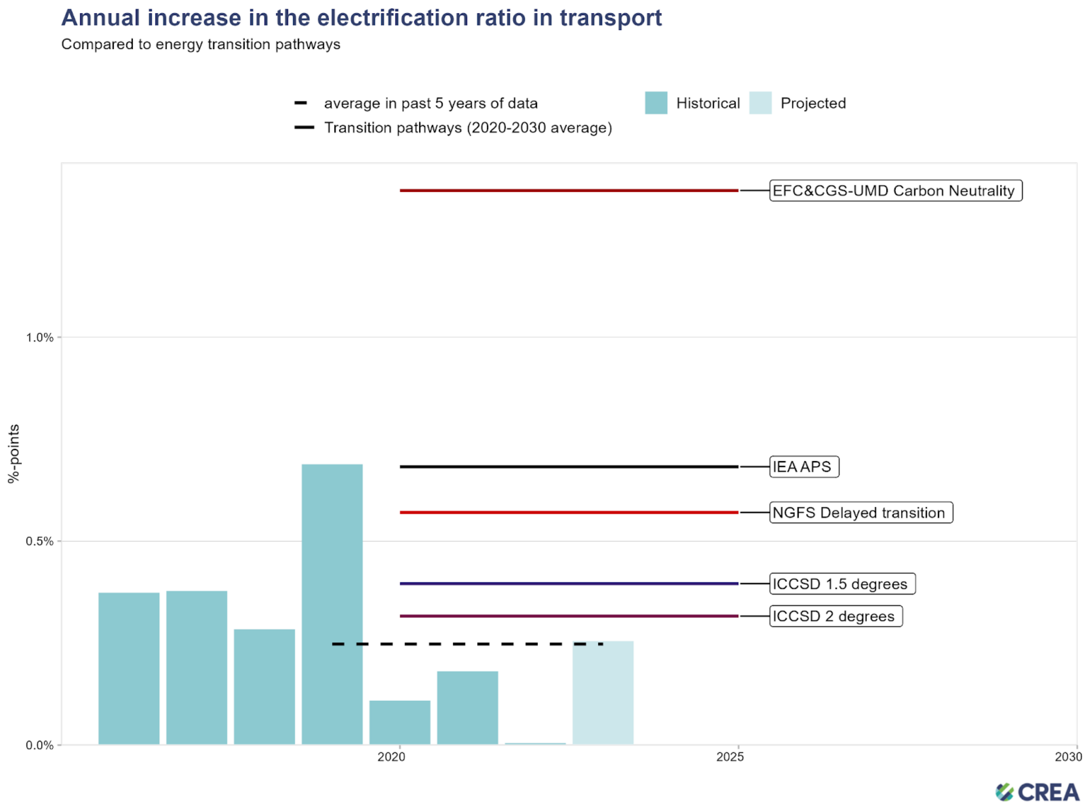

Figure 43 | Annual change in the electrification ratio in transport compared to energy transition pathways

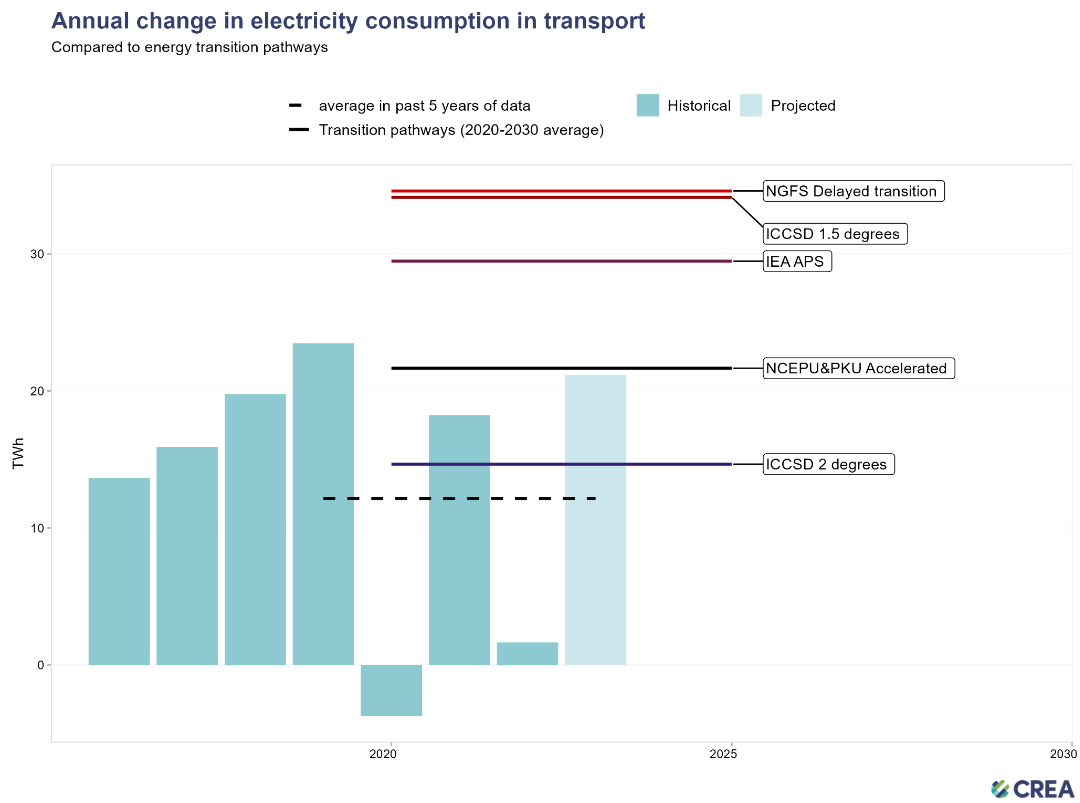

Figure 44 | Annual change in electricity consumption in transport compared to energy transition pathways

The share of electricity in transport energy use rose from 3.4% in 2018 to 4.7% in 2023. This is half of the approximately 0.5%-points/year rate achieved in the transition pathways. It is likely that not all EV charging is showing up in reported electricity consumption for road transportation and charging services, so the actual rate of electrification is likely to be faster.

Electric vehicle production and sales have been skyrocketing, with the share of EVs out of all vehicles produced increasing from 5% in 2019 to 30% in the 12 months up to August 2023. As a result, the share of EVs out of all vehicles sold in the past decade – a proxy for the mix of cars on the road – increased from 4% at the end of 2021 to 12% at the end of August 2023. This means that EV adoption likely shaved approximately four percentage points off gasoline demand growth. Sinopec, China's oil-and-gas giant, recently said that the transition to EVs would cause China's gasoline demand to peak in 2023[153].

Gasoline only represents 20% of China's oil consumption. However, due to the high share of freight in overall transportation oil demand, a lot depends on the development of bulk freight volumes, efforts to shift more freight on rails, and the electrification of freight that is still in its infancy.

The IEA Energy Technology Perspectives projects a 65% share of EVs in new vehicle sales by 2030 globally, which China could well be on track to achieve given the rate of growth. The 30% share of "new energy vehicles" 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.

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.

Investment in rail transportation increased 22% in the first nine months of 2023, from an already high base.

The mix of transport modes doesn't show a major effect from the massive investment. Railway passenger volumes and passenger-kilometres have barely recovered to 2019 levels in the first eight months of 2023. The recovery in air travel is identical, showing no shift from air to rail from 2019 to 2023. Refinery output of gasoline, as a proxy for road travel, was already 15% above 2019 levels in the first eight months of 2023.

In freight, railway tonne kilometres increased by 23% from the first eight months of 2019 to the same period in 2023, showing more progress.

[153] Bloomberg News. (Aug 2023). China's Gasoline Demand to Peak Early on Fast Adoption of EVs. https://www.bloomberg.com/news/articles/2023-08-04/china-s-gasoline-demand-to-peak-early-on-fast-adoption-of-evs?sref=Oz9Q3OZU. News report.

Vehicle production

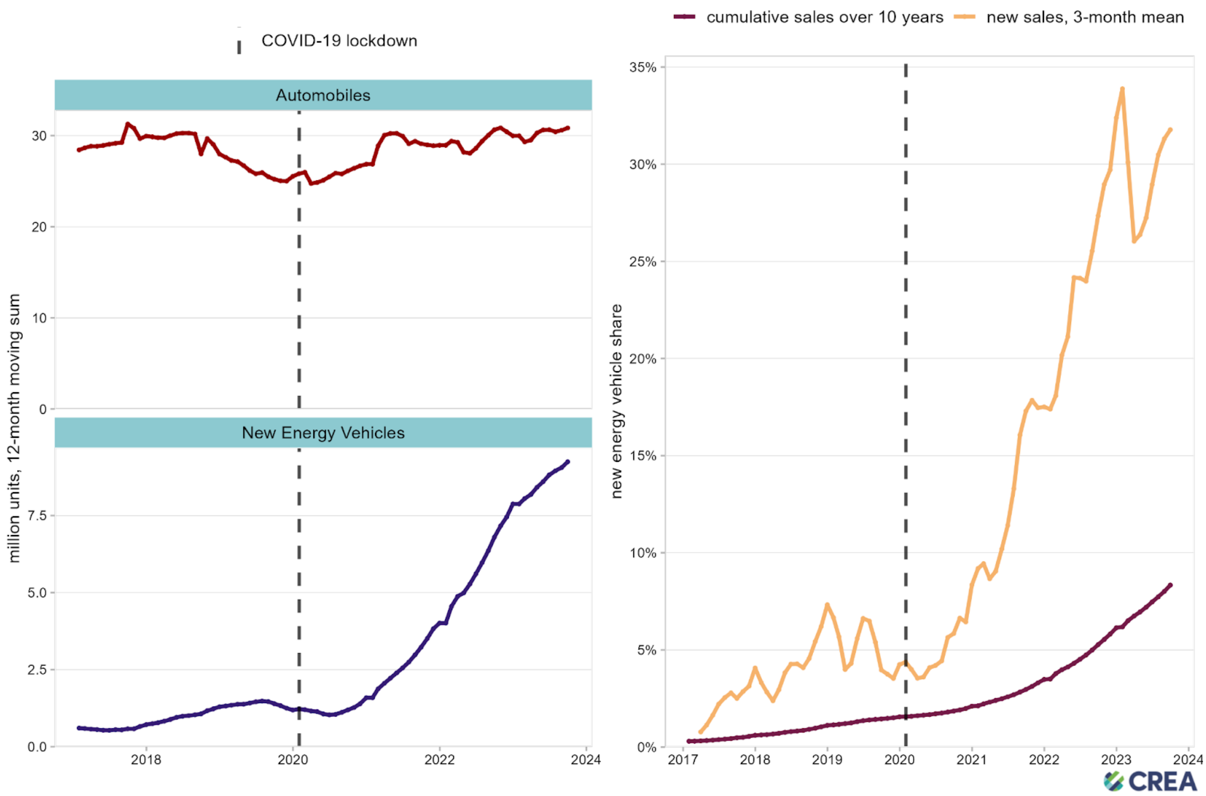

Figure 45 | Vehicle production; 12-month moving sum

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

The Chinese government has laid out three major actions for green and low-carbon transportation: 1) promote new energy vehicles; 2) build green transportation systems; 3) build green transportation infrastructure. We present a selection of policies in Table 9, below.

Table 10 | Selected policies relating to transportation

Policy name	Release date	Targets and highlights
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 (CO_2) emissions per unit of transport turnover of operating vehicles compared to 2020 (5%). Decrease rate of carbon dioxide (CO_2) 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%,

Policy name	Release date	Targets and highlights
		20%). Increase the proportion of new energy and clean energy trucks in international container hub sea-ports (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 CO_2 emission intensity reduction rate (5%).
Guidance on further building a high-quality charging infrastructure system (Office of State Council)	2023-6-19	• Aims to establish a nationwide charging network for EVs by 2030.
Announcement on Continuing and Optimising the Vehicle Purchase Tax Reduction Policy for New Energy Vehicles (Ministry of Finance)	2023-6-19	• Extend the purchase tax reduction during 2024-2027.

Electric vehicles sales and manufacturing

Since the announcement of the *Energy Saving and New Energy Vehicle Development Plan (2012-2020)* in 2012, China's electric vehicle industry has taken a tremendous development and became a global leader. China was again the top market for EVs, with sales increasing by 82% year-over-year to 6.2 million EVs in 2022; that was 59% of the global total[154]. Local brands take up 81% of the EV market, with BYD, Wuling, Chery, Changan, and GAC among the top players[155]. The latest policies that have been put into force in 2023 continue the government's strong support for new energy vehicles — mainly electric vehicles.

- Despite the end of the national purchase subsidy for new energy vehicles at the end of 2022, subsidies from provincial governments have stepped in to replace it. The national purchase subsidy had been in place since 2009, supporting the growth of the new energy vehicles industry starting from scratch[156]. Additionally, the Ministry of Finance extended the vehicle purchase tax reduction for new energy vehicles from 2024 to 2027. The purchase tax reduction for new energy vehicles started from 2014, resulting in accumulated tax cuts of over 200 billion yuan by the end of 2022 and estimated to amount to 115 billion yuan in 2023 only. The extension from 2024 to 2027 will mean a total of 520 million yuan in tax deductions[157].
- The charging infrastructure for EVs is also growing rapidly. The number of charging stations increased from less than 100,000 in 2015 to 6.4 million in May 2023. Over 80% of the downtown

[154] ICCT. (June 2023). Annual Update on the Global Transition to Electric Vehicles: 2022. https://theicct.org/publication/global-transition-electric-vehicles-update-jun23/. Report.
[155] EV Market report. (2023). BYD's Growing Market Share in China's EV Market. https://evmarketsreports.com/byds-growing-market-share-in-chinas-ev-market/. News.
[156] Xinhua News. (Feb 2023). The policy of subsidies for the purchase of new energy vehicles has ended in 2023. http://www.news.cn/fortune/2023-02/21/c_1129382110.htm. News.
[157] People's Daily. (June 2023). The high-quality development of the new energy vehicle industry receives further policy support. https://www.gov.cn/zhengce/202306/content_6887954.htm. News.

areas of first-tier cities (megacities like Beijing, Shanghai, and Guangzhou) have installed charging stations, and 65% of the highway service zones nationwide provide charging service[158]. The *Guidance on Further Building a High-quality Charging Infrastructure System* released in June 2023 aims to establish a nationwide charging network for EVs by 2030. Besides the widespread use of EVs in urban areas, NDRC released the *Guidance on Accelerating the Construction of Charging Infrastructure and Promoting New Energy Vehicles in Rural Areas*.

- Provinces such as Shanghai[159], Zhejiang[160], Jiangsu[161], Anhui, Fujian[162], Guangdong[163] and Hunan[164], all made ambitious plans to develop the new energy vehicle manufacturing industry. EV manufacturers in the Yangtze River Delta (YRD), including Shanghai, Zhejiang, Jiangsu and Anhui, have formed regional industrial clusters. The EV production in YRD in 2022 reached 2.9 million, accounting for over 40% of the national production[165].

Railway construction

We've seen rapid development of the national railways, especially high-speed railways and urban rail transit, in the past two decades (Table 11). The length of the railway lines in use nationwide reached nearly 146,000 km in 2020, including 38,000 km high-speed railways. The combined track length of urban rail transit systems was 6,600 km, which had seen a 2 to 3-fold increase in every five years.

Rail and water transport have the lowest emissions per kilometre and unit transported, while aviation and road transport emit significantly more. With the fast development of the railway network, the proportion of railway freight volume in the total freight volume increased from 7.8% in 2017 to 9.2% in 2021[166].

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[158] Xinhua News. (July 2023). To tackle the challenge of "difficulty in finding charging stations," China is intensifying efforts to expand the infrastructure for new energy vehicle charging. https://www.gov.cn/zhengce/202307/content_6891764.htm. News.
[159] Shanghai Municipal Government. (Feb 2021). Implementation plan for the development of the new energy vehicle industry in Shanghai (2021-2025). https://www.shanghai.gov.cn/nw12344/20210225/c76899471d0d4abea77b26d54d7fb972.html. Policy.
[160] 21st Century Economic Report. (May 2021). Zhejiang's new energy vehicle industry "14th Five-Year Plan" released. https://m.21jingji.com/article/20210507/herald/c2f2877e82d71ad40d5727601df09f29_zaker.html. News report.
[161] Jiangsu Municipal Government. (Nov 2021). 14th Five Year Plan for New Energy Vehicles Development of Jiangsu Province. http://www.jiangsu.gov.cn/art/2021/11/24/art_46144_10124132.html. Policy.
[162] Fujian Municipal Government. (Apr 2022). Plan for New Energy Vehicles Development of Fujian Province (2022-2025). https://fdi.swt.fujian.gov.cn/uploadfiles/file/20220426/1650941604952489.pdf. Policy.
[163] Guangdong Municipal Government. (Oct 2020). Guangdong Province's Action Plan for the Development of Strategic Pillar Industry Clusters in the Automobile Sector (2021-2025). http://www.gd.gov.cn/zwgk/zcjd/snzcsd/content/post_3097936.html. Policy.
[164] Hunan Municipal Government. (Dec 2022). Measures to support the high-quality development of the new energy vehicle industry. https://gxt.hunan.gov.cn/gxt/xxgk_71033/zcfg/gfxwj/202212/t20221230_29171166.html. Policy.
[165] People's Daily. (July 2023). The integrated development of the Yangtze River Delta region has formed a cluster of new energy vehicle industry. http://paper.people.com.cn/rmrb/html/2023-07/25/nw.D110000renmrb_20230725_1-07.htm. News.
[166] Guangming Daily. (Oct 2022). "Road to rail" and "Road to water" have achieved remarkable results, and the transportation structure continues to be optimised. https://economy.gmw.cn/2022-10/31/content_36126790.htm. News.

The total length of China's railway network is still behind the US and EU27[167,168], which are both over 200,000 kilometres. China continues its ambitious construction plan for railways and urban rail transit in the 14 FYP period (2021–2025). 2022 data show national railway fixed asset investment was 710.9 billion yuan, and 4,100 kilometres of new lines were put into operation, including 2,082 kilometres of high-speed railways. The national railway operating length reaches 155,000 kilometres, of which 42,000 kilometres are high-speed railways[169].

Table 11 | Total length of the railway lines and urban rail transit in use from 2005 to 2025 (1,000km)

Type	2005	2010	2015	2020	2025 target (non-binding)
Railway	75	91	121	146	165
High-speed railway			19	38	50
Urban rail transit	0.43	1.4	3.3	6.6	10

Source: 12th Five-Year Plan for Transportation, 13th Five-Year Plan for the Development of Modern Transportation, and 14th Five-Year Plan for the Development of Modern Transportation, government website.

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. 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 are published on an annual basis and with a delay of 1–2 years. Official information on CO_2 emissions from transportation has only been published twice, with the latest data covering the year 2014.

4.8 Provincial actions

4.8.1 Policies in place: China's climate transition requires collective efforts on provincial level

Achieving national goals on carbon peaking and carbon neutrality require collective and coherent efforts from provincial governments, as they are the main functional bodies for implementing the central government's policies. After the national action plan for reaching peak carbon by 2030 was

[167] Wikipedia. (2023). List of countries by rail transport network size. https://en.wikipedia.org/wiki/List_of_countries_by_rail_transport_network_size. Wikipedia
[168] Statista. (2023). Total length of the railway lines in use in the European Union (EU-27) from 1990 to 2020. https://www.statista.com/statistics/451812/length-of-railway-lines-in-use-in-europe-eu-28/. Statista.
[169] People's Daily. (May 2023). National railway fixed asset investment in 2022 reached 710.9 billion yuan. http://finance.people.com.cn/n1/2023/0529/c1004-40001474.html. News report.

released in October 2021[170], 31 provinces and municipalities have rolled out their individual action plans for carbon peaking. Targets for a reduction in energy consumption per unit of GDP, a reduction in CO_2 emission per unit of GDP and non-fossil energy consumption by 2025 and 2030 were raised in these plans.

Based on public sources, three provinces (Hubei, Xinjiang and Tibet) do not have quantitative targets for a reduction in energy consumption and a reduction in CO_2 per unit of GDP by 2025, and Xinjiang does not have a quantitative target for non-fossil energy consumption proportion by 2025. 12 provincial governments (Hubei, Xinjiang, Tibet, Henan, Shanxi, Ningxia, Heilongjiang, Hebei, Qinghai, Yunnan, Guangdong and Chongqing) do not have targets to reduce CO_2 emissions, and six provincial governments (Hubei, Xinjiang, Henan, Jiangsu, Beijing and Yunnan) do not have targets relating to non-fossil energy consumption by 2030.

The responsibility for climate efforts is not always evenly shared, considering natural resources and economic growth are oppositely distributed in western and eastern China. Provinces that have achieved higher economic performance generally have less clean energy resources but larger energy consumption, resulting in less developed regions taking most of the responsibility for decarbonization.

The national goal of reaching around 20% of non-fossil energy consumption proportion is largely supported by western underdeveloped regions which have abundant natural resources of solar, wind and hydro power. The provincial targets for non-fossil energy consumption proportion of Qinghai, Tibet, Yunnan and Sichuan exceed the national target by over 20 percentage points, while the targets of northern provinces which rely heavily on coal-burning, like Tianjin, Hebei, Shandong and Shanxi, are below the national target, with a discrepancy of up to 8.3 percentage points. According to provincial goals, by 2030, Hainan rises to the third place with 54% of non-fossil energy consumption, while regions in Jing-jin-ji area and Fenwei plain have kept non-fossil energy consumption below the national average.

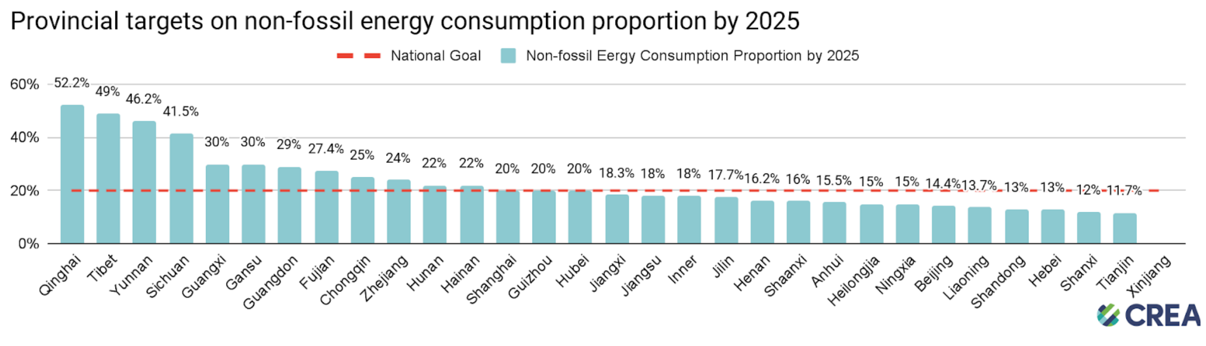

Figure 46 | Comparison of provincial targets on non-fossil energy consumption proportion by 2025

[170] Central government of People's Republic of China. (Oct 2021). Action Plan for Carbon Dioxide Peaking Before 2030. https://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm. Policy

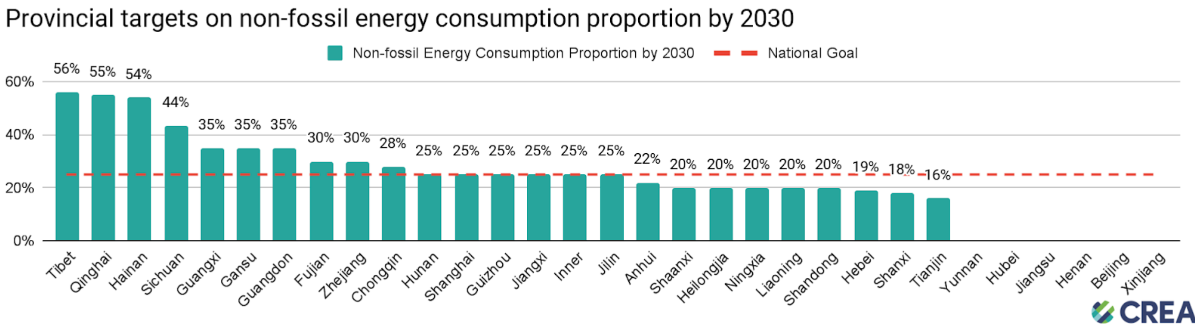

Figure 47 | Comparison of provincial targets on non-fossil energy consumption proportion by 2030

When we examine the non-fossil targets by considering baseline numbers in 2020, the amount of increase is distributed differently. Guangdong is the single province that planned a decrease in non-fossil energy consumption proportion, from 30% in 2020 to 29% in 2025; the provinces that planned for the largest increase in non-fossil fuel implementation are Tibet (8.5% points), Shaanxi (8.1% points) and Jiangsu (7.0% points); the provinces that planned for the smallest increase are Hunan (0.3% points), Shanghai (2.0% points) and Guizhou (2.4% points).

Surprisingly Guangdong, as the province with the largest GDP, is stepping backwards on the promise of clean energy. It led a new coal spree in 2022 and continued in the first half of 2023 to initiate and permit more new coal projects. Guangdong's key power generation construction projects for the year 2023 include 31 GW of coal-fired power and 27 GW of gas-fired power, which represent the majority of new capacity. Guangdong has four times as much dispatchable capacity as there is variable capacity, making the addition of new coal power hardly can be justified as "supportive" to planned solar or wind capacity.

Except for Tibet and Qinghai, the places that set the highest increase in non-fossil energy consumption are mainly the ones with relatively low baseline numbers in 2020. Coal-abundant northern regions like Shaanxi, Inner Mongolia, Hebei and Shandong, and important Yangtze delta provinces including Jiangsu, Zhejiang and Anhui have set targets that are higher than the national target of 5%-point increase.

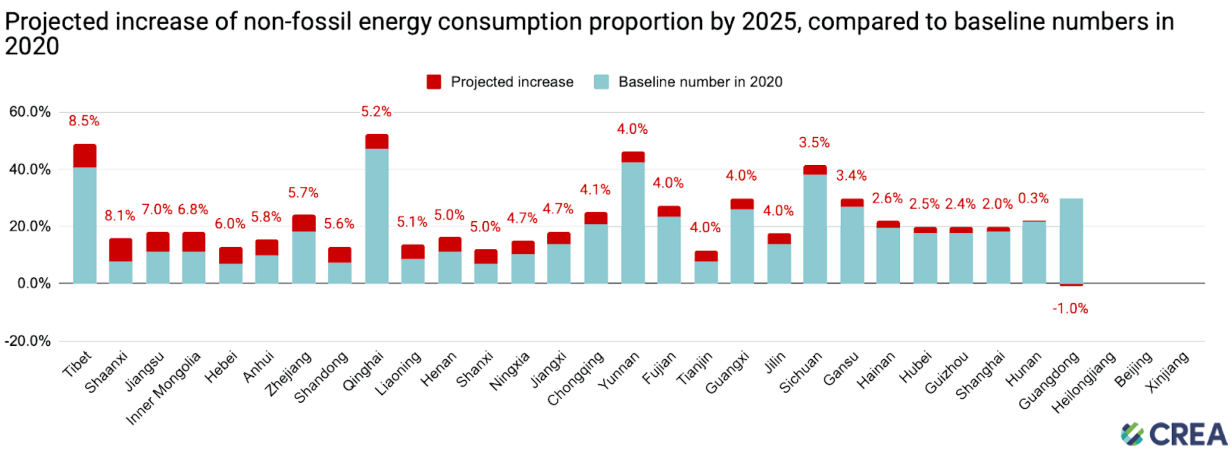

Figure 48 | Comparison of provincial targets for projected increase of non-fossil energy consumption proportion by 2025 with baseline numbers in 2020

Note: Beijing and Tianjin are missing publicly reported baseline numbers for non-fossil energy consumption proportion in 2020, and thus here only shows their target numbers by 2025.

Provincial governments' enthusiasm for clean energy investment has driven up China's total clean energy capacity. Media reported that solar projects were given the best investment deals in history and this pattern is followed everywhere the same across the country. For example, the 56 GW of solar power base of Jingke Energy located in Shanxi has gained great support from the Shanxi government. The major funding of this project, amounting to 20-30 billion RMB, mainly relies on local urban investment funds or urban investment platforms that provide guarantees for corporate bond financing. Furthermore, the government investment return rate is above 30%[171].

The logic behind investments in solar, wind power and electric vehicles production can be explained by the local governments' economic pressure after conducting dynamic zero-COVID-19 policy for three years and the limitations of the energy consumption per unit of GDP reduction goal assigned by the central government. Central government promoted clean energy investment by taking the energy consumption of clean energy production out of the gross energy consumption cap. Provincial governments use clean energy investment as an effective means to obtain financial support from the central government, and to issue new credits and investments.

The overall goal of clean energy investment is to reduce the energy intensity of economic development. However, in some provinces, the lack of compatibility between the development of distributed residential photovoltaics and flexible power regulation sources, as well as energy storage facilities, are resulting in localised oversupply of distributed residential photovoltaics in China.

During the first eight months of 2023, Henan, Shandong and Hubei led solar power installations in China, striving to meet rooftop solar installation targets by the end of 2023. Henan alone has added over 8 GW of solar capacity in this period. Inner Mongolia, Xinjiang and Yunnan led wind capacity installations, with Inner Mongolia has newly installed over 6 GW of wind power so far.

In May 2023, there was an extended period of negative electricity prices in the electricity market of Shandong[172]. The surplus electricity generated by the rapidly growing distributed photovoltaic systems in Shandong may have exceeded the power distribution network's capacity for absorption[173]. It sends a clear signal for the rational planning and deployment of medium- to long-term resources.

Shaanxi, Guangdong and Inner Mongolia ranked top for thermal power installation amid a large wave of new coal power projects in China, which started in summer 2022. New coal projects are largely located in provinces that already have more than enough coal power to support existing and planned wind and solar capacity. Contrary to the central government's guidance, local governments take no effective enforcement of the policies limiting new project permitting[174]. Before emissions peak by 2030, some local governments are rushing to build more high-energy-consuming and high-emission projects before the deadline. Some places began constructing high-energy, high emissions projects

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[171] Caixin. (Sep 2023). Cover Story: Are Chinese Solar Giants Flying Too Close to the Sun? https://weekly.caixin.com/2023-09-01/102099376.html. News article.

[172] Caixin. (Jun 2023). Shandong experiencing consecutive negative electricity prices, a rare occurrence globally. What has happened in China's electricity market? https://zhishifenzi.blog.caixin.com/archives/268002#. Blog article

[173] Energy Magazine. (Oct 2023). Deep Reflection | Has electricity investment overheated? https://mp.weixin.qq.com/s/LImbFPb1mG10DX9MU0Lc-g. Blog article

[174] CREA. (Aug 2023). China's new coal power spree continues as more provinces jump on the bandwagon. https://energyandcleanair.org/publication/chinas-new-coal-power-spree-continues-as-more-provinces-jump-on-the-bandwagon/. Report

before they were approved[175]. In the first half of 2021, the NDRC reported that eight provinces reached the first-level warning on total energy consumption control (and did not meet the target and exceeded the target for over 10%), and five provinces reached the second-level warning (did not meet the target and exceeded the target for within 10%)[176]. Since then, NDRC has stopped publishing the annually reported energy consumption control evaluation results of the local governments, but slow progress on the national level indicates that many provinces are off track.

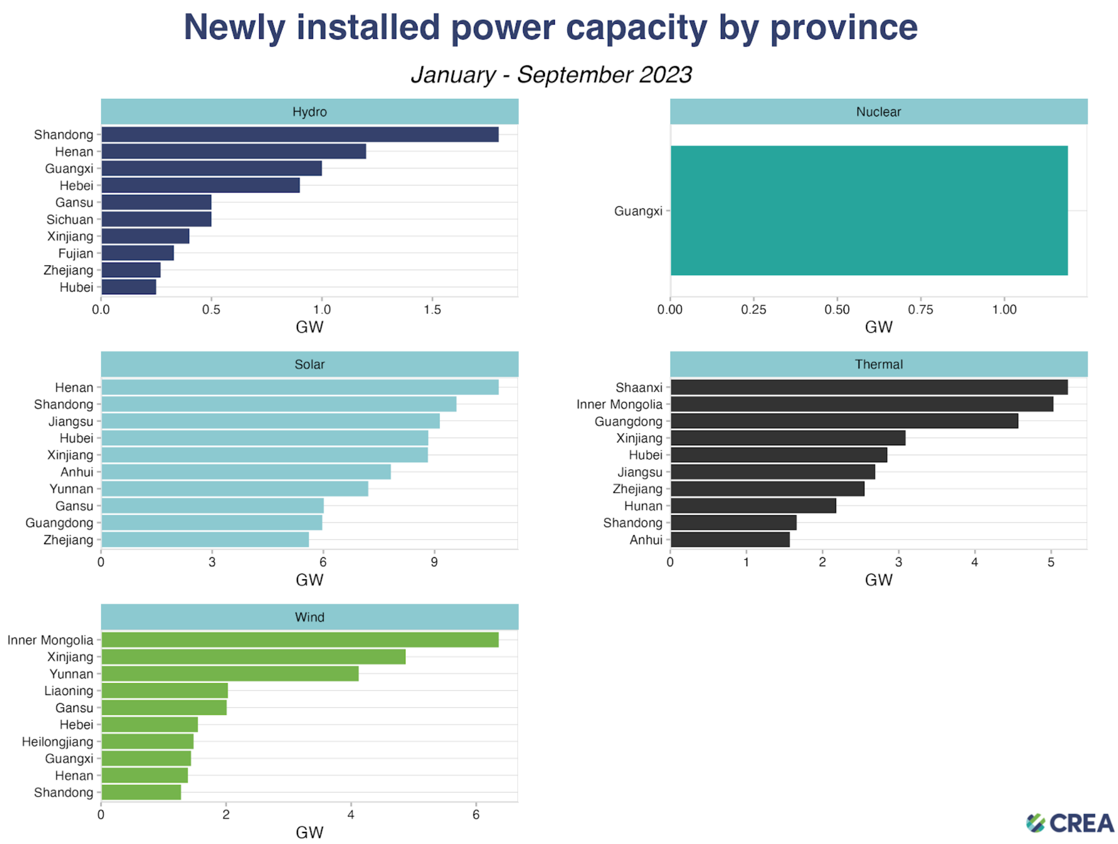

Figure 49 | Newly installed power capacity of different energy sources for the leading provinces between January and August 2023

The provinces' energy consumption and CO_2 emission targets by 2025 and 2030 are highly uniform. This uniformity resulted from the Central Committee of the Communist Party's warning in July 2021 against "campaign style" measures to reduce emissions and order for provinces to follow the plan and pace set on the national level[177]. In early 2021, after the dual carbon targets were made a major policy and public focus by Xi Jinping, the response from the provinces was to set ambitious targets. The central government was concerned that CO_2 peaking was being pursued with excessive zeal, at the

[175] Development Research Centre of the State Council. (Sep 2021). Chang Jiwen: Correcting the 'campaign-style' carbon reduction requires building before breaking. https://www.drc.gov.cn/DocView.aspx?chnid=379&leafid=1338&docid=2903880. Policy interpretation
[176] NDRC. (Aug 2021). Notice on the Issuance of the 'Clear and Rainy Table' for the Completion of Energy Consumption Dual Control Targets in Various Regions in the First Half of 2021. https://www.ndrc.gov.cn/xwdt/tzgg/202108/t20210817_1293836.html. Policy
[177] Development Research Centre of the State Council. (Sep 2021). Chang Jiwen: Correcting the 'campaign-style' carbon reduction requires building before breaking. https://www.drc.gov.cn/DocView.aspx?chnid=379&leafid=1338&docid=2903880. Policy interpretation

expense of other policy goals, with provinces competing to outdo each other[178].

[178] NDRC. (Aug 2021). Answer to August Press Conference Question Four. https://www.ndrc.gov.cn/xxgk/jd/jd/202108/t20210817_1293876_ext.html. Press release

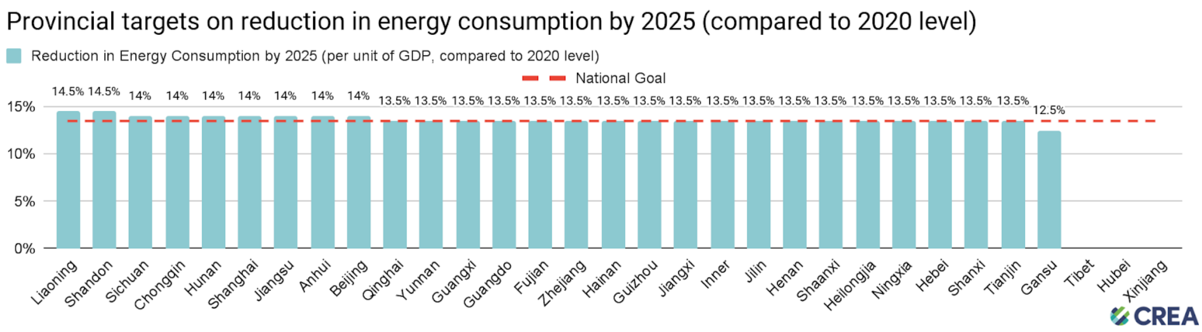

Figure 50 | Comparison of provincial targets on reduction in energy consumption by 2025 (compared to levels in 2020)

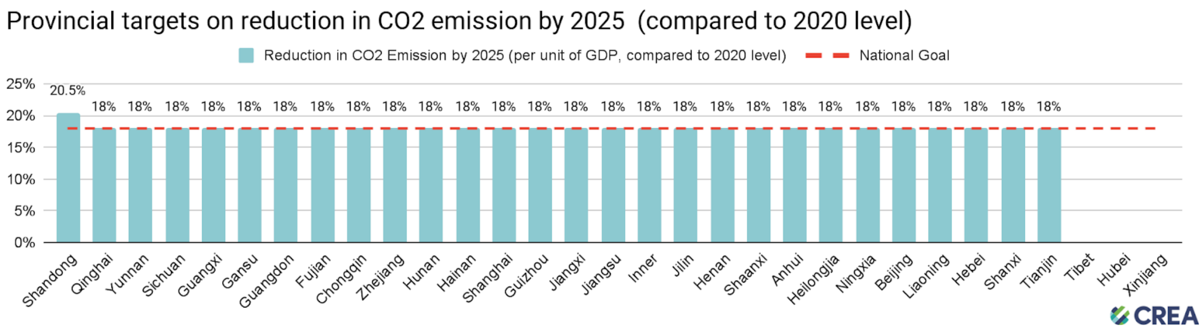

Figure 51 | Comparison of provincial targets on reduction in CO_2 emission by 2025 (compared to levels in 2020)

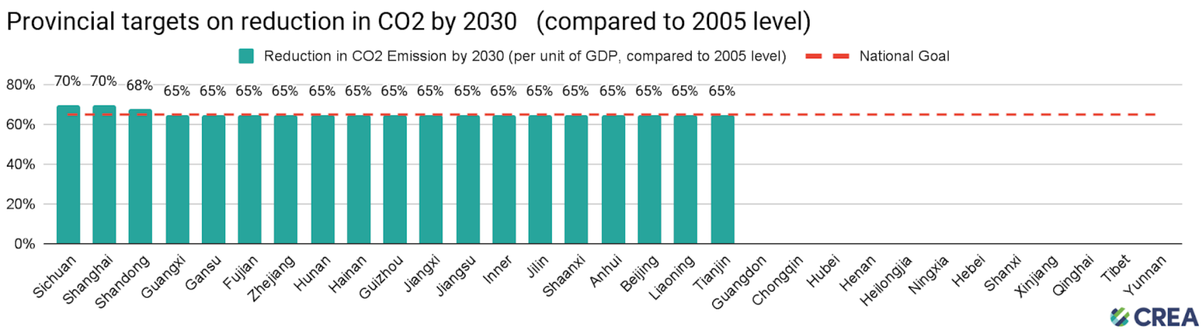

Figure 52 | Comparison of provincial targets on reduction in CO_2 emission by 2030 (compared to levels in 2005)

4.8.2 Recent adjustments to targets

The energy-intensive pattern of economic growth during and after zero-COVID-19 has made it hard for most provinces to meet their targets.

Since provincial carbon-peaking policies have been laid out, a few provinces have adjusted their plans to open up space for fossil fuel development.

Earlier in June 2022, Guangdong set a target of “more than 32%” for the proportion of non-fossil energy consumption in its carbon-peaking action plan[179]. In May 2023, Guangdong Province issued the "Implementation Plan for Promoting High-Quality Energy Development," reducing the proportion of non-fossil energy consumption target to approximately 29% by 2025[180].

Sichuan increased the targeted share of thermal power in its Provincial 14th Five-Year Period Electricity Development Plan[181] from 15.6% to 16.6% by 2025 to increase the use of locally produced coal, according to Sichuan's provincial power and grid development plan (2022–2025) released in December 2022.

Between September 1st and 8th 2023, provincial Development and Reform Commissions of Hubei, Shanxi, Gansu and Qinghai were engaged in talks with the NDRC, which oversees China's carbon peaking and carbon neutrality work, about falling behind on fulfilling energy saving targets for the 14th FYP period[182]. In October, NDRC also engaged Zhejiang, Anhui, Guangdong and Chongqing provincial governments in the same talks about lagging behind on reducing energy intensity[183]. These meetings have pointed out that the eight provinces and municipalities that were engaged in the talks had relaxed energy-saving controls and poor management of projects with high energy consumption, high emissions and low standards. In these meetings, NDRC emphasised that the reduction of energy consumption intensity must be met, however, energy consumption grew rapidly while energy efficiency improved slowly in these regions in the first two years of the 14th FYP period, even after deducting energy consumed by raw materials production and the use of renewable energy. Energy intensity has even gone up rather than down in certain regions, causing concerns that the provincial government departments are not carrying out the energy consumption control properly.

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[179] People's Government of Guangdong Province. (Feb 2023). Notice from the People's Government of Guangdong Province on the Issuance of the Implementation Plan for Carbon Peaking in Guangdong Province. http://www.gd.gov.cn/zwgk/wjk/qbwj/yf/content/post_4091117.html. Policy

[180] Guangdong Provincial Development and Reform Commission. (May 2023). Notice from the Guangdong Provincial Energy Bureau on the Issuance of the Implementation Plan for Promoting High-Quality Energy Development in Guangdong Province. http://drc.gd.gov.cn/ywtz/content/post_4186277.html. Policy

[181] Sichuan Provincial Development and Reform Commission. (May 2022). Notice from the Development and Reform Commission of Sichuan Province and the Energy Bureau of Sichuan Province on the Issuance of the '14th Five-Year Plan for Electricity Development in Sichuan Province. https://fgw.sc.gov.cn/sfgw/c106096/2022/5/26/2d856d99f07c40b1a945c900731a7a85.shtml. Policy

[182] NDRC. (Sep 2023). The National Development and Reform Commission's Environmental Protection Division Holds Talks with Selected Local Energy Conservation Authorities. https://www.ndrc.gov.cn/fzggw/jgsj/hzs/sjdt/202309/t20230914_1360598.html. News release

[183] NDRC. (Oct 2023). The National Development and Reform Commission's Environmental Protection Division Holds Talks with the Energy Conservation Authorities of Zhejiang, Anhui, Guangdong, and Chongqing. https://www.ndrc.gov.cn/fzggw/jgsj/hzs/sjdt/202310/t20231019_1361344.html. News release

5 Expert survey and interviews

2023 Highlights

- Responses from an expanded group of 89 experts this year have shown views shifted towards a more optimistic direction compared to the results from last year. The results suggest that the majority of experts acknowledge China is on track to reach its carbon peak before 2030, though limiting emissions increases during this decade remains a significant challenge.
- This year's survey results showed a large difference in answering whether China's coal consumption peaked compared with last year's, with 34% of experts answering unsure, which increased from 12% last year. This may reflect that the development of coal policies over the past year has injected more uncertainty.
- The results of the past two surveys reveal a growing divergence in expert opinions regarding peaking carbon emissions in China's power sector. The proportion of the experts believing that carbon emissions in the power sector already peaked or the peak will occur after 2030 have both increased.

To map expert views and expectations towards China's emissions trajectory, outstanding experts from various fields were invited to participate in a questionnaire survey on the progress and prospects of this significant undertaking[184]. The same survey questionnaire was used in 2022 to facilitate a detailed comparison with last year's data. This is aimed to identify changes and trends since last year, especially to determine if significant changes have occurred in specific areas or issues.

In the questionnaire, the participants were asked to provide their views on when China will reach its peak in both CO2 emissions and total energy consumption. They were also asked to provide their expectations regarding the CO_2 emissions trajectories across various emission-intensive sectors, including electricity, industry, construction, and transportation. Most of these experts specialise in energy, environmental economics, and climate change (refer to Figure 53). Their professional backgrounds are extensive and varied, spanning higher education, coal, electricity, renewable energy, and the oil and gas industries (refer to Figure 53). These professionals are affiliated with academic institutions, consulting firms, and the energy industry, such as electricity, oil, and natural gas sectors (refer to Figure 55).

The survey, conducted between 25 August 2023 and 15 September 2023, received a total of 89 valid responses. Of these, 64 were from domestic experts and 25 were from overseas experts. In addition, virtual interviews were also conducted with select experts.

In contrast to conventional quantitative studies, which are predominantly based on mathematical modelling or normative analyses, the experts engaged in our survey leveraged their extensive professional expertise and hands-on experience to address the questions posed in the questionnaire.

[184] ISETS, CREA. (Nov 2023). China's Climate Transition Outlook 2023: Expert Survey and Interviews. https://energyandcleanair.org/publication/chinas-climate-transition-outlook-2023-expert-survey-and-interviews/. Report.

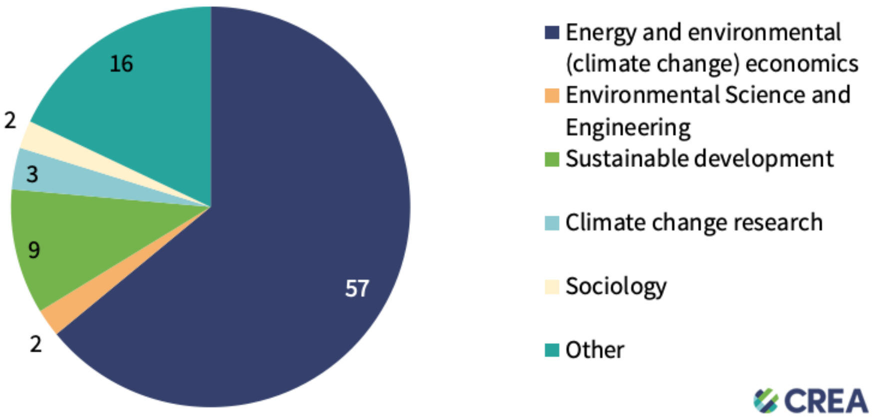

Figure 53 | Expert fields of expertise (persons)

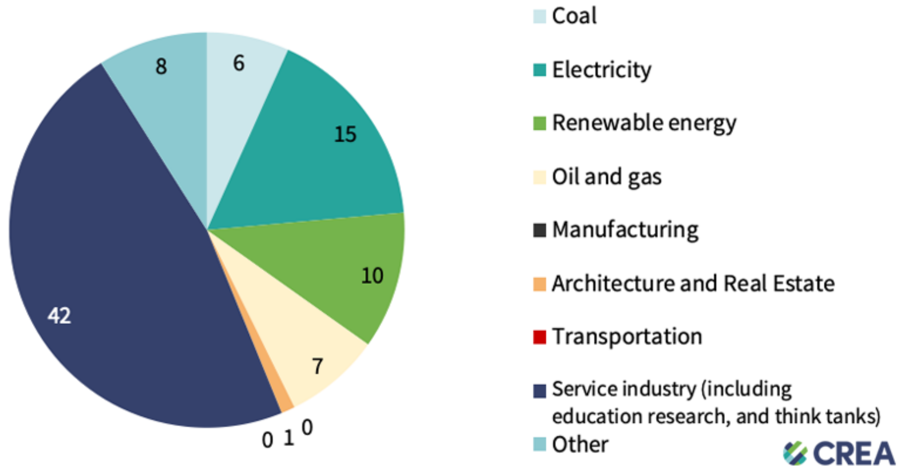

Figure 54 | Expert industries (persons)

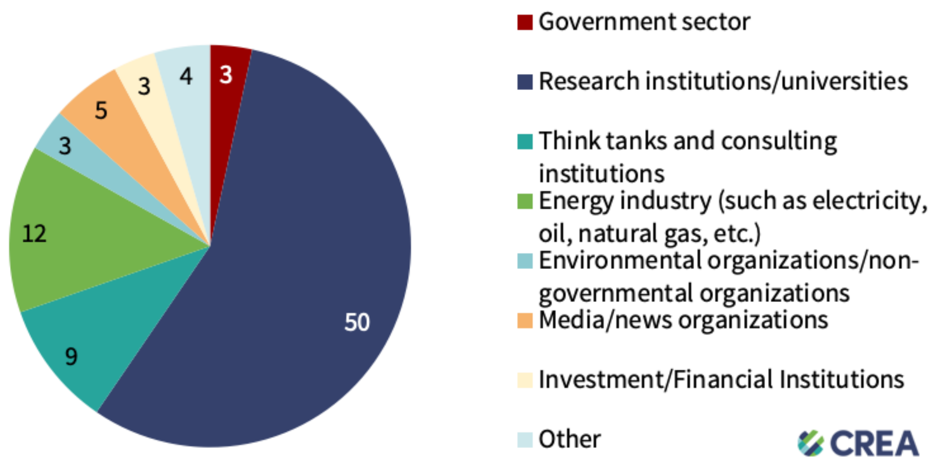

Figure 55 | Status of affiliated institutes (persons)

The survey participants include scholars from universities and research institutes and outstanding representatives from various fields, such as government agencies, industrial associations, domestic and international think tanks, state-owned companies, other energy companies, non-governmental organisations, and news media. Their viewpoints reflect the mainstream perspectives in their respective domains to a certain extent. Additionally, their diverse backgrounds ensure our survey results' broad representativeness and reliability.

5.1 Total emission of carbon dioxide

More than 70% of the experts surveyed believe that China can achieve its goal of peaking CO_2 emissions before 2030. Of these, two experts think that China's CO_2 emissions have already peaked. While 17 experts predict that China will reach its carbon peak before 2025, 45 experts suggest it will occur between 2026 and 2030 (see Table 12).

Table 12 | Survey results on China's carbon emission peaking year

When do you predict China's total carbon dioxide emissions will peak?			Which would be the possible peak year if it peaks between 2026 and 2030?	
Option	Number of responses	Percentage (%)	Year	Number of responses
A. Already peaked	2	2%	2026	2
B. Before 2025	17	19%	2027	3
C. After 2030	25	28%	2028	14
D. Between 2026 and 2030	45	51%	2029	10
			2030	13
			Uncertain	3

China's implementation of its transition policies has positively influenced expert views, with the proportion of experts believing the country will reach its peak carbon emission by 2025, increasing from 15% in 2022 to 21% in 2023. Among them, two experts believe China's CO_2 emissions may have already peaked. Correspondingly, the proportion of experts predicting that China's CO_2 emissions will peak after 2030 has decreased from 31% in 2022 to 28% in 2023. This change may reflect the experts' increased expectations for China to achieve its emission reduction goals and greater confidence in the Chinese government's efforts to strengthen emission reduction.

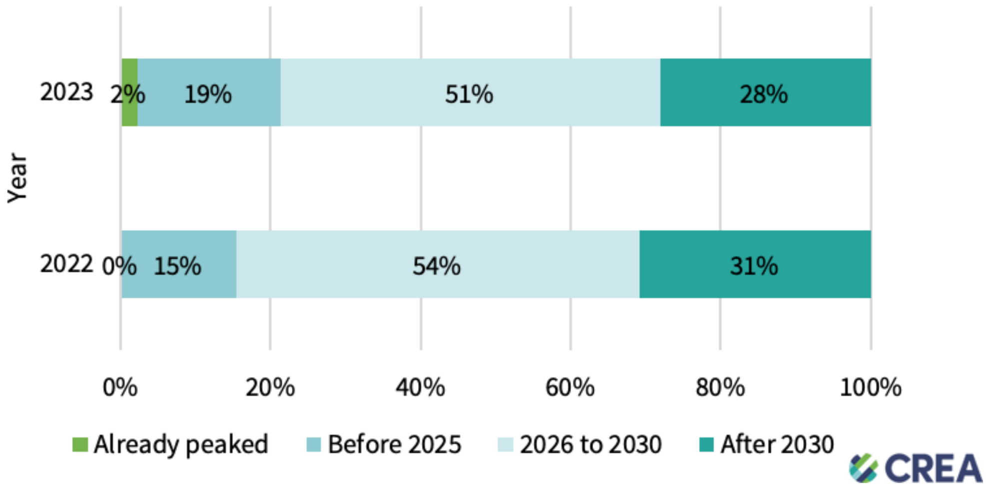

Figure 56 | The peak year of China's carbon emissions

In the 2023 survey, most experts believe that China is on track to peak its carbon emissions before 2030. The key question is to which level of CO_s emissions will they peak. Fifty out of 89 experts predict that the peak level would be more than 15% higher than China's carbon emissions in 2020 (see Figure 57).

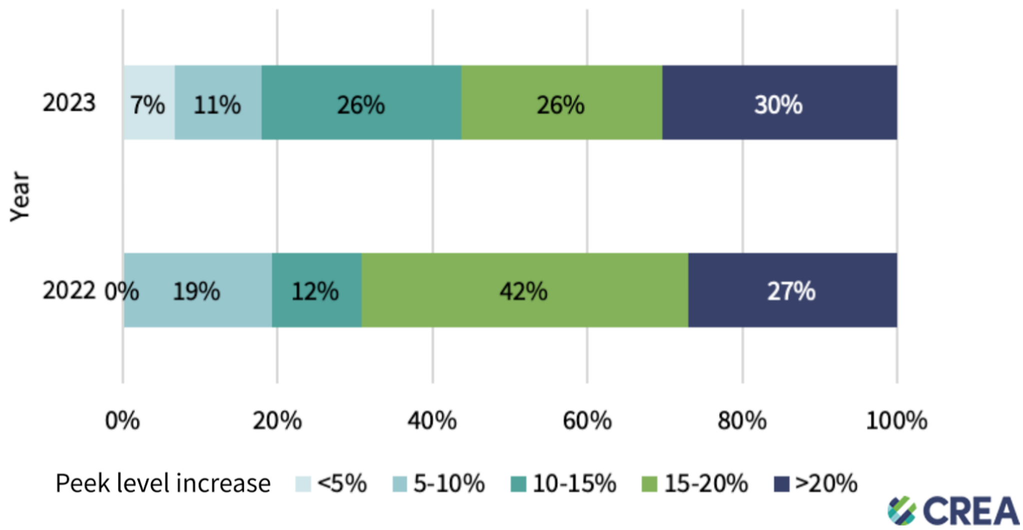

Figure 57 | Carbon emission peak

5.2 Consumption of primary energy and coal

More than half of the experts (54 out of 89) believe that China's primary energy consumption will peak before 2030, probably reflecting their confidence in China's ability to control the growth of energy consumption. Furthermore, 13 experts predict that primary energy consumption will peak in 2035, reflecting their cautious attitude. Twenty-two experts believe that China's primary consumption will continue to increase beyond 2035, highlighting their conservative view that the country's energy demand will continue to increase along with its rapid and continuous economic growth.

Table 13 | 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	7
B. By 2030	47
C. By 2035	13
D. After 2035	22

Regarding the timing of China's peak primary energy consumption, the 2023 survey results show a more positive trend than the previous year. Firstly, the proportion of experts who believe China's energy consumption has already peaked has doubled from 4% in 2022 to 8% in 2023. Secondly, 53% of the experts believe China will achieve a peak in primary energy consumption before 2030, up from 50% in the 2022 survey. Overall, the percentage of experts leaning towards the belief that China's total primary energy consumption will peak before 2030 has risen from 54% to 61%.

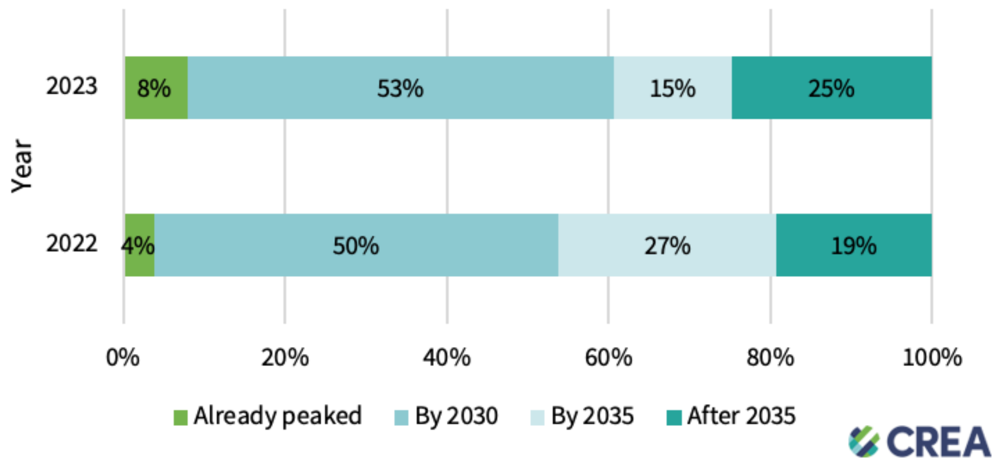

Figure 58 | Year of peak primary energy consumption in China.

China announced in 2021 that it will strictly control the growth of coal consumption during the 14th FYP period (2021-2025) and achieve a gradual reduction in coal consumption during the 15th FYP period (2026-2030), implying that China's coal consumption will peak around 2025[185]. Of the 89 experts we surveyed, 18 believe China's coal consumption has already peaked. However, nearly half (41 out of 89) believe otherwise. Furthermore, 30 experts responded with "not sure", as they consider the peaking of coal consumption to be closely related to China's political and economic situation in the coming years.

Twelve experts predict the peak to arrive by 2025, while four predict 2026. Sixteen experts believe that China's coal consumption will peak after 2027, among which six experts chose 2028, five experts chose 2030, and one selected 2040. Overall, about one-third of the experts who chose "no" believe that

[185] Central Government of China. (October 2021). Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy. https://www.gov.cn/zhengce/2021-10/24/content_5644613.htm. Policy.

China's coal consumption will peak in 2025. All surveyed experts emphasised that the peaking of coal consumption needs to consider the correlation between energy transition, the global and domestic economic situation in China, and the importance of energy security, sometimes even surpassing control of carbon emissions.

Table 14 | Survey results on the year of peak coal consumption in China

Do you think China's coal consumption has already peaked?			**Peak year**	
Option	Number	Percentage (%)	Year	Number
A. Yes	18	20%	2025	12
B. Not Sure	30	34%	2026	4
C. No	41	46%	2027	2
			2028	6
			2030	5
			2035	1
			2038	1
			2040	1
			Uncertain	9

In the 2023 survey, the proportion of experts who believe coal consumption has already peaked increased by 5 points, reaching 20% (see Figure 59). On the other hand, the proportion of experts who believe that China's coal consumption has not yet peaked decreased from 73% in 2022 to 46% in 2023. The percentage of experts answering "not sure" increased significantly from 12% in 2022 to 34% in 2023. Among the experts who believe that the peak has not been reached, this year's survey shows more experts are inclined to think that coal consumption will peak by 2025 (see Table 14 and Figure 60).

However, it's worth noting that the percentage of experts unsure about the year of coal peaking has significantly increased. The 2022 survey results indicated that only 12% of experts were "not sure", while 2023 saw a substantial increase to 34%. This may be due to increased uncertainty as a result of China's coal policies over the past year.

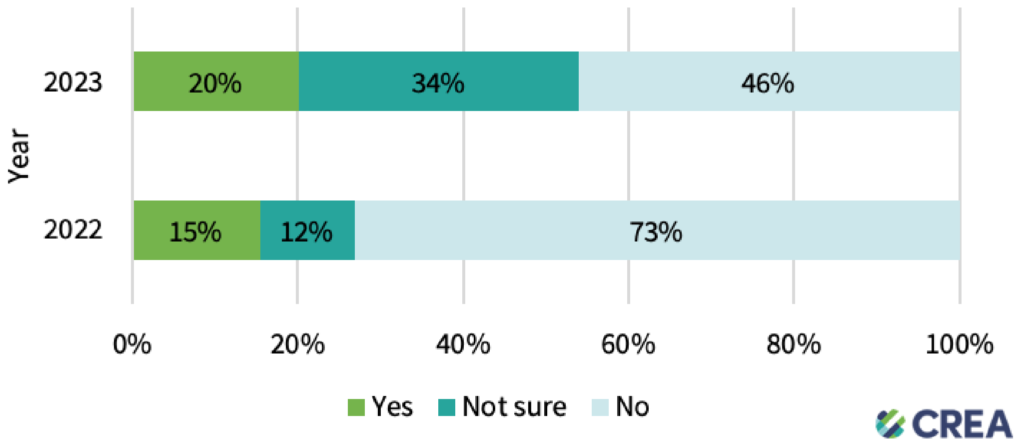

Figure 59 | Has China's coal consumption peaked?

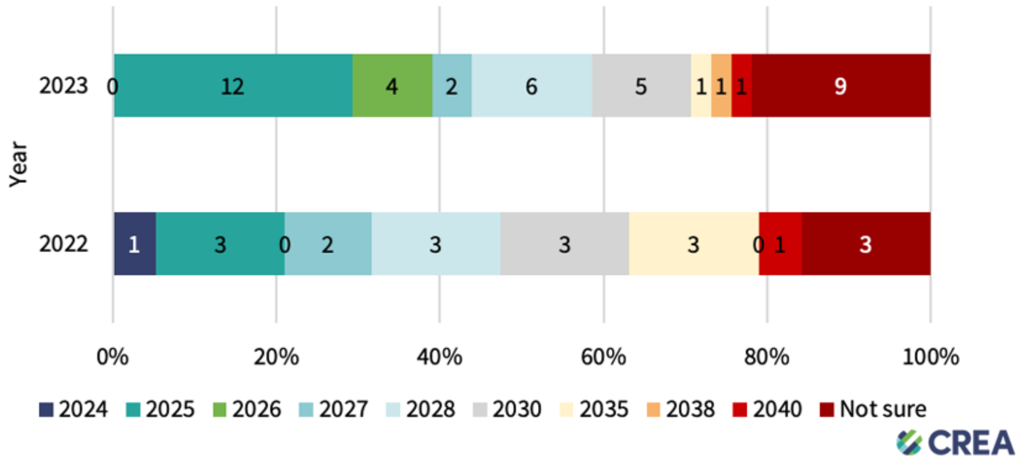

Figure 60 | Number of responses for different years of coal consumption peaking

5.3 The power sector

The power sector, contributing to 40% of the country's total carbon emissions, plays a crucial role in China's efforts to decarbonise its industries. Yet, opinions vary on when the sector will reach its emissions peak. While 27 experts foresee this happening after 2030, 22 believe it will happen between 2026 and 2030.

Of these 22, 19 provided their predictions for specific years. Among them, seven predicted 2027, five predicted 2028, and another five predicted 2030 - the self-imposed deadline by the Chinese government. One expert predicted 2026, while another predicted 2029.

Table 15 | Survey results on the peak year of carbon emissions in China's power sector

When do you predict China's power sector's carbon dioxide emissions will peak?			**Which would be the possible peak year if it peaks between 2026 and 2030?**	
Option	Number	Percentage (%)	Year	Number
A. Already peaked	5	6%	2026	1
B. Before 2025	35	39%	2027	7
C. After 2030	27	25%	2028	5
D. Between 2026 and 2030	22	30%	2029	1
			2030	5
			Uncertain	3

The past two surveys reveal a growing divergence in expert opinions when it comes to peaking carbon emissions in China's power sector. The proportion of experts who believe that carbon emissions in the power sector have already peaked and those who believe the peak will occur after 2030 has increased. On a positive note, 6% of the experts in 2023 believe that China's power sector has already peaked its carbon emissions, a view that was not held by any experts in 2022. On the other hand, the proportion of the experts in the 2023 survey who believe that China's power sector will only peak its carbon emissions after 2030 has risen to 30%, up significantly from 19% in 2022. This may reflect a more pessimistic view of some experts regarding the future carbon emissions reduction in the power sector.

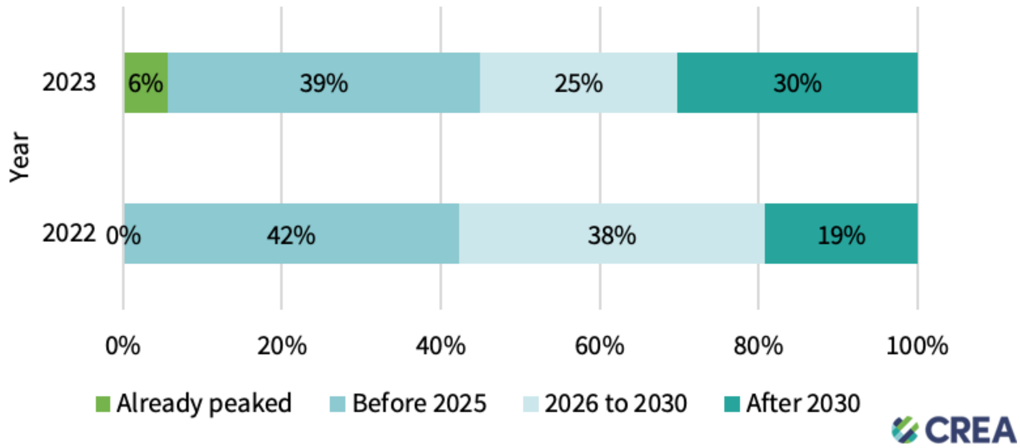

Figure 61 | Peak year of carbon emissions in China's power sector

5.4 The industrial sectors

The steel industry is the second-largest source of carbon emissions in China. As shown in Table 15, there are varied opinions on when the steel sector would peak in its carbon emissions. Thirteen experts believe that emissions in this industry have already peaked, while 35 experts predict it will peak before 2025. Nearly half of the experts (48 out of 89) express a relatively optimistic view. In addition, 21 experts believe that carbon emissions in the steel industry will peak after 2030, while 20 experts place the peaking time frame between 2026 and 2030. This diversity of viewpoints reflects different expert perspectives on the carbon reduction prospects in the Chinese steel industry, highlighting the challenges and uncertainties this industry faces in emissions reduction.

Further investigation results regarding the experts predicting carbon emissions in the Chinese steel industry peaking between 2026 and 2030 show a certain distribution. Specifically, two experts predict emissions will peak in 2026, 3 experts believe the peak will occur in 2028, 5 experts predict 2029, and 4 experts anticipate carbon emissions will peak in 2030.

Table 16 | Survey results on the peak year of carbon emissions in China's steel industry

When do you predict China's steel industry's carbon dioxide emissions will peak?			**Which would be the possible peak year if it peaks between 2026 and 2030?**	
Option	Number	Percentage (%)	Year	Number
A. Already peaked	13	15	2026	2
B. Before 2025	35	39	2027	0
C. After 2030	21	24	2028	3
D. Between 2026 and 2030	20	22	2029	5

			2030	4
			Uncertain	6

The 2023 survey suggested that the decarbonisation of the steel sector has a positive outlook as experts believe that its peak will occur earlier than previously anticipated. Around 15% of experts believe that carbon emissions in the steel industry have already peaked (Option A), compared to 8% the previous year. The 2023 survey revealed a significant increase in experts predicting the steel sector's peak to arrive before 2025, from 27% of those surveyed in 2022 to 39% in 2023. The increase is from those who initially estimated that the Chinese steel industry would peak in 2026-2030. In the 2023 survey results, 22% of experts believe that carbon emissions in the steel industry will peak between 2026 and 2030 (Option D), a significant decrease from 42% in 2022. This suggests that, over the two years, fewer experts hold the view that the peaking time will be delayed until 2026-2030. There is little change when it comes to those predicting the peak to occur after 2030 (Option C), from 23% in 2022 to 24% in 2023.

These results indicate that some experts are more optimistic about the steel industry's emission reduction achievements and the year of its peak. In particular, one-fifth of experts surveyed have brought forward the peaking year by 1-5 years.

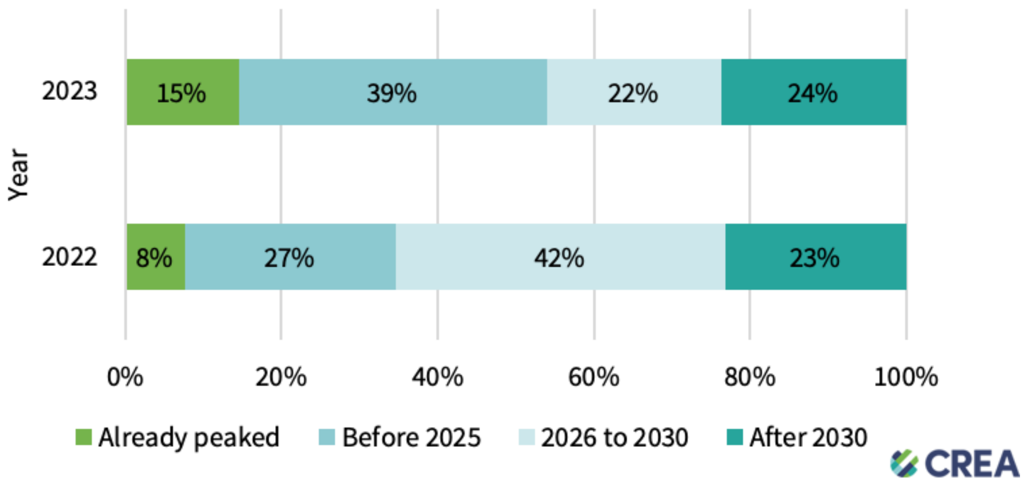

Figure 62 | Peak year of carbon emissions in China's steel industry

The cement industry is listed as China's third-largest source of carbon emissions. The 2023 survey results show that nearly 60% of experts believe that carbon dioxide emissions in China's cement industry will peak before 2025; approximately 21% of experts believe that carbon emissions in the cement industry have already peaked, and 38% of experts predict that the peak will occur before 2025. Among the remaining 40%, 17% of experts predict the peak will occur between 2026 and 2030, while 24% of experts believe the peak will occur after 2030.

Of the experts predicting the peak year between 2026 and 2030, none predict it to happen in 2026. However, two experts predict the peak year to be 2027, four experts anticipate 2028, and other two and three experts forecast 2029 and 2030, respectively. Four experts did not provide specific years (Table 17).

Table 17 | Survey results on the peak year of carbon emissions in China's cement industry

When do you predict China's cement industry's carbon dioxide emissions will peak?			Which would be the possible peak year if it peaks between 2026 and 2030?	
Option	Number	Percentage (%)	Year	Number
A. Already peaked	19	21%	2026	0
B. Before 2025	34	38%	2027	2
C. After 2030	21	24%	2028	4
D. Between 2026 and 2030	15	17%	2029	2
			2030	3
			Uncertain	4

This year's survey has shown increased optimism amongst experts, with 21% believing the cement industry has already peaked in its carbon emissions in 2023, up from 8% last year. Meanwhile, the proportion of experts who think the cement industry will not reach its peak until after 2030 has decreased from 38% in 2022 to 24% in 2023. As for the predictions of peaking before 2025 (Option B) and between 2026 and 2030 (Option C), the proportions of experts remain roughly the same.

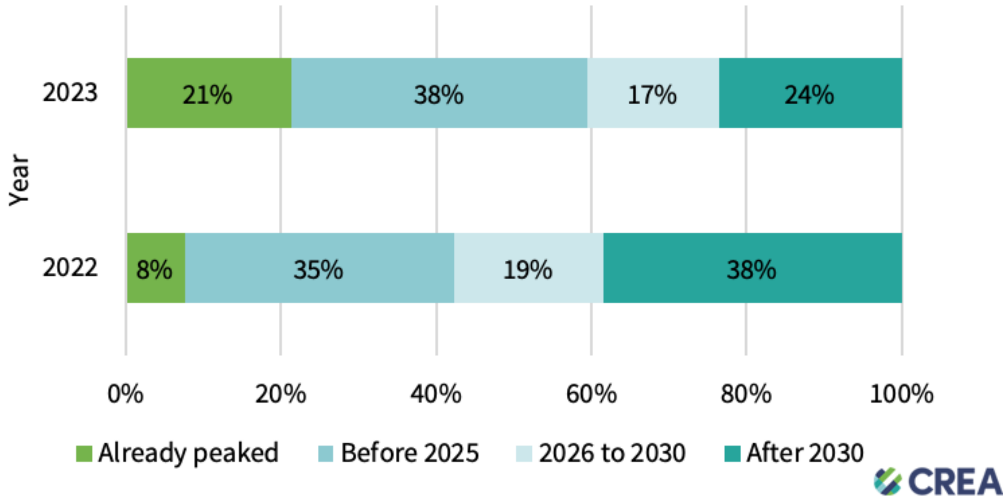

Figure 63 | The peak year of carbon dioxide emissions in China's cement industry

5.5 The transportation sector

Since the 1980s, China's transportation sector has experienced a sharp increase in passenger and freight vehicles, leading to a significant rise in energy consumption and carbon dioxide emissions. Road transport, which primarily relies on petroleum, is this sector's largest carbon dioxide emissions source. Comprehensive measures need to be taken to reduce carbon dioxide emissions from the transportation sector.

As per the 2023 survey, 37% of the experts believe that the transport sector will reach peak carbon emissions before 2030 (Option A), while 43% predict it to happen between 2030 and 2035 (Option B). Some 15% anticipate peaking between 2035 and 2040 (Option C), while 5% predict after 2045 (Option D) (Table 18). Compared to previous predictions, these results indicate that experts have a more diversified view on the peaking time of carbon emissions in the Chinese transportation sector without a clear consensus, as seen in earlier studies.

Table 18 | Survey results on the peak year of carbon dioxide emissions in China's transportation sector

When do you predict China's transportation sector's carbon dioxide emissions will peak?	
A. Before 2030	33
B. 2030-2035	38
C. 2035-2040	13
D. 2045 and beyond	5

The survey results in 2023 and 2022 indicate that more experts have brought forward the peak time of carbon dioxide emissions in China's transportation sector. The experts anticipating peaking before 2030 (Option A) significantly increased from 23% in 2022 to 37% in 2023. In contrast, the experts predicting the sector to peak between 2030 and 2035 (Option B) decreased from 50% in 2022 to 43% in the 2023 survey. Meanwhile, the experts forecasting the peaking time between 2035 and 2040 (Option C) also decreased from 19% in 2022 to 15% in the 2023 survey.

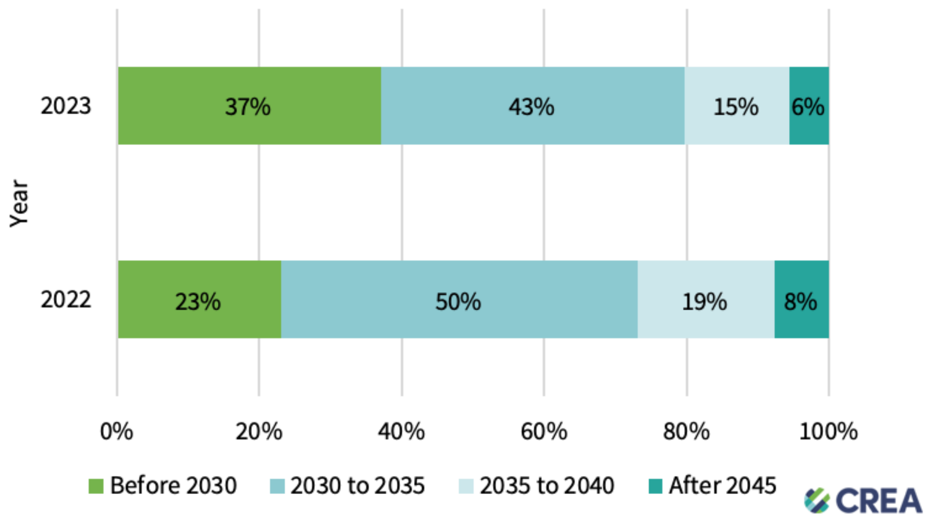

Figure 64 | Peak years of carbon dioxide emissions in China's transportation sector

5.6 New dynamics

The COVID-19 pandemic has had multifaceted impacts on energy transition. On the one hand, the pandemic slowed economic activities, causing lower energy demand and reducing the capacity to invest in clean energy. On the other hand, government economic stimulus measures have created opportunities to develop clean energy technologies. Empirical research by Li et al. (2022) found that the COVID-19 pandemic increased low-carbon electricity generation and accelerated the transition to low-carbon energy sources. The IEA predicts that investment in clean energy technologies will be nearly twice that of fossil fuels by 2023. Considering the power shortages the country faced the last two years, we included two questions to understand expert opinions and recommendations for the energy transition.

Experts hold differing views on the impact of the post-pandemic economic situation in China on the energy transition process. Over half (51%) of the experts believe that the post-pandemic economic situation will accelerate the energy transition, possibly because some low-carbon trends, such as decreased carbon emissions and increased renewable energy adoption, emerged during the pandemic. However, 34% of experts are concerned that the current economic situation will slow the energy transition, possibly considering that economic development may be prioritised over low-carbon energy transition. Additionally, 9% of experts believe that the economic situation will not affect the energy transition, and 7% are unsure. This may reflect the high uncertainty level in China's current economic situation, making it difficult to accurately predict the specific impact on the future of the energy transition.

Table 19 | Survey results on the impact of China's post-pandemic economic situation on the energy transition process

How do you think the economic situation in China after the pandemic will affect the energy transition process?		
A. No impact	8	9%
B. Accelerate the energy transition	45	51%
C. Slow down the energy transition process.	30	34%
D. Unclear	6	7%

Regarding the question of whether China's "dual carbon" strategy and goals need adjustment, The majority of the experts surveyed (65%) suggest adhering firmly to "dual carbon goals" while adapting implementation strategies and action plans to changing circumstances. Additionally, 9% of experts believe that the strategy and goals should be executed resolutely, unaffected by the economic conditions. Notably, 12% of the experts believe that goals could be moderately reduced to support economic development, probably reflecting their concern for economic growth. Moreover, 8% (7 experts) suggest that even more ambitious targets should be set.

Table 20 | Survey results on views or recommendations regarding China's "dual carbon" strategy and goals

"What are your thoughts or suggestions regarding China's 'dual carbon' strategy and goals?		
A. Moderately lower the goals to promote economic development.	11	12%
B. Keep commitment to the goals but be prepared to make adaptive adjustments in the implementation of strategies and action plans.	58	65%

"What are your thoughts or suggestions regarding China's 'dual carbon' strategy and goals?		
C. The strategy and objectives remain steadfast, and strategies and actions should not be swayed by economic conditions	8	9%
D. Perhaps we can consider more ambitious goals	7	8%
E. No suggestion	5	6%
F.Other opinion	0	0%

6 Conclusions

China’s President, Xi Jinping, emphasised in July 2023 that China's determination to achieve the goals of reaching a carbon peak by 2030 and carbon neutrality by 2060 remains steadfast. “But the path, method, pace and intensity to achieve this goal should and must be determined by ourselves, and will never be influenced by others,” he said.

Emissions targets remain on the agenda, but policymakers’ priorities shifted amid the domestic economic slowdown and escalation of geopolitical tension. However, the economic headwinds have resulted in an unprecedented boom in clean energy manufacturing and deployment, opening up the possibility of a much faster peak and decline in emissions than expected or targeted by the government.

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

- Clean energy investments
- Electrification
- Building sector coal use
- Steel and cement output
- Construction materials sector emissions
- Electric vehicle sales

We also found the following indicators to be still off track at least until 2022–2023:

- Total CO_2 emissions
- Total energy consumption
- Industrial energy consumption
- Transport energy consumption
- Buildings energy consumption
- Investments in coal-based power capacity
- Investments in coal-based industrial capacity, particularly iron and steel capacity

Key 2023 trends:

Emissions rebound

There was an upswing in CO_2 emissions in 2023 due to a rebound in oil consumption after the end of zero-COVID-19, and a precipitous drop in hydropower due to droughts. All the transition pathways require emissions to fall from 2020 to 2030, implying a peak well before 2030 and emissions reductions thereafter. In all transition pathways, emissions reductions need to accelerate dramatically from the rates projected for 2020–2030 immediately after 2030 in order to meet their temperature targets.

The rapid increase in total energy consumption has meant that 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.

Surge in clean energy paves the way for earlier peak

China's deployment of clean energy technology, particularly solar power and electric vehicles, exceeded all expectations in 2023. We estimate that the added annual non-fossil power generation in 2023 will exceed the average annual growth in total electricity generation for the first time. This means that if clean energy growth is maintained and electricity consumption growth is at or below historical average, power sector emissions will peak in the next few years.

The boom in deployment was accompanied by growth in clean energy manufacturing. The rapid growth made clean energy and cleantech the driver of investment and GDP growth, for the first time, cementing their place as a key part of economic policy.

The importance that China has placed on clean energy manufacturing will be a motivation for fast domestic transition, and means that China has a significant interest in the success of the energy transition in the rest of the world.

Investments in coal-based capacity yet to align with emissions peak

Until 2022, China's net additions of thermal power capacity, mainly coal and fossil gas, 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. Yet, 2023 saw a sharp acceleration in new capacity being added. Permitting new coal-fired power plants accelerated further in 2022 and 2023.

Announcements of coal-based steelmaking capacity continued at a high rate in 2023, remaining out of step with the prospect of emissions peaking and a shift to more steel production from scrap. There was some progress in increasing investments in electric arc capacity, and budding progress with hydrogen direct reduced iron (DRI), technologies that will play a key role in decarbonized steelmaking.

Clean technology manufacturing boom while oversupply looms

Progress in cleantech manufacturing has been rapid since the carbon neutrality announcement in 2020, and accelerated in 2022–2023 as a result of an unprecedented boom in investment. Cleantech is a major economic driver, absorbing an estimated 24% of all investment in 2023 and responsible for all of the net growth in investment. However, with numerous players running into these sectors oversupply looms and results in utilisation rate decrease.

Experts grew more optimistic on carbon peaking

To gauge the views and expectations of practitioners in the field, Outlook 2023 surveyed an expanded pool of 89 experts representing diverse specialisations in the field of climate and energy. The experts in this year's survey are more optimistic than those interviewed last year, with 21% of experts believing China's CO_2 will peak before 2025, up from 15% in 2022's survey. The percentage of experts expecting China's CO_2 emissions to rise more than 15% above their 2020 before peaking fell from 69% to 56%. This change may reflect the experts' increased expectations for China to achieve its emission reduction goals.

Most of the experts believe that China is on track to peak its carbon emissions before 2030, but achieving carbon neutrality remains a significant challenge. This suggests that although China can achieve the goal of carbon peaking before 2030, significantly reducing carbon emissions remains an extremely challenging task, requiring unwavering effort and collective collaboration across society.

Disappointing progress on emissions reporting and controlling non-CO_2 greenhouse gases

For non-CO_2 greenhouse gases, there was no substantial progress on overall policies. There are no official quantitative targets or regular emissions reporting that would allow the assessment of trends or progress. The national action plan on methane emission reduction also lacks specific or measurable targets. It is currently not specified whether the 2060 carbon neutrality target includes all greenhouse gases or only CO_2, 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. There was some progress on CO_2 emissions reporting on industrial plant level but no progress on national or provincial level.

Appendix: Historical data sources

Historical data was obtained from the China Energy Statistical Yearbook 2022, with data for 2021, from the National Bureau of Statistics, IEA World Energy Balances 2023, which includes officially reported data for China, and the annual and monthly electricity statistics from the China Electricity Council.

For 2023, 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 2022 was taken from the BP Statistical Review of the World's Energy and for 2023 from the Ember Global Electricity Review.

Table 21 | Historical data sources

Sector	Indicator	Product	Data source	2023 Data source
All	GHG emissions	CO_2	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	CO_2	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

Sector	Indicator	Product	Data source	2023 Data source
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

CO_2: 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: China's Five-Year Plan

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-CO_2 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