CLIMATE ENERGY FINANCE

POWER SHIFT: Staggering rise of renewables positions China to end new coal power before 2030

New China electricity market modelling shows coal use to peak pre-2030, then plateau and decline as massive renewables surge further accelerates, with profound implications for global transition & Australia

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Established in 2022, Climate Energy Finance (CEF) is an Australian based, philanthropically funded think tank. We work pro-bono in the public interest on mobilising capital at the scale needed to accelerate decarbonisation consistent with climate science. Our analyses focus on global financial issues related to the energy transition, and the implications for the Australian economy, with a key focus on the threats and opportunities for Australian investments and exports. Beyond Australia, CEF's geographic focus is the greater Asian region as the priority destination for Australian exports. CEF also examines convergence of technology trends in power, transport, mining and industry in accelerating decarbonisation. CEF is independent, non-partisan, and works with partners in the NGO, finance, business, research, and government sectors.

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We pay our respects to the Traditional Owners of the unceded lands on which we live and work.

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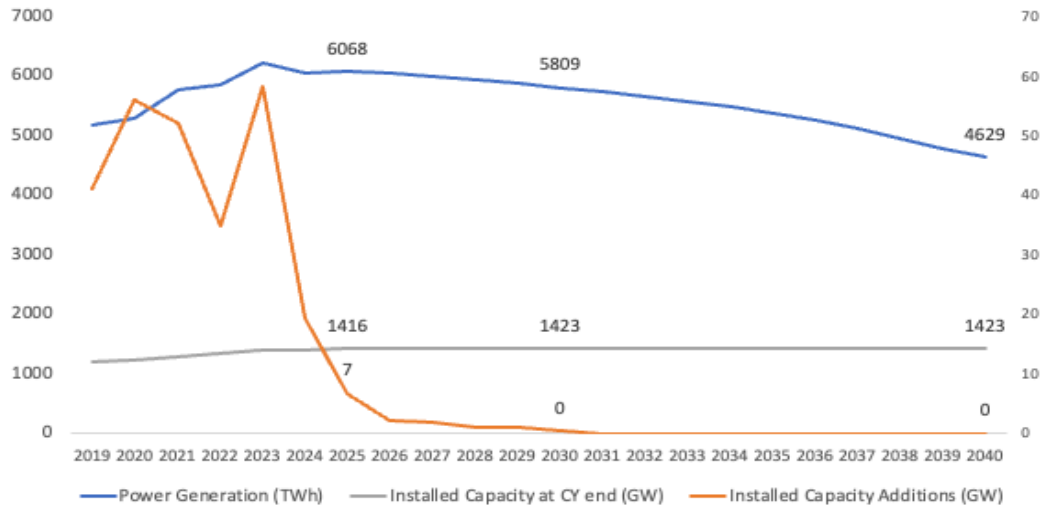
Key Findings

1. Rapidly declining wind, solar and storage costs are dramatically changing the economics of China's electricity system, and driving a massive increase in renewables capacity. CEF forecasts that China will see coal power generation peak well before 2030, then plateau and decline (Figure 1).

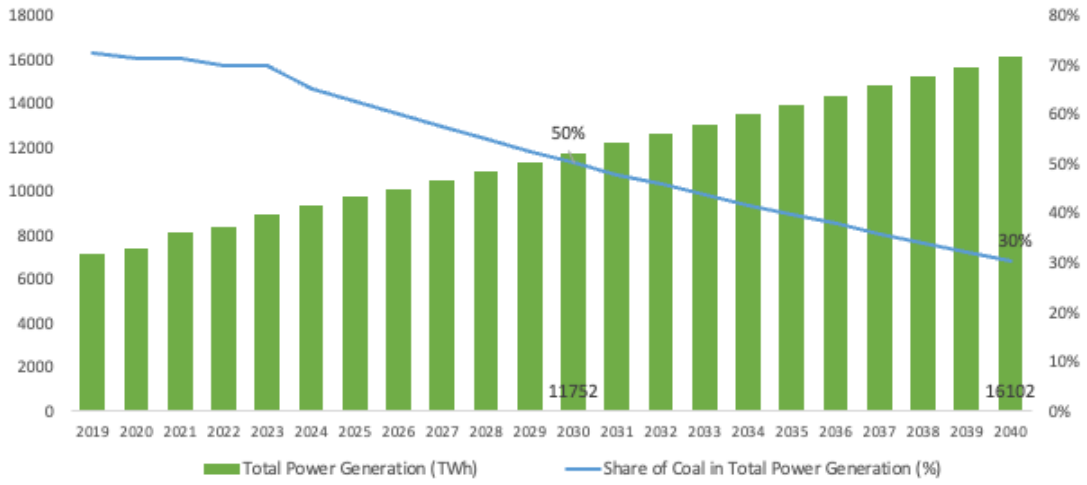
Figure 1 China Thermal Power Forecast to 2040



Source: China NEA; Forecasts by CEF

Coal will fade from its current position as a central pillar of China's power generation, moving to what will be a backup role in ensuring national energy security in the next 16 years as the transformation accelerates. While China's total electricity demand will continue to rise through 2040 due to sustained strong economic growth and economy-wide electrification, the share of thermal power in total generation will progressively decline, with our model forecasting just 50% by 2030 and potentially just 30% by 2040 versus the 70% in 2023 (section 4.1). If delivered, this is a staggering trajectory of profound global importance.

Figure 2 Total Power Generation and the Share of Thermal Power in Total



Source: China NEA; Forecasts generated from CEF's national electricity model

2. China will likely **reach its 14th Five Year Plan (FYP) 2030 target of 1,200 gigawatts (GW) of installed solar and wind capacity six years early**. By the end of CY2023, after a record 293GW of installs, China already had total wind and solar capacity of 1,050GW (section 4.2 & 4.3). During the first quarter of CY2024, it installed an additional 61GW of wind and solar; sustaining this rate would see China have a total wind and solar capacity of 1,294GW by the end of 2024, significantly exceeding the 2030 target. In the first 3 months of calendar 2024, 91% of China's newly installed capacity was variable renewable energy (VRE), which includes, in addition to wind and solar, hydropower, totalling 63GW, (the total installed capacity of the Australian National Energy Market), a 35% y-o-y increase. On CEF estimates, China will add as much as 340GW to reach 1,390GW of wind and solar capacity by the end of 2024, well above its 2030 target (section 2).

3. CEF forecasts that through to 2040, China will install 323GW per annum of solar capacity, 80GW of wind, 1GW of hydropower and 3GW of nuclear. Sustaining this rate of installation of >400GW pa of zero-emissions additions would **see China achieve ahead of time its 'dual carbon' targets – to peak carbon emissions by 2030 and reach carbon neutrality by 2060.**

4. China needs to show resolve to cease building new coal-fired power plants, and commit to progressive end of life coal-fired power plant retirements. The expansion of zero-emissions installs at or above the scale and speed we model, coupled with the accelerating buildout of transmission lines and utility scale battery storage to overcome VRE's intermittency, suggests China can generate enough zero-emissions energy to supply the country's electricity demand whilst progressively reducing its over-reliance on thermal power. This requires strategic planning of grid distribution, especially transmission lines in southwestern China to connect the southwest and northwest. **On the basis of progress to date, CEF views it as entirely feasible for China to dramatically slow the rate of its thermal energy buildout and cease construction of net new coal power plants before 2030.**

5. China's economic growth is reflected in a 8% year on year (y-o-y) increase in electricity demand during the first quarter of 2024. However, this does not necessarily mean more emissions. With China's multi-decade 'electrification of everything' strategy, the share of electricity in total energy demand has increased from 12% in 2002, to 19% in 2023, and CEF is expecting this share to reach over 25% by 2040 (section 1.4). Accordingly, accompanied by China's decade-long effort in greening the national electricity grid, **its reliance on fossil-fuels and imported crude oil imports should decline in the upcoming decade, complementing an increase in the momentum of its electricity market transition away from coal-fired power.**

6. China's gross domestic product (GDP) growth trend and technological and industrial innovation shows a similar trajectory to other developed countries, and it is now the fastest-growing developed nation in the world. It also leads on all fronts of clean technology installation, manufacturing and investment (except steel). With leadership comes responsibilities. As the fastest-growing green economic powerhouse, **China has the opportunity to be more ambitious in its climate targets and energy goals and transition to net zero at least in line with other world-leading nations,** as it helps accelerate the energy transformation globally. Its growing opportunity to

green the $US900bn Belt and Road Initiative's (BRI) vast international infrastructure development program is under the spotlight.

7. China's global dominance in all zero-emissions industries, its accelerating decarbonisation, and the transition in China's electricity market away from coal power prefigures a critical shift in the global energy and trade landscape – including the **inevitable and overdue decline in demand for coal within China.**

   This highlights the **imperative for Australia to hasten the transition of its economy from historical overdependence on fossil fuel exports, diversify its economic base and secure domestic cleantech supply chains.** The Federal Government's April 2024 announcement of its landmark new Federal Future Made in Australia (FMIA) Act grasps the scale of this challenge and opportunity by looking to align Australia's economic exposures with the global transition, led by China, and enable regional partnerships and joint ventures in clean energy, value-added processing of critical minerals, resources and strategic metals, and cleantech manufacturing.

Key Recommendations

On the basis of our findings we recommend that CHINA:

1. Cease net new addition of coal-fired power plants well before 2030. This shift needs to be evidenced through an accelerating decline in the share of thermal power in overall power generation in the national electricity mix.

2. Leverage its GDP growth – which is demonstrably linked with the clean energy sector – to continue to accelerate the momentum of its utility renewable energy infrastructure buildout, and maintain its leading position in clean technology innovation, utilising its high national savings rate to green the country's overall investment. Expand clean energy market participation, drive market-wide transformation, incentivize local governments to boost renewable adoption, reduce coal reliance, and expand transmission line construction. China is well positioned to counter oversupply in the clean energy industry by accelerating decarbonisation of the domestic manufacturing supply chain, building more zero-emissions capacity to power processing and manufacturing of its cleantech, and accelerating coal's exit.

3. Intensify existing efforts to 'electrify everything' domestically, further accelerating the rollout of transmission infrastructure, energy productivity and the buildout of battery and hydro storage systems to meet increasing energy demand led by growing GDP. This should include efforts to more effectively use current transmission infrastructure capacity, and improve the planning of transmission infrastructure integration with utility-scale wind and solar projects.

4. Increase its decarbonisation ambition and update its double-carbon targets, so that it aims to peak CO_2 emissions by 2025 and reach carbon neutrality by 2050 or 2055. This is necessary to align its targets with climate science, the Paris Agreement, and to ratchet up the ambition of other leading nations.

5. As the world leader across all renewables fronts, assist emerging markets and developing economies (EMDEs) to accelerate their energy transition. China's efforts to green the BRI are a key opportunity to leverage its successes to enable the decarbonisation of less developed economies. Achievement of global transition and climate goals also requires other leading economies to increase their ambition and commitments into climate mitigation financing and clean energy investment in EMDEs. China should lead the way.

On the basis of the report's findings, we recommend that AUSTRALIA:

1. Safeguard its economic prosperity, energy security and national interests by rapidly responding to the accelerating global pathway to net zero of China and its other trading partners. Australia must increase the momentum of its investment and industry pivot from its carbon-based export economy toward future-facing industries, transitioning its economy and value-adding its critical minerals and strategic resources, including its world #1 reserves in lithium and iron ore.

2. Leverage the framework and capital allocations of the new Future Made in Australia Act to explore opportunities to collaborate and joint venture with China on value-added onshore minerals and resources processing and cleantech supply chain manufacturing, powered by Australia's superabundant renewable energy potential. This is a substantial opportunity for Australia to export "embodied decarbonisation" while sharing expertise with China, playing to each nation's strengths, and enhancing bilateral trade and economic ties. This approach would enable Australia to both consolidate strategic relations with the world's green economic powerhouse and build sovereign capabilities in its national interest.

Introduction

China's electricity market transformation

This report aims to unpack China's current electricity market, and provide a comprehensive forecast of China's renewable, nuclear, hydro and thermal power generation and capacity, energy efficiency and electricity demand growth out to 2040. We investigate each fuel type in China's electricity mix and analyse the likely trajectory for future development. We explore what needs to be done in China's electricity market to ensure peak coal power generation this decade and then chart a progressive phase out fossil fuel dependence so as to reach China's 'double carbon targets' – to peak CO_2 emissions before 2030 and achieve carbon neutrality by 2060 – ahead of schedule.

We undertake this analysis to contribute to the topic of what China's progressive greening of its electricity sector means to the global energy market and progress on energy transformation the world needs to see to deliver on the imperative to rapidly decarbonise, as dictated by climate science.

April 2024 saw China's draft energy law submitted by the State Council to the National People's Congress Standing Committee for consideration, designed to safeguard energy supplies, promote the shift to low-carbon power and support sustainable development. This has been in development since 2006, delayed by incumbent vested interest resistant to change, as is also clearly evident here in Australia.[1]

China's electricity market is undergoing a staggering energy transformation trajectory. It moves at a speed and scale that has decisive impacts on the world's potential to tackle the climate crisis. The figures are extraordinary. The world newly installed a total of 510GW renewable energy capacity in 2023, and China contributed more than 50% of this.[2] It installed a total of 292.8GW of new VRE in 2023, representing a 99% y-o-y increase, and accounting for 81% share of its total newly installed capacity of 2023. Newly installed solar power capacity took the lead, reaching a total of 216.9GW, or 60% of the total newly installed capacity, a 148% y-o-y increase.

China's energy demand is rising as GDP growth remains strong. In the meantime, China's multi-decades long electrification of everything strategy, and its greening of the national electricity grid, is increasing the share of electricity demand of total energy. This is a great opportunity for China to reduce use of fossil fuels and imported crude oil, helping to improve its domestic energy security, and national security against global supply chain disruptions.

China is also massively scaling up renewables manufacturing, significantly, permanently lowering the cost for Chinese renewable products, batteries for firming, and new electric vehicles (NEV). The price for polysilicon is down 52% y-o-y after China produced 1.45m tons of polysilicon in 2023, a 81% y-o-y increase, representing almost 90% of global production.[3]

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[1] South China Morning Post, China's draft energy law finally sees the light after 18 years in the making, 20 April 2024
[2] 国家能源局. 潘慧敏:2023年全球可再生能源新增装机5.1亿千瓦，中国贡献超过50%. 25th January, 2024
[3] PV Magazine. China polysilicon prices fall 51.8% year-on-year amid supply glut. 20th January, 2024

The price for solar panels decreased 42% in 2023, with China accounting for 80% of global solar manufacturing capacity.[4]

The solar module price slump has spurred concerns in Europe, as its solar industry warns that cheap Chinese imports have flooded the European market and threaten European solar businesses with bankruptcy. The European Union (EU)'s wind turbine industry is currently going through a similar crisis, as is the auto sector.[5]

China has also invested heavily in the new energy vehicles (NEV) industry in 2023, a total of US$442bn – US$177bn in manufacturing capacity, US$14bn in charging infrastructure, and US$311bn in production of EVs.[6] BYD surpassed Tesla as the world's number one NEV maker in 4QCY2023, with a total production of 3.02m in 2023.[7] Chinese NEV makers have the capacity to supply 75% of NEV demand worldwide, with BYD exporting an estimated 250,000 cars in 2023 and collectively with other Chinese NEV makers dominating the global NEV market.[8]

This development has posed significant challenges for European carmakers, and geopolitical tensions are rising. Despite the US's effort to block and counter China's growing dominance through Inflation Reduction Act (IRA) there are growing US concerns that Chinese NEV companies could one day 'crack the US market'.[9]

In short, China leads the world in all renewables and zero-emissions industries of the future.

This is good news given the urgency of climate science, but concerning news for some, particularly global corporations and nations which have been very slow to invest in zero emissions technologies at speed and scale and lack the critical mass and monumental wall of strategic public capital investment of the Chinese centralised government system.

It becomes more vital and urgent for the world to understand China's electricity market, and renewable industry, at present and in future.

Leveraging the Chinese electricity market and demystifying how it functions is essential for non-Chinese allies, competitors and trade partners to understand the speed of technology enhancements so as to better strategise pathways to net-zero while maintaining their own energy security and national security.

It is also essential for global decarbonisation that developed nations like China – we argue given its monumental growth and technological progress can no longer be considered a developing nation – seek better energy cooperation to jointly help developing economies to boost their energy transition pathways to net-zero. Without this coordinated global effort, emissions reduction goals and energy transition in line with science cannot be achieved.

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[4] Reuters. China solar panel costs drop 42% from year ago - report. 14th December, 2023
[5] Reuters. Explainer: China's dominance in wind turbine manufacturing. 10th April, 2024
[6] Carbon Brief. Analysis: Clean energy was top driver of China's economic growth in 2023. 25th January, 2024
[7] The Guardian. China's BYD overtakes Tesla as top-selling electric car seller. 3rd January, 2024
[8] Australia Financial Review.China's electric vehicle dominance presents a challenge to the West. 7th January, 2024
[9] Australia Financial Review. China's electric vehicle dominance presents a challenge to the West. 7th January, 2024

China's impressive trajectory in energy transition with 'Chinese characteristics' has shown the rest of the world that it is possible to deploy renewable energy at an unprecedented speed and scale, with careful planning, policy clarity and investment. What's more, 40% of China's GDP growth in 2023 was generated by the clean energy sector, demonstrating that its intentional effort to pivot from its heavy focus on domestic real estate sector and diversify its economy via massive investments in zero-emissions industries of the future has set the example of how a country can benefit economically from energy transition.

We note, however, that China's trajectory is still far from perfect. It is still undertaking a totally unsustainable program of new coal-fired power plant building, on the basis that this will ostensibly help ensure the nation's energy security and in light of the strong ongoing electricity demand growth spurred by two decades of electrification of everything.

We also note that significantly improved energy efficiency is a critical priority for achieving carbon neutrality,[10] and the new targets set early in 2024 need to be ongoing, and ideally accelerated. China's economic growth of the last five years has been excessively emissions intensive, making this a huge opportunity, in conjunction with the decades long program to electrify everything and the sustained growth in zero emissions capacity additions.

CEF's national electricity sector modelling of the pace of China's zero-emissions capacity additions, combined with its massive battery storage systems buildout, shows this is sufficient to ensure energy security and stability and underpin the start of an ongoing coal power phasedown ahead of 2030.

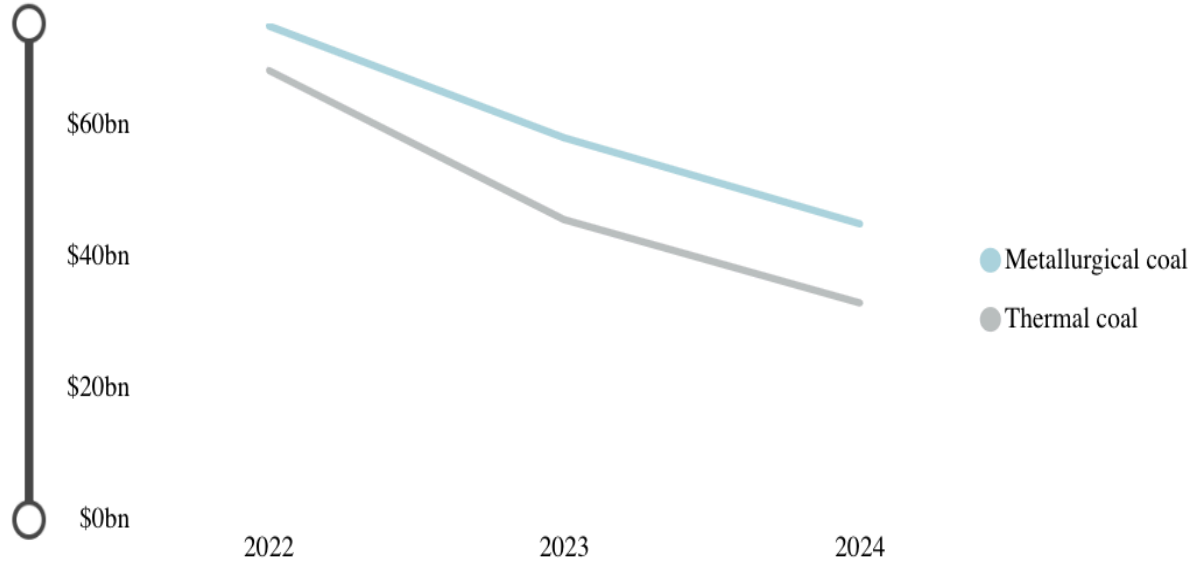
Implications for Australia

Prime Minister Anthony Albanese's April 2024 announcement of a landmark new Future Made in Australia Act looks to align Australia's economic exposures, energy transition and industry development trajectory with the massive opportunities that arise from global decarbonisation, led by China, and enable regional partnerships that accelerate Australia's transformation to a zero-emissions trade and investment leader.

As China starts to pivot from coal – at an accelerating pace as this report outlines – Australia must diversify its economy beyond its historic reliance on fossil fuel exports and move away from its dubious status as a world top 3 petrostate, seizing the opportunity to remake itself as a renewable energy and cleantech power. This is essential if it is to secure its long term economic prosperity, ensure its energy independence, capture more of the energy value- and supply chain onshore, and bolster its national security in the newly emerging economic and geopolitical order.

[10] Energy Research Institute of Chinese Academy of Macroeconomic Research, China Energy Transformation Outlook 2023

Figure 3 Annual value of commodity exports, Australia



Source: Department of Industry, Science and Resources, Resources and Energy Quarterly, December 2023

This trend of declining coal export values is already apparent. According to the Office of the Chief Economist, as shown in figure 3, Australia's thermal coal export value is expected to fall to $33bn in 2024 from $45bn in 2023 and $68bn in 2022, while coking coal exports are estimated to fall to $45bn in 2024 from $58bn in 2023 and $75bn in 2022.[11]

Australia can no longer rely on its traditional fallback as a dig-and-ship, zero value-add resources economy. China's breathtaking scale and ambition of investment in manufacturing, technology, domestic deployments and exports in all zero-emissions industries of the future changes everything. The US$1 trillion of public subsidies in the US IRA changes everything. The Koreans, Japanese, EU, Indian and Canadian governments have all responded at scale to the massive once in a century challenge and opportunity of global decarbonisation with huge strategic public funding programs.

The FMIA Act flags Australia's new-found industrial policy ambition and a significant injection of strategic national-interest public capital into transition, providing a key signal to catalyse private capital investment. Australia has the advantages of a globally dominant abundance of critical minerals and strategic metals reserves such as lithium and iron ore, a leading supply of the raw materials needed to support the global energy system transformation, and world-leading renewable energy potential as well as ample landmass. Its considerable financial firepower includes a A$3.6 trillion superannuation pool, and substantial capital allocations to Federal authorities tasked with financing transition and re-industrialisation.

These factors underpin Australia's transformative opportunity to attract a wave of domestic and foreign capital and collaboration into decarbonisation, and its potential to position itself further along the cleantech supply chain, for example in green metals and renewables manufacturing. By processing energy transition materials onshore powered by renewables, Australia can export "embodied decarbonisation".

[11] Department of Industry, Science and Resources, Resources and Energy Quarterly, December 2023.

Key to this is enhancing partnerships and bi- and multilateral agreements in the Asian region, a central premise of the new FMIA Act, including with China. There is enormous potential to collaborate and joint venture with China in Australia, by leveraging Australia's abundant natural resources and expertise, collaborating in research and development (R&D), refining local resources such as quartz and lithium, and value-adding via onshore processing and manufacturing, from critical minerals to renewables components and technologies, powered by Australia's superabundant, low-cost zero-emissions energy.

Rather than competing with China, Australia could strategically contribute to the global solar industry based on its own national strengths and interests, leveraging our four decades of solar technology global leadership, as outlined in the Silicon to Solar (S2S) roadmap.[12]

This is a substantial opportunity for Australia to share expertise with China, playing to each nation's strengths and building future-facing trade and economic ties, as Australia both consolidates strategic relations with the world's green economic powerhouse and simultaneously builds its sovereign capabilities.

CEF notes Australian Treasurer Jim Chalmers has referenced a modernisation of Foreign Investment Review Board rules to clarify and give greater transparency to the rules of engagement, and fast-track approvals where appropriate.[13]

As the President of the Australia-China Business Council has pointed out, collaboration with China's world-leading technology firms is key, as "China's energy transformation offers new economic opportunities that can also unlock Australia's potential as a green economy leader in our region."[14]

[12] ARENA, Roadmap provides a pathway for domestic solar manufacturing, 2 February 2024
[13] Australian Financial Review, Budget to fast-track investment approvals, 3 April 2024
[14] Australian Financial Review, Australia must collaborate with China to unlock the green economy, 11 April 2023

1: Economic growth and electricity demand

1.1 China's economic growth profile

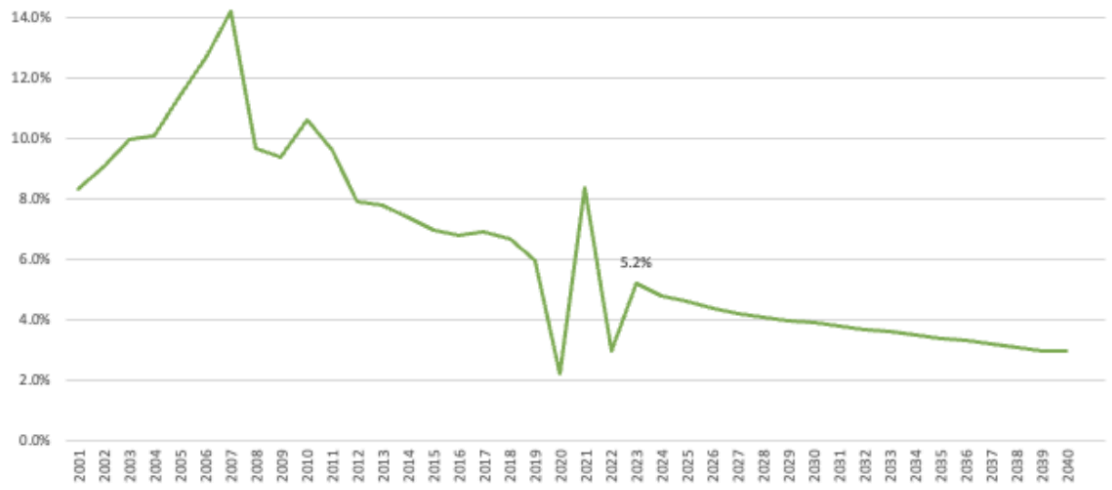
China's GDP growth has tempered from a compound annual growth rate (CAGR) of 10% in the decade to 2013 to 6.0% over the decade to 2023. The best growth of any large developing economy in the world. CEF forecasts GDP growth will temper to average 4.1% over the decade to 2033, reflective of the maturing of the economy, the end of a multi-decade construction sector boom and the inevitable outworking of China's population peaking in 2022. We note this still represents a staggeringly strong performance, the best of all large developed economies in the world.

However, a positive economic growth outlook brings higher energy demands in China. As China is greening the electricity grid, and electrifying everything, it comes with higher electricity demand. And a need for greater focus on energy productivity.

And China today is a world leader, no longer a developing country. China needs to take on this mantle of responsibility and leadership, it is already a technology leader.

China's GDP growth remains relatively strong after decades of economic boom.

Figure 1.1.1 China's GDP Growth (%) and CEF's Forecast to 2040



Source: China NBS; Calculated by CEF

CEF's electricity model assumes a strong GDP growth in 2024 at 4.8%, noting the very strong start in the 1QY2024 results, including +5.3% y-o-y GDP growth and +8.0% y-o-y growth in electricity demand,[15] higher than most forecasts and Chinese official's targets,[16] led by China's export volumes up 14% y-o-y, even as the price index of those exports fell 12%, highlighting the global benefits of China exporting deflation.

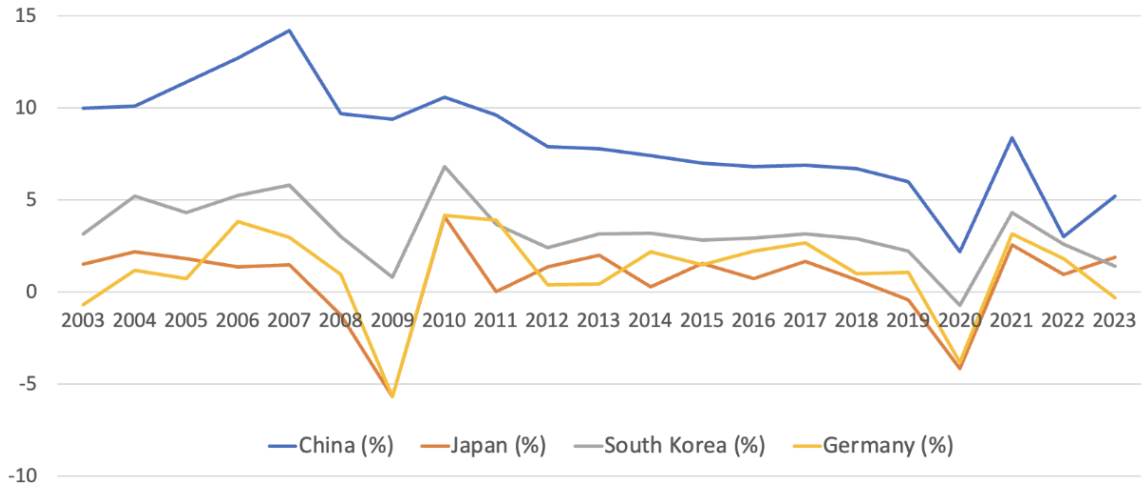
CEF models that this will temper to 4.2% per annum (p.a.) during 2025-2030, 3.6% p.a. during 2031-2035 and 3.1% p.a. over 2036-2040 - Figure 1.1.1.

[15] China National Bureau of Statistics, Monthly data
[16] 国家统计局. 一季度国民经济实现开局良好. 16th April, 2024

CEF's forecast is in alignment with the International Monetary Fund (IMF) who reports China's GDP grew 5.2% in 2023 and is forecasting a lower growth rate of 4.6% this year,[17] slowing to 4.1% in 2025.[18] A number of independent economists support this forecast with estimations of 4.2 - 4.8% y-o-y GDP growth for 2024.[19] The International Energy Agency (IEA) forecasts more conservative growth rates of just under 4% GDP growth per year until 2030.[20] The Lowy Institute forecasts depict a much bleaker picture of growth rates at ~3% by 2030, slowing to 2% by 2040, and an average growth rate of 2 - 3% until 2050.[21]

Chinese officials remain optimistic about their GDP growth targeting 5% for 2024,[22] of which target is lower than the average GDP growth which saw a CAGR of 6.1% over the past decade from 2013 to 2023 - Figure 1.1.1.

Figure 1.1.2 GDP Growth Rate (%) of China, Japan, South Korea and Germany



Source: The World Bank, EU, Bank of Korea, OECD; Calculated by CEF

The slowing growth is a partial indicator of China as a developed nation instead of a developing country. We have witnessed a similar GDP growth trend in other developed countries, such as Japan, South Korea, and Germany - Figure 1.1.2.

In the meantime, China's GDP growth rate remains well above the developed countries. As shown in Figure 1.1.2, Japan's GDP growth in 2023 was 1.9%,[23] the Organisation for Economic Co-operation and Development (OECD) forecasts that Japan's GDP growth will slow down to 1.0% in 2024 and 1.2% in 2025.[24] The Bank of Korea reports that the 2023 GDP growth in South Korea was 1.4%, dropped from 2.6% in 2022, and projects a growth

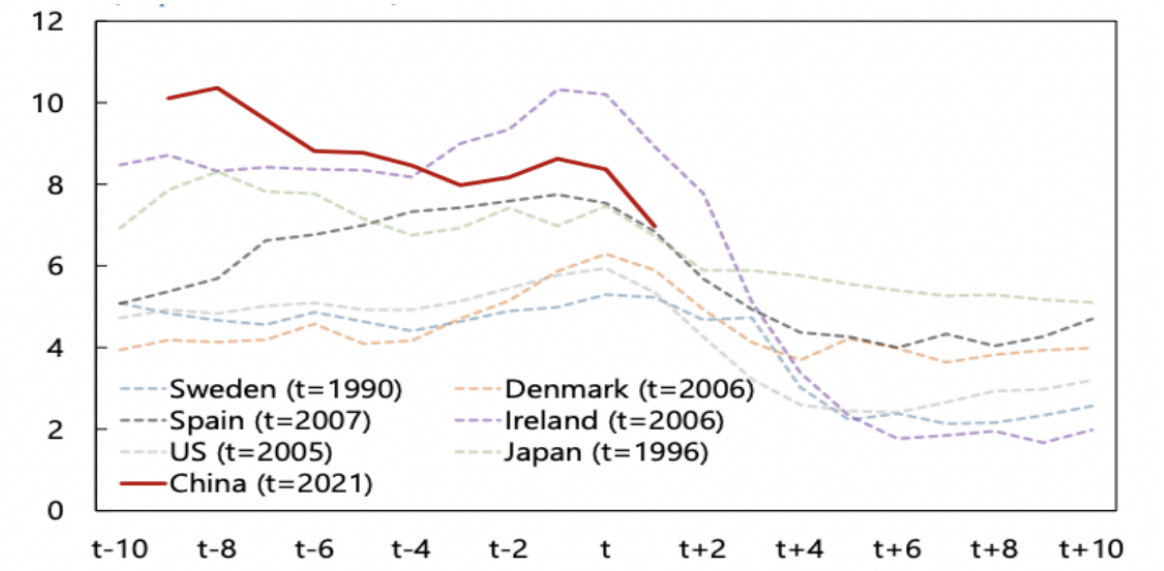
[17] IMF. MODERATING INFLATION AND STEADY GROWTH OPEN PATH TO SOFT LANDING. January, 2024
[18] IMF. Regional economic outlook. Asia and Pacific : challenges to sustaining growth and disinflation. October, 2023
[19] Australian Financial Review. China to miss lofty economic growth target without major stimulus, 9 April 2024
[20] IEA.World Energy Outlook 2023. October, 2023
[21] The Lowy Institute. Revising down the rise of China. 14th March, 2022
[22] 中华人民共和国中央人民政府. 国家发展改革委:GDP增长5%左右的目标符合经济运行走势. 7th March, 2024
[23] Bank of Japan. Outlook for Economic Activity and Prices (January 2024). 23rd January, 2024
[24] OECD. Economic Outlook - Japan. November, 2023

rate of 2.1% in 2024, and 2.3% in 2025.[25] The EU reported a -0.3% GDP growth in 2023 for Germany, forecasts a 0.3% growth in 2024 and an increase to 1.2% in 2025.[26]

We used these three countries to benchmark and model China's rapid progress in becoming a developed economy. China's 20 years of superior GDP growth is expected to slowly normalise as the Chinese economy matures - a common growth trend for countries moving into the developed world. With that comes the need to accelerate China's net zero target.

There are uncertainties and challenges regarding China's economic growth outlook, such as the downturn in China's real estate sector.[27] However, CEF argues that the falling of one sector is being balanced by growth in zero emissions industries of the future, and not enough to slow down China's economic growth materially.

Figure 1.1.3 Selected Countries: Residential Real Estate Investment (% of GDP)



Source: Haver Analytics; and IMF staff calculations[28]

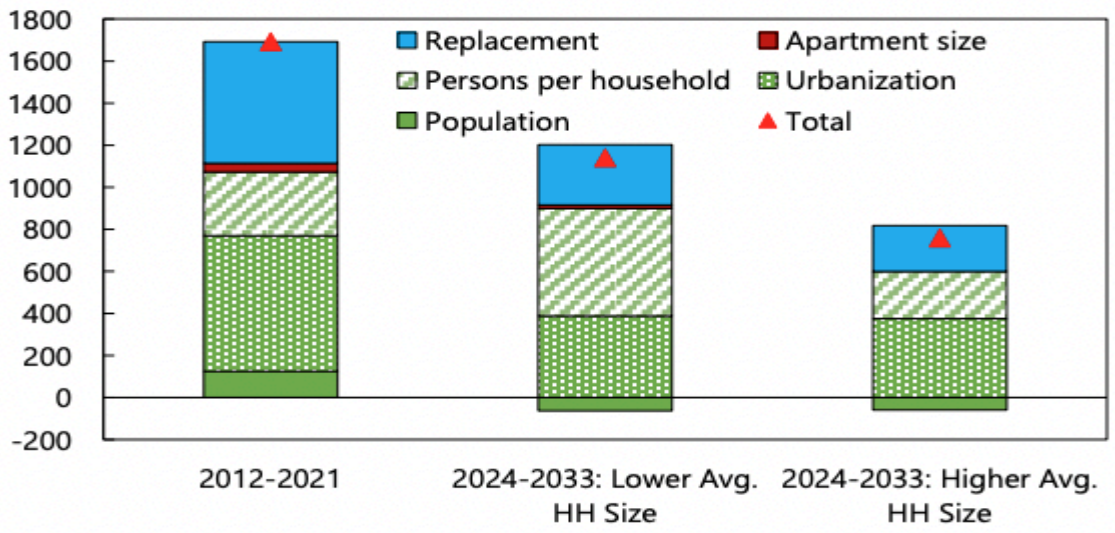
Massive China's investment into the real estate sector in the last decade showed that the economy has been over-reliant on domestic investment in real estate and infrastructure. It is estimated that the direct and indirect impact of the real estate sector in the economy in 2021 was 22% of China's GDP.[29] According to the IMF, as shown in Figure 1.1.3, China's peak share of residential real estate investment to total GDP in the 2010s was on par or higher than property booms in other countries.

Nevertheless, this trend is changing with less new investments flowing into the Chinese housing industry. According to the National Bureau of Statistics (NBS), China's annual real estate development investment declined by 9.6% y-o-y over 2023, among which investment

[25] Bank of Korea. Korea Economic Outlook. November, 2023
[26] EU. Economic forecast for Germany. 15th February, 2024
[27] Bloomberg. China Growth May Fall to 2.9% If Property Crisis Widens, S&P Says. 24th October, 2023
[28] IMF. People's Republic of China: 2023 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for the People's Republic of China. 2nd, February, 2024
[29] East Asia Forum. Diminishing returns on real estate threaten Chinese economic growth. 7th December, 2023

in residential buildings decreased 9.3% y-o-y, and investment in commercial buildings was down 16.9% y-o-y.

Figure 1.1.4 Estimated Annual Fundamental Housing Demand (Millions of m^2)



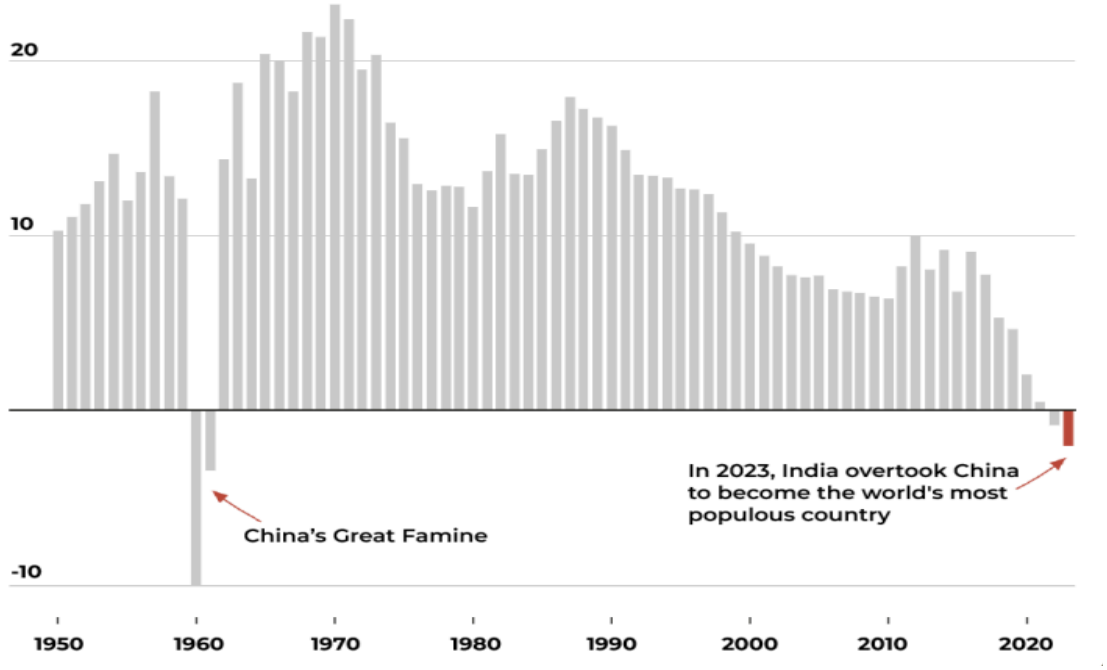
Sources: CEIC Data Company LImited; and IMF staff calculations[30]
Note: HH=Household

This is as a result of decreasing housing demand in China.The IMF forecasts China's fundamental new housing demand in coming years will drop by 35-55%, due to decreasing demand for housing replacement, as well as the now shrinking population Figure 1.1.4.

The shrinking population in China was highly associated with the one child policy from 1979 to 2015, which has resulted in population decline that emerged in the last two years, which is forecast to accelerate over the coming two decades.

[30] IMF. People's Republic of China: Selected Issues. 9th February, 2024

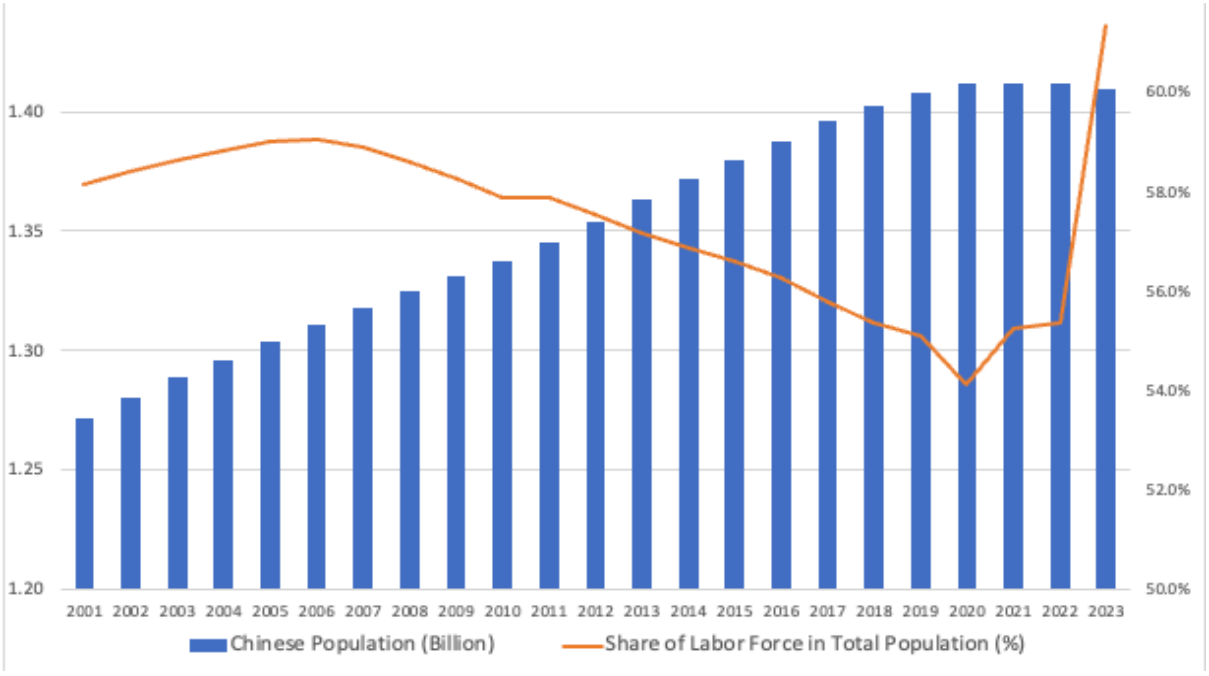
Figure 1.1.5 China's Annual Population Change (in millions)



Source: Reuters[31]

China's NBS says that China's population by the end of 2023 has decreased by 2.08 million compared to 2022, as demonstrated in Figure 1.1.6. However, the share of labor force in total population has been increasing since 2020, which is more important than absolute growth in population itself for a country's economic growth.

Figure 1.1.6 China's Total Population and Share of Labor Force in Total Population



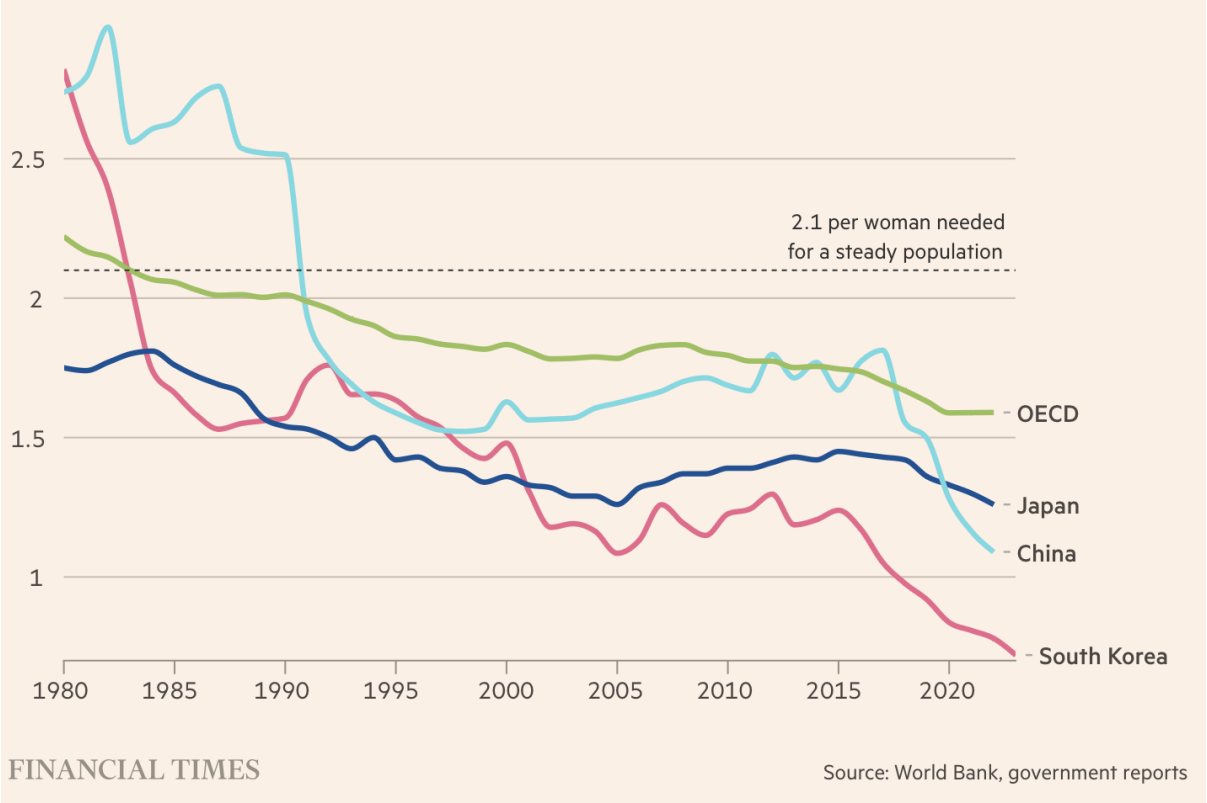
Source: World Bank; Calculated by CEF

[31] Reuters. China's population drops for second year, with record low birth rate. 17th January, 2024

In the meantime, the educational level of the population continues to increase, according to Chinese NBS, with an all time record number of university graduates in 2023. The NBS said that China's population size remains huge, the labour resources remain abundant, and a comprehensive dividend of talents is emerging, along with continued labour force productivity gains.[32] As shown in Figure 1.1.6, China's share of the labour force in total population declined from 59% in 2006 to 54% in 2020, but rebound to reach 61% in 2023.

Although population decline could potentially impact a country's development negatively, it is yet another indicator of China's economy gradually maturing and growing into a developed nation.

Figure 1.1.7 Fertility rate (births per woman)

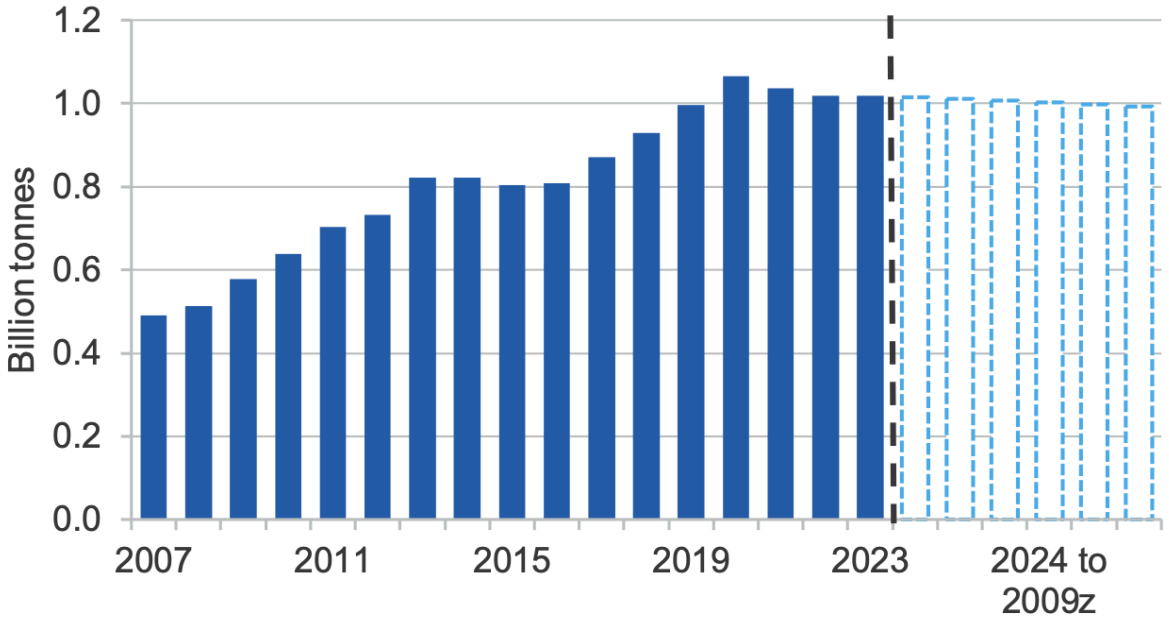


Source: Financial Times (FT)[33]

Population decline is increasingly seen in a range of developed countries. Figure 1.1.7 shows that South Korea has the lowest fertility rate in the world, falling from 0.78 in 2022 to 0.72 in 2023 which is way below 2.1 the OECD defined as necessary fertility rate to ensure a broadly stable population. Similarly, developed countries such as Japan and other OECD countries all showed a declining trend in fertility rate from 1980 to 2005.

[32] 国家统计局. 王萍萍: 人口总量有所下降 人口高质量发展取得成效. 18th January, 2024
[33] FT. $75,000 for a baby? South Korean businesses float incentives as demographic crisis looms. 28th March, 2024

Figure 1.1.8 China's Annual Steel Production



Source: World Steel Association; Australian Department of Industry, Science and Resources

The decline in housing demand has led to China's steel sector overcapacity, and this in turn is now being exported, creating a glut in the global steel market.

Strong growth in exports has played a key role in supporting China's steel sector, by partly offsetting the effects of property sector weakness. Chinese steel exports were up 35% in 2023 — a seven-year high. Steel production has past its peak, and is now plateauing, as shown in Figure 1.1.8.

China's rising exports have increased trade tensions with a number of trading partners as China produces over half the world's steel each year, and this is a very energy intensive process. China's massive ongoing investment in blast furnaces and failure to pivot to electric arc furnaces means these exports have an extremely high carbon emissions intensity. Overall, the Office of the Chief Economist in Australia forecasts China's steel production in 2024 to experience a mild 0.5% decline. This trend is expected to continue over the rest of the outlook period, with projected falls of 0.4% a year to 2029.[34]

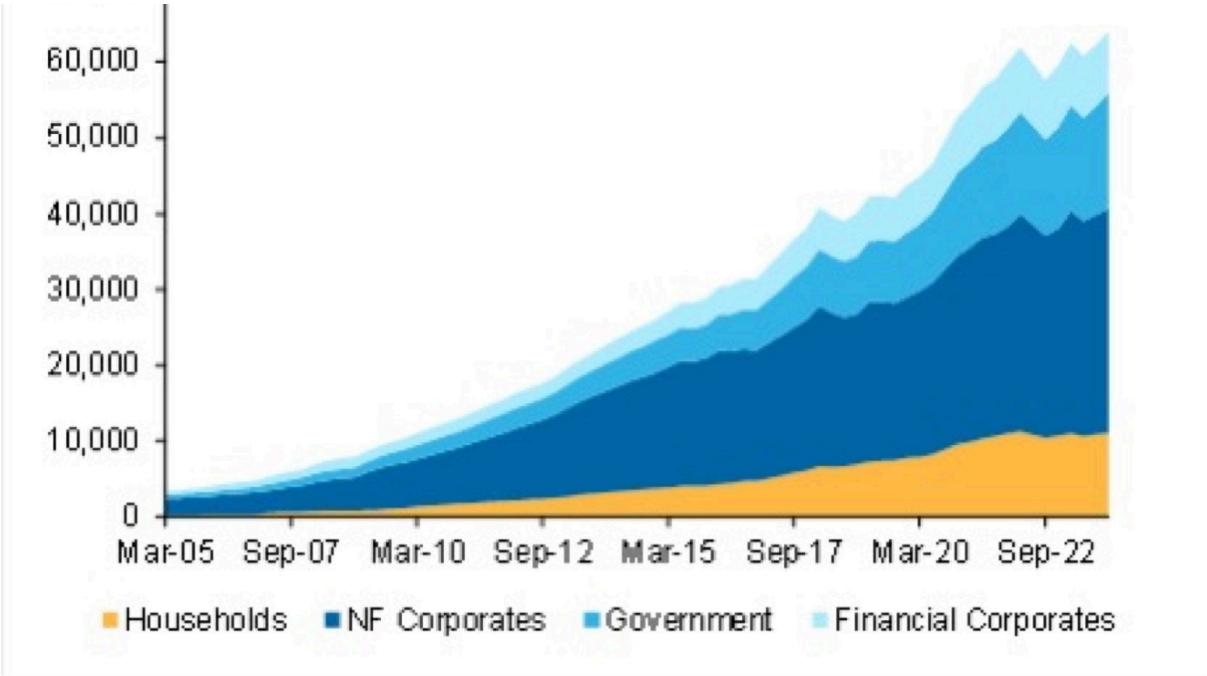
China needs a shift in policy focus to prioritise energy productivity and GDP per capita growth, and a pivot away from strong new housing, building and infrastructure demand towards consumer services, a critically important economic shift from high to lower energy intensity economic activities. China is undergoing an economic structural change, as noted in section 1.5, this process needs to be accelerated to make up for the loss from the housing sector crisis, as well as reduce energy intensity in GDP growth. For China, a slowly declining population, a still strongly growing GDP, and a pivot towards a more service-focused economy can lead to better life quality.

[34] Australian Government, Department of Industry, Science and Resources, Resources and Energy Quarterly, April 2024

Western calls for the need for a more substantial fiscal stimulus from the central government are growing as a result of the ageing population, the population decline, and the downturn in the housing sector.

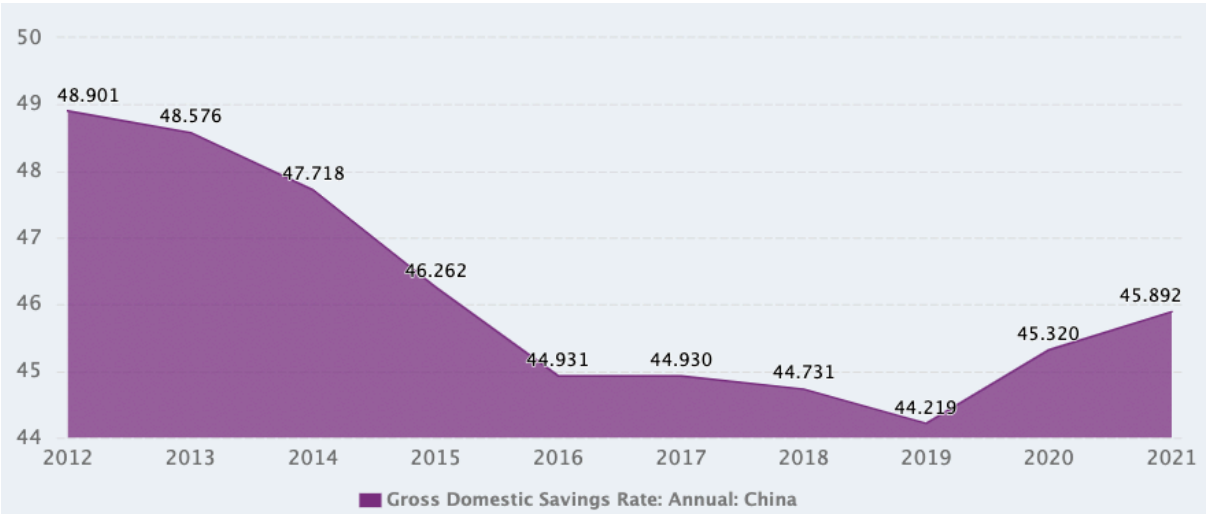
There has been a strong response from the central government after the 'two sessions' this year. March 2024 saw China issue RMB1trn (US$139bn) of ultra long bonds to stabilise the country's financial system profile in support of their 5% GDP growth target.[35] There has been a dramatic rise in gross debt in China over the last two decades - Figure 1.1.9.

Figure 1.1.9 China - Debt (US$bn)



Source: Viktor Shvets, Macquarie Group, March 2024.[36]

Figure 1.1.10 . Annual Gross Domestic Savings Rate - China

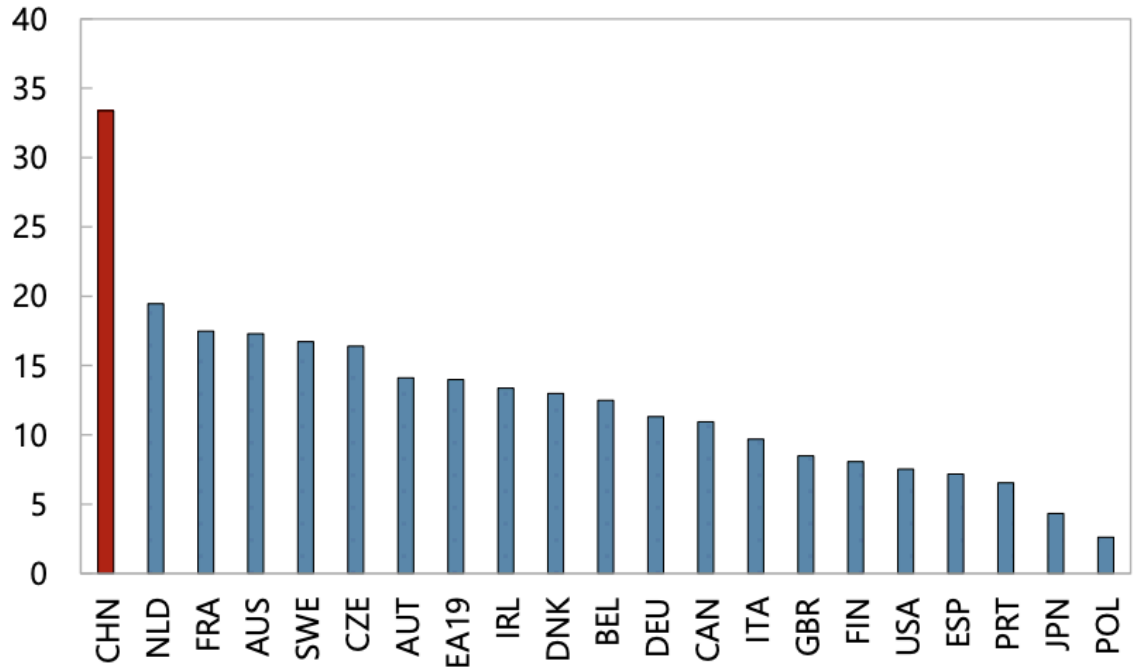


Source: CEIC Data[37]

[35] SCMP. Explainer | What makes China's 'ultra-long' bonds special? Here's what we know about Beijing's trillion-yuan offering to stabilise economy. 22nd March, 2024
[36] LinkedIn. Viktor Shvets. March 2024
[37] CEIC. China Gross Savings Rate

However, combined with a relatively closed domestic financial system, the growth in gross debt has been accompanied by an equivalent growth in national savings. This is regularly absent from the western commentators' debt discussion that China has maintained an exceptionally high national savings rate, reaching 45.9% of China's GDP in 2021 - Figure 1.1.10.

Figure 1.1.11 Household Savings Rate, 2022 (%)



Sources: Haver Analytics; NBS China; and IMF staff calculations.[38]

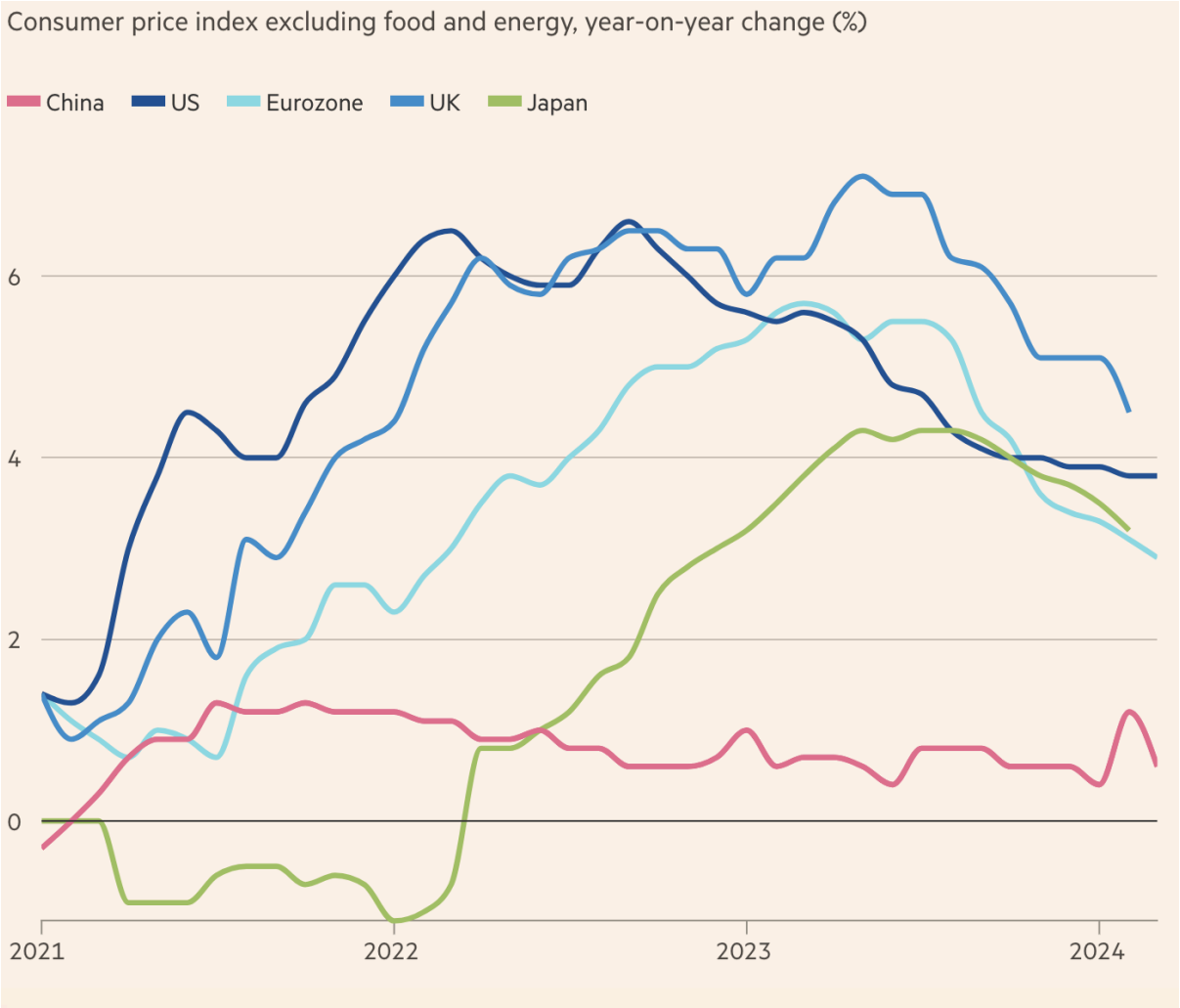
China also has an extremely high household savings rate, as shown in future 1.1.11.

A high household savings rate can potentially contain consumption. However, the upside is that it could also result in significant investment from the banks to stimulate economic growth in China.

With the significantly high national savings rate, China's GDP growth outlook also benefits from other aspects of China's economy, such as inflation, low bank interest rates for investments, and a decrease in export price.

[38] IMF. People's Republic of China: 2023 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for the People's Republic of China. 2nd February, 2024

Figure 1.1.12 China's 'core' inflation remains far lower than that of peers

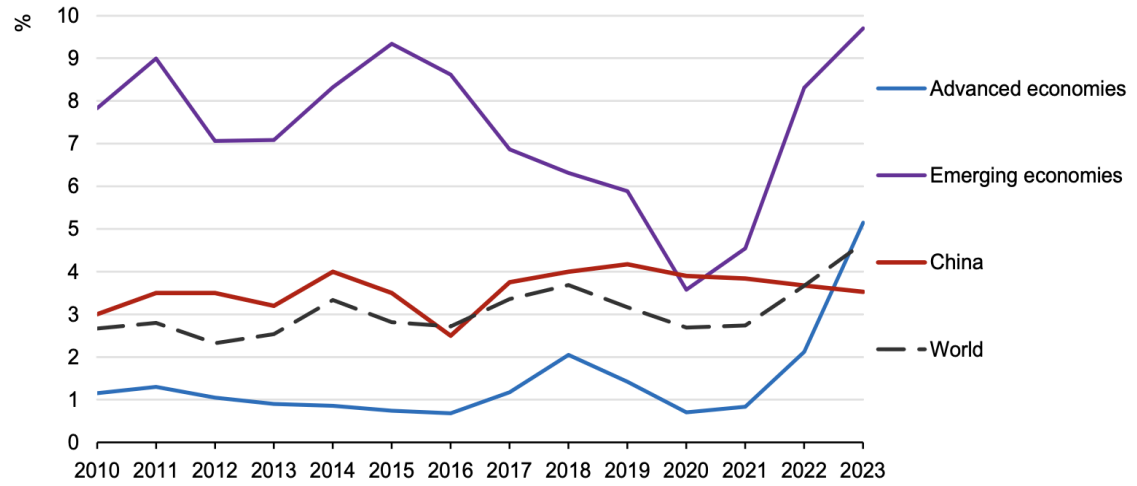


Source: Bloomberg via FT[39]

China's inflation rate remains below 1% p.a. - Figure 1.1.12. At a time many developed economies have seen central banks ratcheting up interest rates in response to surging inflationary pressures post the Covid-19 pandemic. And there is scope for central interest rate reductions to help stimulate investment in delivery of the government's 5% GDP growth target for 2024.[40]

[39] FT. Weak China inflation data fuels concern over consumer demand. 11th April, 2024
[40] FT. China's prices fall at fastest rate in 15 years as economy battles deflation. 8th February, 2024

Figure 1.1.13 Average central bank base interest rates weighted by renewable energy deployment, 2010-2023

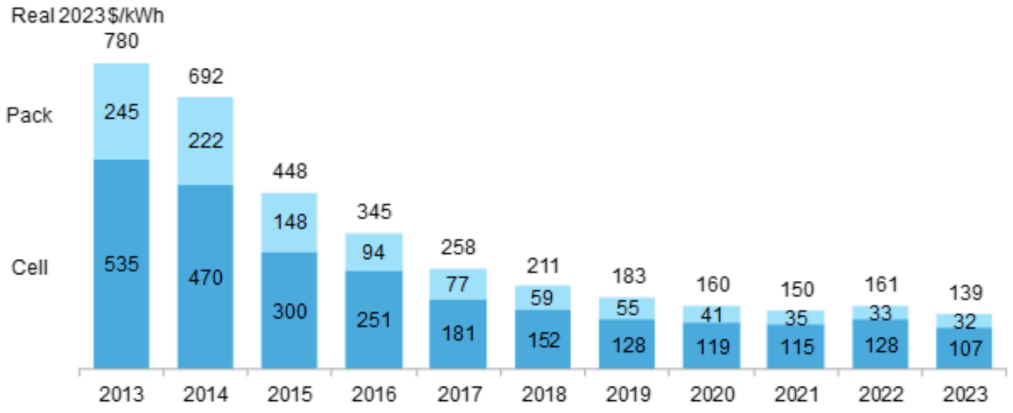


Sources: IEA Renewables 2023 Analysis and forecasts to 2028, January 2024, page 70[41]

As shown in Figure 1.1.13, in 2023, the financing of new renewable energy capacity in advanced economies faced higher base interest rates compared to both China and the global average for the first time, largely due to the Chinese government's decision to cut interest rates, diverging from the prevailing global trend. Inflation in China and low bank interest rates for renewable projects, combined with the high household savings rate in China makes investments in renewable energy more profitable.

China's deflation is also expected to help lower inflation rates worldwide over 2024, with this most evident in the 40-50% y-o-y declines evident in solar prices, and significant falls in the prices of China NEV exports. Analysts from Citigroup said that China export price deflation could assist to 'hasten moves by central banks in emerging markets to cut interest rates this year, particularly in countries that consume relatively large shares of Chinese goods'.[42]

Figure 1.1.14 Volume-weighted average lithium-ion battery pack price, 2013-2023

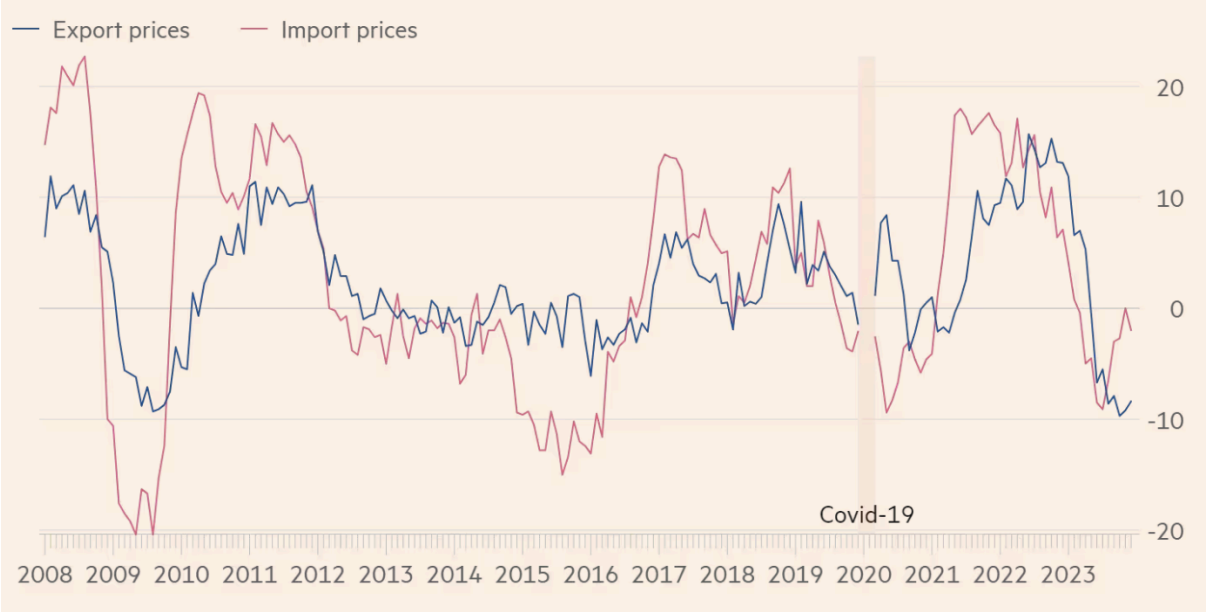


Source: BloombergNEF[43]

[41] IEA. Renewable 2023 Analysis and Forecasts to 2028. January 2024
[42] FT. China to export deflation to the world as economy stumbles. 9th February, 2024
[43] BNEF. Lithium-Ion Battery Pack Prices Hit Record Low of $139/kWh. 26th November, 2023

The deflation is especially seen in China's renewable products, from solar panels, to wind turbines, to batteries and so on. After the double digit price declines last year - Figure 1.1.14. 2024 saw a further 18% decline in the price for battery energy storage system (BESS) due to China's manufacturing scaling up.[44]

Figure 1.1.15 Chinese export prices and import prices annual change (%)



Source: NBS via FT[45]

2023 saw China's export prices significantly lower than import prices, as shown in Figure 1.1.15, which makes Chinese exports even more price competitive in the global market, as well as playing the role of driving down the global inflation outside of China.

The Chinese economy is set to grow further as it shifts the GDP growth focus on renewable energy. With the strong price competitiveness in renewables, led by massive manufacturing scaling up, lower bank interest rates in financing renewable energy capacity, low export prices and deflation, China is in the leading seat in the global renewable energy market. These are all strong traits in China's economy that will continue to contribute to economic growth, while providing good news - cheap renewable products - to the world to boost global energy transition.

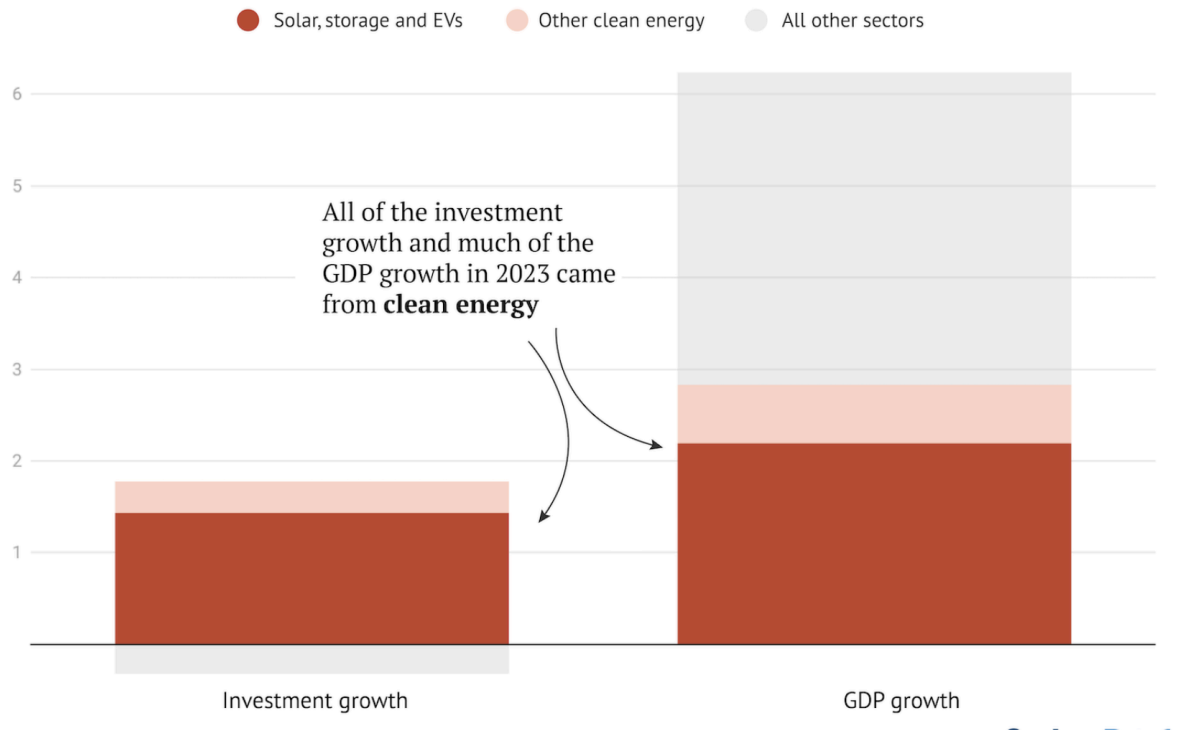
[44] Energy Storage News. BESS prices in US market to fall a further 18% in 2024, says CEA. 7th February, 2024
[45] FT. China to export deflation to the world as economy stumbles. 9th February, 2024

1.2 40% GDP growth comes from cleantech

We note the profound shifts in composition of China's GDP, from agriculture to heavy industry to tertiary sectors. And with this, the shift from reliance on property construction to new zero emissions industries of the future to underpin more sustainable, and less emissions intensive economic growth. An estimated 40% of 2023 GDP growth was sourced from solar, batteries and EVs. And China leads the world in cleantech investments, at US$890bn, this is more than double the US or EU.

An estimated 40% of China's GDP growth last year was driven by expansion in cleantech, clean energy has contributed RMB11.4tn (US$1.6tn) to China's economy in 2023, according to analysis by Lauri Myllyvirta from Centre for Research on Energy and Clean Air (CREA).[46]

Figure 1.2.1 Investment growth (left) and GDP growth (right) by sector, trillion yuan



Source: CREA analysis for Carbon Brief

This is as a result of all investment growth in China last year came from clean energy. As shown in Figure 1.2.1, China saw a RMB1.7tn (US$240bn) y-o-y increase in investment in clean-energy in 2023, while China's total investment growth was by just RMB1.5tn (US$210bn). During CY2023, China has invested an estimated RMB6.3tn (US$890bn) in the clean-energy sector, CREA says, a 40% y-o-y increase.The strongest growth in investment in clean energy is witnessed in solar, energy storage and EVs, with a total investment in manufacturing capacity for these three sectors reaching RMB2.5tn (US$348bn) in 2023. Investment in clean power generation and energy storage capacity reached RMB1.7tn (US$236bn).

[46] Carbon Brief. Analysis: Clean energy was top driver of China's economic growth in 2023. 25th January, 2024

China is also putting significant emphasis on “new quality productive forces” as a new strategic objective to revive China’s economic fortunes. As Wang Rongshuo, the founder of Guangdong Yangshuo Green Technology, indicates that “tech breakthroughs in new energy are crucial for China’s national security.”[47] The idea is that disruptive breakthroughs will help China dominate the technologies of the future, fueling growth and productivity gains across the economy, as well as improved national energy security and more sustainable growth.[48]

Concerns over China’s massive investment in clean-energy are widespread globally. Woodmac notes that China is pouring billions into green energy and dominates the world's solar supply chain.[49] US Treasury Secretary Janet Yellen has really elevated the threat of a geopolitical response to the continued investment in Chinese world leadership of these zero emissions industries of the future with her visit in April 2024.[50]

Against this, the New York Times in April 2024 acknowledged that it was crucial for the US to recognise that China’s “Green Leap Forward” is on balance, great news: “If American politicians, investors and businesses recognize that climate change is humanity’s biggest threat, that could open pathways for diplomacy, collaboration and constructive competition with China that benefit us all.”[51] And Bloomberg noted that trade wars invariably cause retaliations, and unintended consequences are often better avoided, particularly where Chinese technology is increasingly world leading.[52]

The Chinese government should launch targeted fiscal support to leverage the excess manufacturing capacity that has been established in these sectors to both accelerate China’s energy system transformation and energy security.

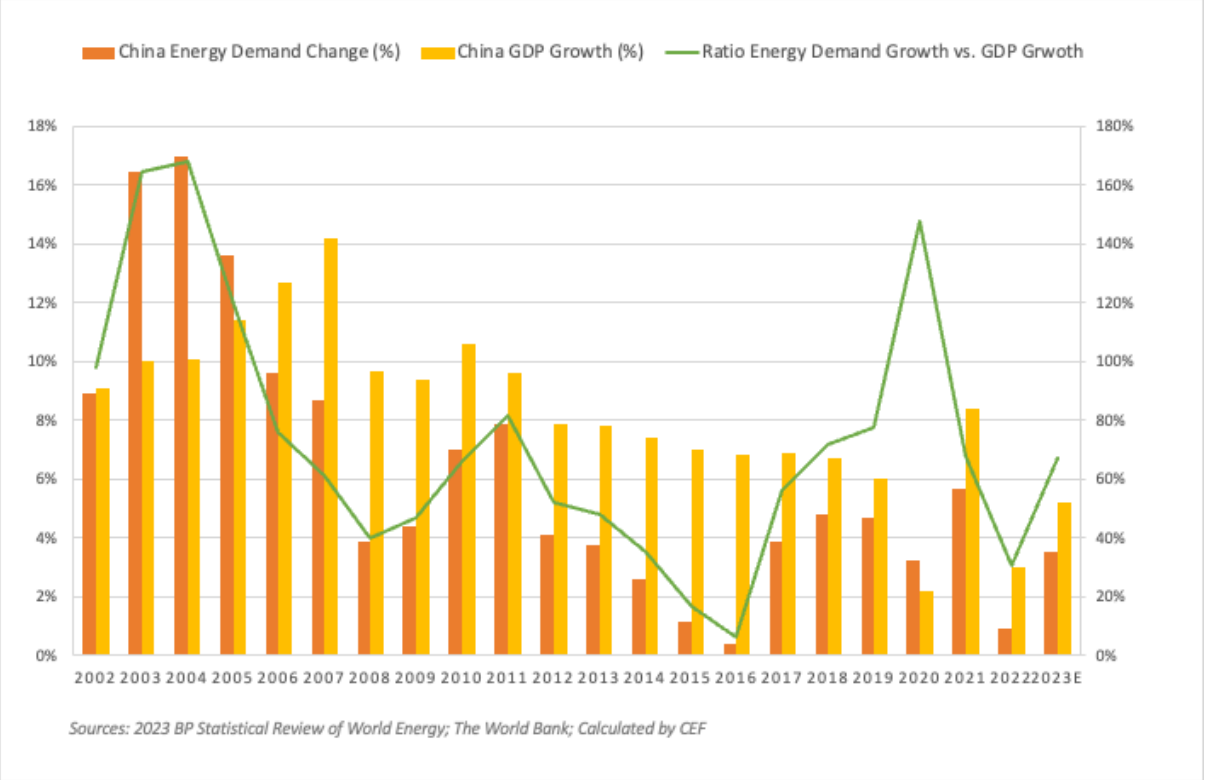
[47] SCMP, Behind China’s new-energy overcapacity as it changes the face of manufacturing and raises the stakes of competitiveness, 1 April 2024
[48] Bloomberg, China’s Economy Needs a Strategy. Not a Buzzword, 5 April 2024
[49] India Economic Times, China's green-tech manufacturing powerhouse, 5 April 2024
[50] India Economic Times, China is too big to export its way to rapid growth: Yellen, 5 April 2024
[51] New York Times, Xi Thinks China Can Slow Climate Change. What if He’s Right? 19 April 2024
[52] Bloomberg, A China NEV Trade War Would Be Self-Defeating for Carmakers, 15 April 2024

1.3 Implication for Energy Demand of China's Economic Growth

China's energy demand has grown in the last decade at half of the growth in GDP, that being 3.2% CAGR for total energy demand vs 6.4% for GDP growth, meaning energy productivity has improved 3.2% annually. We take confidence in China's target for 2.5% improvement in energy productivity in 2024.

Significant economic growth comes with an increase in energy demand. However, China's strategic pivot in economic growth shows that higher energy demand does not necessarily lead to higher emissions.

Figure 1.3.1 China's Energy Demand Change (%), GDP Growth (%), and the Ratio for Energy Demand Growth vs. GDP Growth



Sources: 2023 BP Statistical Review of World Energy, the World Bank; Calculated by CEF

China's energy demand growth rate in the past decade was nearly half of China's GDP growth rate during the same period. The CAGR for China's energy demand in the last decade was 3.2% while the rate for GDP growth was 6.4%. Figure 1.3.1 shows that in the past decade China's energy demand change has been lower than the GDP growth except during COVID-19 in 2020, which China's GDP continues to grow.

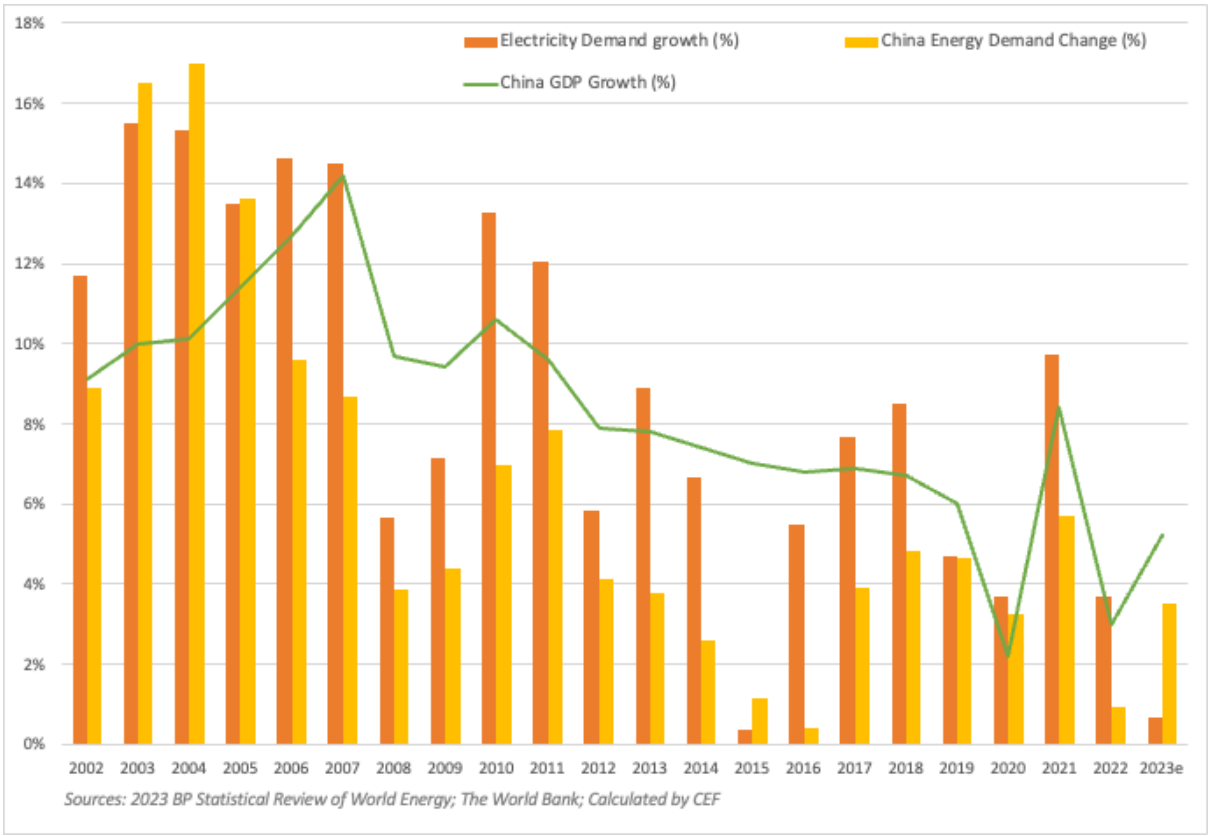
This trend indicates that China has improved energy efficiency - energy productivity in China has gained 3.2% annually in the last decade. This is also resulted by the shift in China's economic composition, from emphasis on energy intensive secondary industry to tertiary industry where less energy was needed (refer to section 1.5).

1.4 Implication for Electricity Demand of China's Energy Demand Growth

China's continuous GDP growth has inevitably led to energy demand growth as discussed in section 1.3. China's electricity demand has grown at 5.8% CAGR over the last decade, 95% of the 6.1% CAGR for GDP. In the meantime, China has been undergoing a multi-decade-long electrification of everything, which has led to less demand for oil and gas, but an increase in electricity demand. From just 11.8% in 2002, China's electrification share overtook the US and the EU in 2015, and caught up with Japan in 2019 to reach 19% in 2023. CEF forecasts this trend will continue, with electricity demand growth remaining well above energy demand growth, and electricity's share reaching 21.4% in 2030, and over 25% by 2040.

This is positive for China's own energy security as the world has witnessed disruption in the global oil and gas supply chain since the Russia-Ukraine War erupted, and China is highly relying on oil imports. However, China's current national grid still shows a high reliance on fossil fuels. This makes decarbonisation of electricity harder as electricity demand growth remains strong, consistent with GDP growth. CEF calls for China to not let the higher electricity demand lead to more use in coal-fired power plants, but to accelerate the greening of the grid and the deployment of renewable energy power generation.

Figure 1.4.1 China's Electricity Demand, Energy Demand and GDP Growth (%)

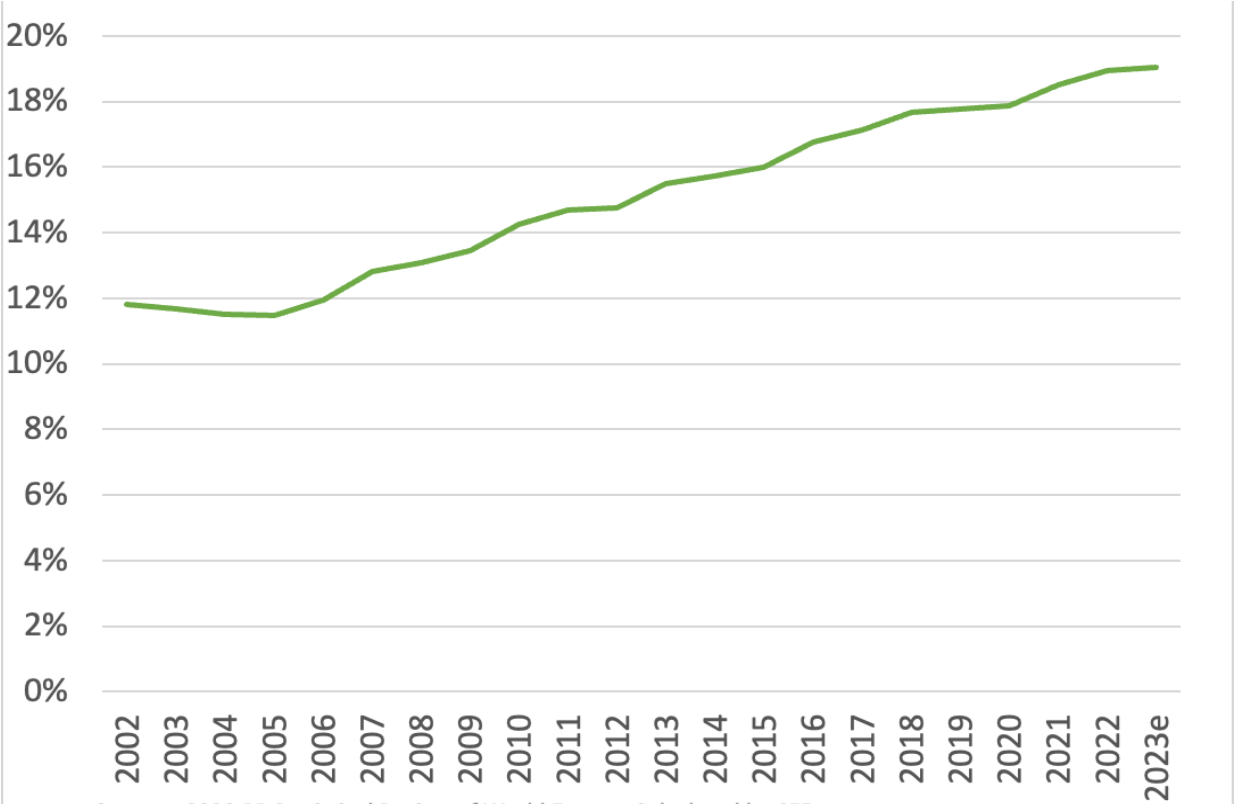


Sources: 2023 BP Statistical Review of World Energy, the World Bank; Calculated by CEF

China's electricity demand is rising strongly, as a result of the Increasing GDP growth and energy demand growth, and the electrification of everything. The IEA forecasts that China's electricity demand growth will slow down to 5.1% in 2024, 4.9% in 2025, and 4.7% in 2026.[53]

In 2015, China's electricity and energy demands both declined significantly - Figure 1.4.1, this was caused by lower steel production due to weak steel demand and a supply glut.[54] China announced in 2015 that it will cut as much as 80Mt of steel capacity in the following three years.[55] In the meantime, China's GDP composition shift showed an increase in the service industry which has a significantly lower energy intensity.[56]

Figure 1.4.2 Share of Electricity Demand in Energy Demand (%)



Sources: 2023 BP Statistical Review of World Energy; Calculated by CEF

China's electricity demand continues to climb. This is partially due to the nation's strategy in electrifying the industry. Professor Elizabeth Thurbon argues that the early movers in industrialization were powered by fossil fuels, while China as a latecomer to industrialization, will now increasingly power its energy system with rising levels of electric power. China's level of electrification overtook the US and the EU in 2015, and caught up with Japan in 2019. As per Figure 1.4.2 above, the share of electricity demand in energy demand has reached 19% in 2023.

China's electrification strategy serves its national interests, especially in terms of energy independence. While China highly relies on imports for energy sources such as crude oil,

[53] IEA. Electricity 2024: Analysis and forecast to 2026. January, 2024
[54] Enerdata. China's power generation fell in 2015, for the first time since 1968. 21st January, 2016
[55] Reuters. China to cut 80 mln T of steel capacity over 2015-17 - official. 28th March, 2015
[56] Reuters. China 2015 power, steel output drop for first time in decades. 19th January, 2016

especially relying on Russia.[57] China understands how geopolitical issues could impact its energy import, and therefore hinder its national energy security. China's strategy in electrifying the power system has progressively reduced this risk but increasing reliance on domestic renewable energy, including hydro-electricity, and coal-fired power plants, >95% supplied by domestic coal mining.

Moreover, the electrification of everything also offers China its best opportunity to progressively green the grid. But China needs to firstly burn less coal in order to reach its climate targets. This report has analysed China's current electricity mix, all aspects of China's electricity market, and what China needs to do to achieve its 'dual carbon' targets in section 4.

[57] U.S. Energy Information Administration. China imported record volumes of crude oil in the first half of 2023. 18th September, 2023

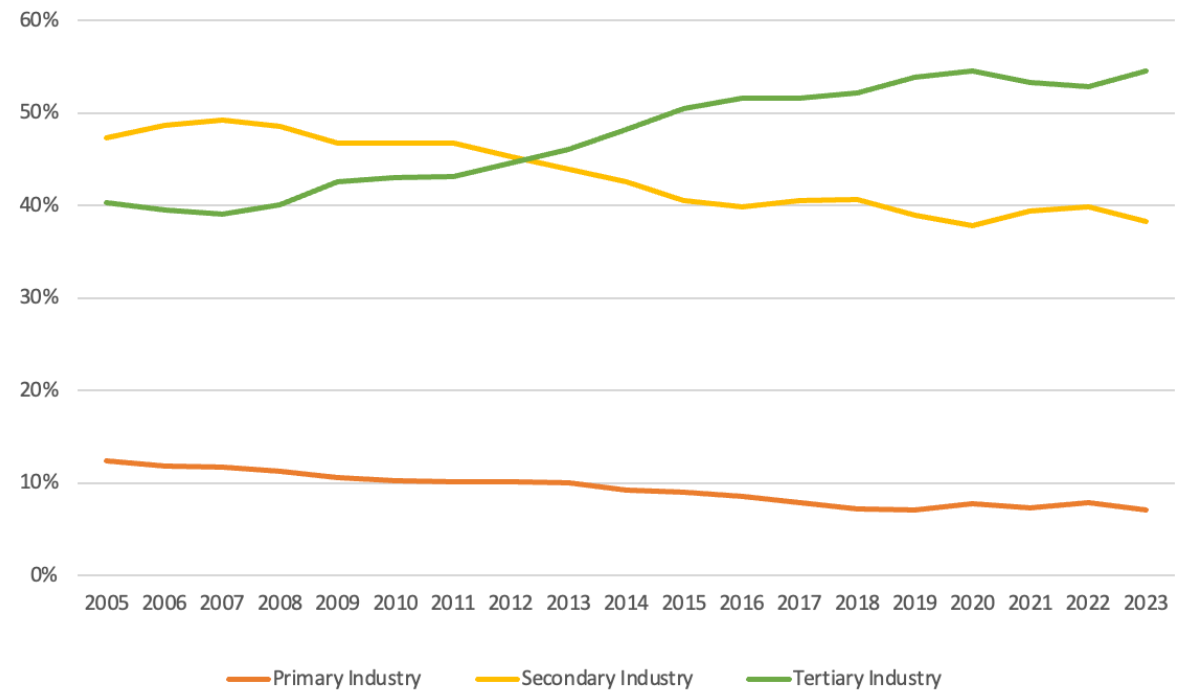
1.5 Structural Change in China's GDP Composition

Reflecting the maturing of economic development, China's GDP structure has changed dramatically over the last two decades. Even as primary industries have become progressively less significant over time, so too has secondary industry, shrinking from a ~50% peak share in 2007 to 39% in 2023. This structural change in GDP composition also impacts China's overall energy consumption, energy intensity, and the process of energy transition, as the rising tertiary sector is the least energy intensive sector in the composition.

China, like many other countries, categorised its industry into three major categories.

The primary industry refers to agriculture, forestry, animal husbandry and fishery; secondary industry refers to mining, manufacturing, electricity, production of gas and water, and construction; and tertiary industry includes services and consumer activities, as well as other industries that are not included in the primary and secondary industries.[58]

Figure 1.5.1 China's Economic Composition of GDP by Sector (%)



Sources: China NBS; Calculated by CEF

Figure 1.5.1 shows China's economic composition has undergone a significant transformation since the reform and opening-up in 1978. It transformed China's economy from secondary industry focused to tertiary industry focused.

In 1978, the contribution of the primary industry in China's GDP was 27.7%, secondary industry 47.7% and tertiary industry 24.6%. In 1985, the tertiary industry surpassed the primary industry for the first time in China, the contribution of the primary industry in China's GDP was 27.9%, secondary industry 42.7% and tertiary industry 29.4%. In 2012, the tertiary

[58] 中国人民共和国中央人民政府. 国家统计局关于印发《三次产业划分规定》的通知. 15th May, 2003

industry surpassed secondary industry, the contribution of the primary industry in China's GDP was 9.1%, secondary industry 45.4% and tertiary industry 45.5%[59]. In 2023, the contribution of the primary industry in China's GDP was 7.1%, secondary industry was 38.3% and tertiary industry was 54.6% - Figure 1.5.1.

This shift will bring down energy intensity in China's GDP growth. Among the three major industries, the secondary industry is the most energy intensive industry. In 2023, China's primary industry consumed 127.8TWh of electricity, secondary industry consumed 6,070TWh of electricity, tertiary industry consumed 1,670TWh of electricity.

All three industries exhibited a rapid increase in electricity consumption in 2023. Professor Xunpeng Shi indicates that this is due to two reasons, one is the electrification progress deepens, an increase in electricity consumption will not necessarily lead to an increase in energy consumption increase. Second reason is due to the fast progress in technology improvement and industrial upgrading. "The optimization and upgrading of China's economic structure, especially the transformation to high-tech and high value-added industries, often have greater demand for power supply. For example, with the rapid growth of the 'new economy' industry in recent years, high-power consumption data centres and the 'explosive' growth of digital currency, which has significantly pushed up total electricity consumption." says Shi.[60]

The structural change in China's economic composition will pivot China's heavy reliance on the real estate sector, improve economic resilience. In the meantime, transforming the economy to a less energy intensive format can help boost the energy transformation progress in China.

[59] 中华人民共和国国家发展和改革委员会.【专家观点】"十四五"时期我国产业结构变动特征及趋势展望. 12th October, 2021
[60] 证券时报网. 深度丨近十年单位GDP电耗下降18% 经济低碳化成效渐显. 20th February, 2024

1.6 China Needs More Ambitious Climate Objectives

China can no longer call itself a developing country today, which comes with more responsibilities in countering climate change as a developed nation. After two decades as the fastest growing large economy in the world, and as now by far the second largest economy four times the size of the German and Japanese economies. In the meantime, China is now in the box seat as global leader in all zero emissions industries of the future.

China's formal climate targets need to be more ambitious to align with its economic strength, and be accelerated to faster than a peak by 2030, and net zero by 2060. A Chinese version of Carbon Border Adjustment Mechanism (CBAM) would help provide the right financial and policy incentive for China's key trading partners to help both drive decarbonisation.

China's rapid economic growth has propelled it to the forefront of the global stage, prompting a reevaluation of its status from a developing to a developed nation. With this transition comes increased responsibility, particularly in addressing pressing global issues such as climate change. This section explores China's evolving role in climate change mitigation and the imperative for more ambitious climate targets commensurate with its economic strength.

China's ascent as a global economic powerhouse positions it as a key player in driving climate action. The BRI serves as a tool for global climate diplomacy, offering opportunities for technology transfer and clean energy infrastructure development in partner nations. China's expertise in renewable energy technology, finance, and manufacturing places it in a unique position to support developing nations in their transition away from fossil fuels.

China's current climate targets, encapsulated in the 'double-carbon' targets, fall short of international benchmarks such as the Paris Agreement. While China is aiming to peak CO2 emissions before 2030 and achieve carbon neutrality by 2060.[61] Although the targets are supported by many other supporting policies from different government departments, including the carbon pricing established in its national emissions trading scheme (ETS) covering the electricity sector. These goals do not align with the urgency of limiting global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030.[62] Furthermore, they lag behind the more ambitious targets set by other developed nations - reaching carbon neutrality by 2050.[63] In reality all developed nations including China need to accelerate their targets before 2050 to buy time for the development nations.

There is a pressing need for China to elevate its ambition in climate objectives to reflect its economic prowess and global leadership aspirations. This entails revisiting and revising the 'double-carbon' targets to align with more aggressive timelines.

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[61] United Nations. 'Enhance solidarity' to fight COVID-19, Chinese President urges, also pledges carbon neutrality by 2060. 22nd September, 2020
[62] United Nations Climate Change. The Paris Agreement.
[63] OECD. The Climate Action Monitor 2023: Providing Information to Monitor Progress Towards Net-Zero. 17th November, 2023

CEF calls for China to update its ‘dual-carbon’ targets to peak emissions by 2025 and achieve carbon neutrality by 2050 or 2055. Collaboration with international partners, particularly the EU, can enhance climate policies and foster global buy-in.

China's leadership in cleantech innovation presents an opportunity to support developing nations in their climate transition efforts. By exporting financing, engineering expertise, technology, and manufacturing capacity, China can catalyze clean energy adoption worldwide. This not only aligns with its commitment to global sustainability but also enhances its influence on the international stage.

As China assumes its role as a developed nation, it must embrace greater responsibility in countering climate change. By adopting more ambitious climate targets and leveraging its global leadership in cleantech innovation, China can play a pivotal role in advancing the transition to a sustainable future. The time for action is now, and China's leadership will be instrumental in shaping the trajectory of global climate efforts.

We also call for China to expand on its lead in global energy transition in manufacturing as well as in setting up science-based climate targets and expanding its national emissions trading scheme (ETS) in collaboration with the EU, to encourage and enhance other countries buy-in e.g. Australia’s enhancements to its Safeguard Mechanism so it is a credible decarbonisation tool for heavy industry. We call for China to update its double-carbon targets - peak CO_2 emissions by 2025, and reach carbon neutrality by 2050 or 2055, and to leverage its global cleantech leadership by exporting this financing, engineering, technology and manufacturing capacity to developing nations.

2. Electricity Market

China's electricity market continues to showcase a staggering energy transformation trajectory. 2023 saw China's total installed non-fossil fuels energy capacity surpassed thermal power for the first time, accounting for more than 50% of China's total installed capacity in the national electricity grid. The year of 2024 starts strong with further acceleration in renewable capacity additions, with 47.6GW of zero-emissions capacity added during the first 2 months, a 62% y-o-y increase. With China's ongoing massive investment in renewable energy, the world is witnessing a production glut in solar, wind, battery production led by China. Many nations have voiced concerns as the oversupply has resulted in bankruptcies of local businesses.

When China moves, it moves at the speed and scale that have globally significant impacts. It is getting more and more essential each day for the rest of the world to understand China's electricity market, the transformation in the electricity grid, and the outlook for China's electricity market.

China has continued to green its national electricity grid at an accelerating rate over the last decade, marking a pivotal shift in its energy landscape. According to the China Electricity Council (CEC), by the end of 2023, installed non-fossil fuels energy capacity exceeded thermal power for the first time, accounting for more than half of China's total installed capacity. The investment in electric power has grown rapidly, with non-fossil energy power generation investment in 2023 accounting for a record high 90% of power investment.[64']

According to the National Energy Administration (NEA) of China, in 2023, the country's electricity consumption reached 9,224TWh, a 6.7% y-o-y increase. Of which, China's industry power generation reached 8,909TWh,[65] a 6.2% y-o-y increase.[66]

The momentum in renewable energy expansion carried into 2024. The first 3 months of CY2024 shows a strong acceleration in installing new renewable capacity to the grid. China's electricity demand started strong in CY2024, showing a 8% y-o-y increase during the first quarter. This again indicates that Chinese economic growth remains strong.[67] In 1QCY2024, 91% of China's newly installed capacity was VRE capacity, totalling 63GW, a 35% y-o-y increase.

CEC forecasts that in 2024, the combined installed capacity of grid-connected wind and solar power will exceed coal, taking up more than 40% of the total installed capacity in the grid.[68] CEF forecasts that China will exceed its 2030 target of 1,200GW of installed wind and solar in 2024, six years ahead of schedule.

While preserving the role of provinces in designing their local markets, the National Development and Reform Commission (NRDC) guidance of 2022 requires the creation of a

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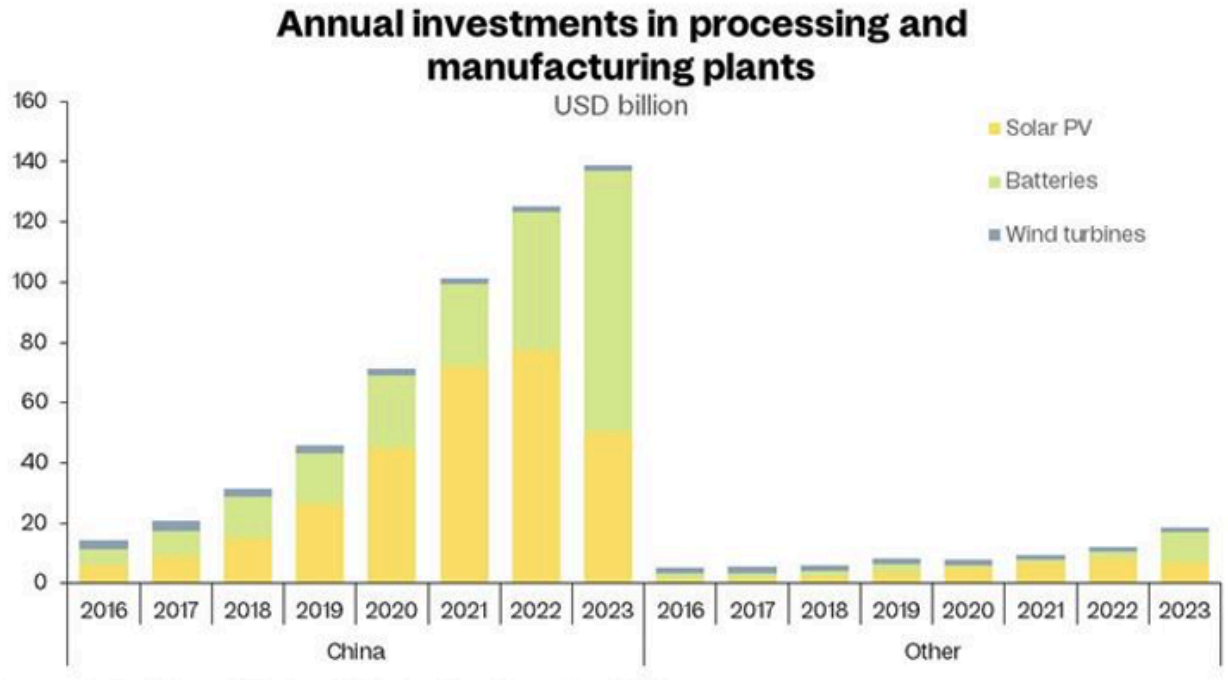
[64] China Electricity Council. "2023-2024 National Electricity Supply and Demand Situation Analysis and Forecast Report", 30 January 2024
[65] 国家能源局. 2023年全社会用电量同比增长6.7%. 18th January, 2024
[66] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review| Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024
[67]国家能源局. 国家能源局发布1-2月份全国电力工业统计数据. 25th March, 2024
[68] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30 Jan 2024

multilayer market architecture with a national coordination system, to be established by 2025 and completed by 2030.[69]

Figure 2.1 Annual Investments in Processing and Manufacturing Plants



Source: Rystad Energy[70]

China's strategic investments in processing and manufacturing plants for solar PV and batteries have positioned it as a global leader in clean energy technology. The total investment in these two sectors is almost 7 times more than the rest of the world combined. Rystad Energy says that China is 20-years ahead of the rest across many industries, as shown in Figure 2.1, while suggesting that it is impossible to catch up with China by 2030. To build domestic supply chains for material mining, processing, refining, and manufacturing for green tech will cost the west US$700bn while China is spending US$140bn per annum in further scaling up its already significant manufacturing capacity in solar and batteries.[71]

Recognizing the need for accelerated innovation and adoption of green technologies, China's central government has called for greater emphasis on green science, technology, and manufacturing during the recent 11th Collective Study Session of the Political Bureau of the CPC Central Committee.[72] This directive aligns with China's ambition to build a green and low-carbon circular economic system, leveraging its expanding clean-energy manufacturing sector to dominate the global market.

Pivoting from the traditional pillars of Chinese exports, the 'old three', clothing, home appliances, and furniture, China is now exporting the 'new three' - solar cells, lithium-ion

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[69] IEA, Building a Unified National Power Market System in China, April 2023
[70] Rystad Energy. Too little, too late: regional clean energy supply chains not possible until at least 2030. 15th December, 2023
[71] ABC News. Rystad Energy says breaking China's clean tech stranglehold 'not possible' this decade. 25th January, 2024
[72] 澎湃新闻. 习近平在中共中央政治局第十一次集体学习时强调：加快发展新质生产力，扎实推进高质量发展. 1st February, 2024

batteries, and EVs. It reflects China's commitment to global clean energy leadership. China accounts for over 80% of global solar cell exports, over 50% of the global lithium-ion batteries exports, and over 20% of the global NEV exports.[73] In 2023, China's total exports of the 'new three' [74] exceeded RMB1tn (US$140bn), a 29.9% y-o-y increase.[75]

However, this has fueled concerns from many countries who are under the pressure of its domestic market being flooded with Chinese imports, which endangers local businesses. The EU solar manufacturers have voiced concerns over bankruptcies due to cheap Chinese solar products.[76]

In the meantime, China is exporting an increasing amount of steel due to its overcapacity in steel production and slowdown in steel demand domestically. According to the new CREA report, China's steel industry has invested more than US$100bn in new capacity expansions in the last three years alone, and 99% of that capex went into ultra-high emissions blast furnaces, even as China's domestic steel demand has peaked due to the housing sector collapse.[77]

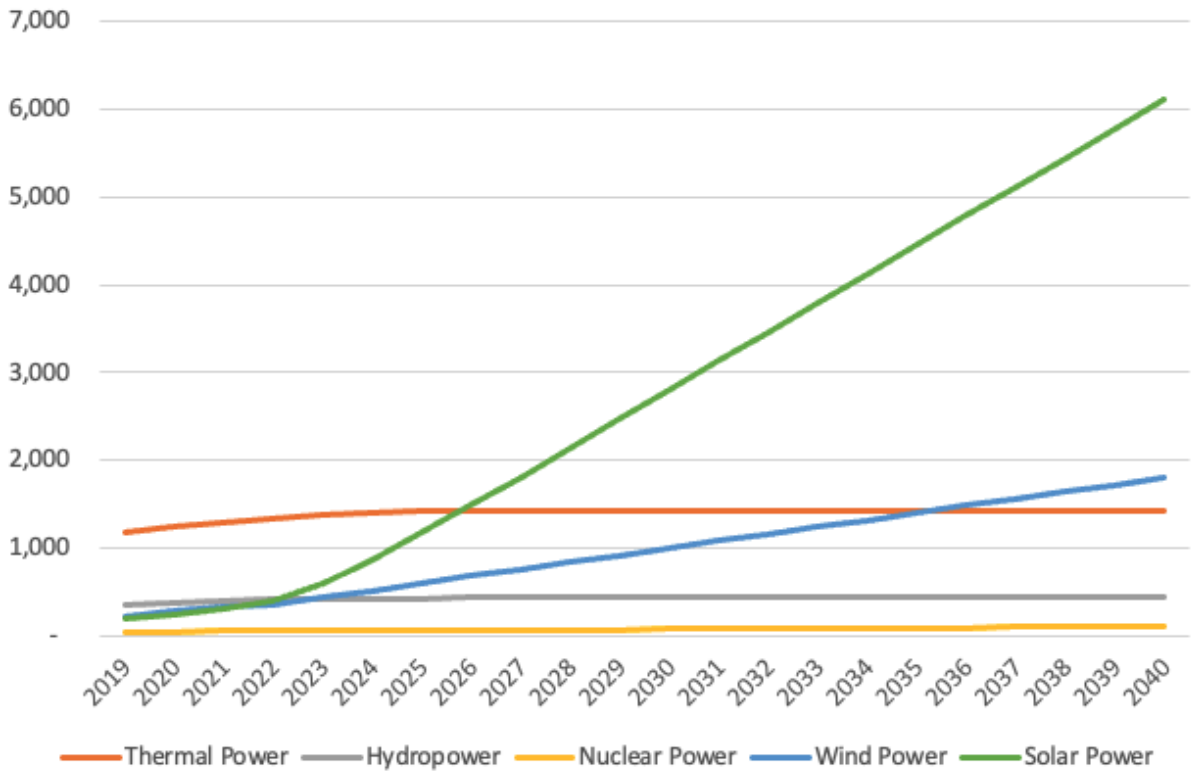
CEF identifies this as an opportunity for Australia and China energy collaboration. As Australia exports more than 50% of the world's iron ore, and over 50% of the world's coking coal, this is the window for Australia to be really exposed to steel sector decarbonisation - as number one investment as well as export opportunity for Australia - pivoting from iron ore to green iron exports, in collaboration with China Baowu and South Korea's POSCO, and Japan. It will also be geopolitical strategic, as it furthers the tie between Australia, South Korea and Japan, enhancing the alliance for like-minded middle powers.

[73] Energy Post. China is still playing the long game with its 'new three': solar cells, lithium batteries, EVs. 12th December, 2023
[74] Including all manufactured solar exports, from polysilicon, wafer, cells, modules and inverters, rather than the literal inclusion of only solar cell exports
[75] 中华人民共和国中央人民政府. "新三样"逆袭的启示. 8the February, 2024
[76] FT. Europe's solar industry warns of bankruptcies over Chinese imports. 12th September, 2023
[77] Centre for Research on Energy and Clean Air. Steel sector decarbonisation in China stalls, with investments in coal-based steel plants since 2021 exceeding USD 100 billion despite overcapacity and climate goals. 27th March, 2024

2.1 China's Electricity Market Outlook till 2040

CEF constructed our China electricity model based on two decades of historical data from China NBS and NEA, incorporating updated policy indications to forecast the outlook. For a detailed breakdown of the electricity market forecast by fuel types, please refer to section 4.

Figure 2.1.1 China's Total Installed Capacity at CY End by Fuel Types Forecast till 2040 (GW)



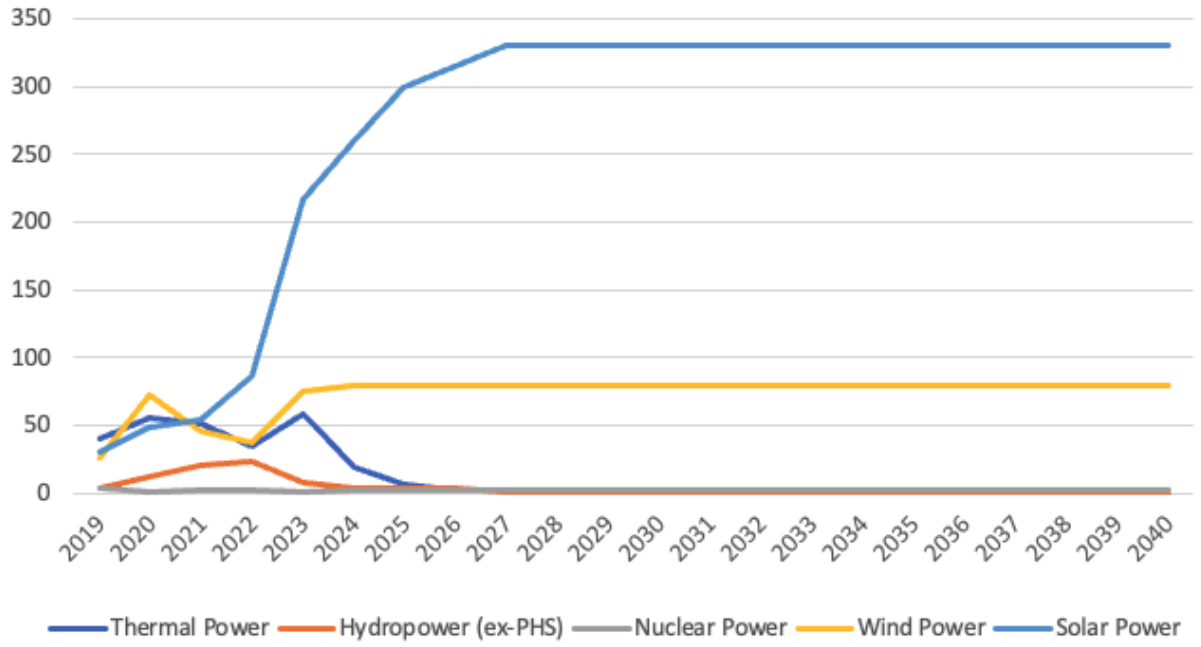
Source: China NEA; Calculated by CEF

Figure 2.1.1 illustrates the projected total installed capacity in China by fuel types until 2040, sourced from China NEA data and calculated by CEF.

As a result of heavy investment into cleantech, China sees a surge in installed renewable energy capacity in recent years, especially in solar power generation.

As shown in Figure 2.1.1, CEF forecasts that installed solar capacity will surpass thermal power in 2026 for the first time, reaching 2,804GW in 2030, and 6,104GW in 2040. Similarly, installed wind capacity will surpass thermal power in 2036 for the first time, reaching 1,001GW in 2030, and 1,801GW in 2040. Installed hydropower capacity will increase to 438GW by 2030, and plateau at 438GW till 2040. Installed nuclear capacity will increase to 78GW in 2030, and 108GW in 2040. Installed thermal capacity will peak in 2030, reaching 1,423GW, and plateau at 1,423GW till 2040.

Figure 2.1.2 China's Installed Capacity Additions by Fuel Types Forecast till 2040 (GW)

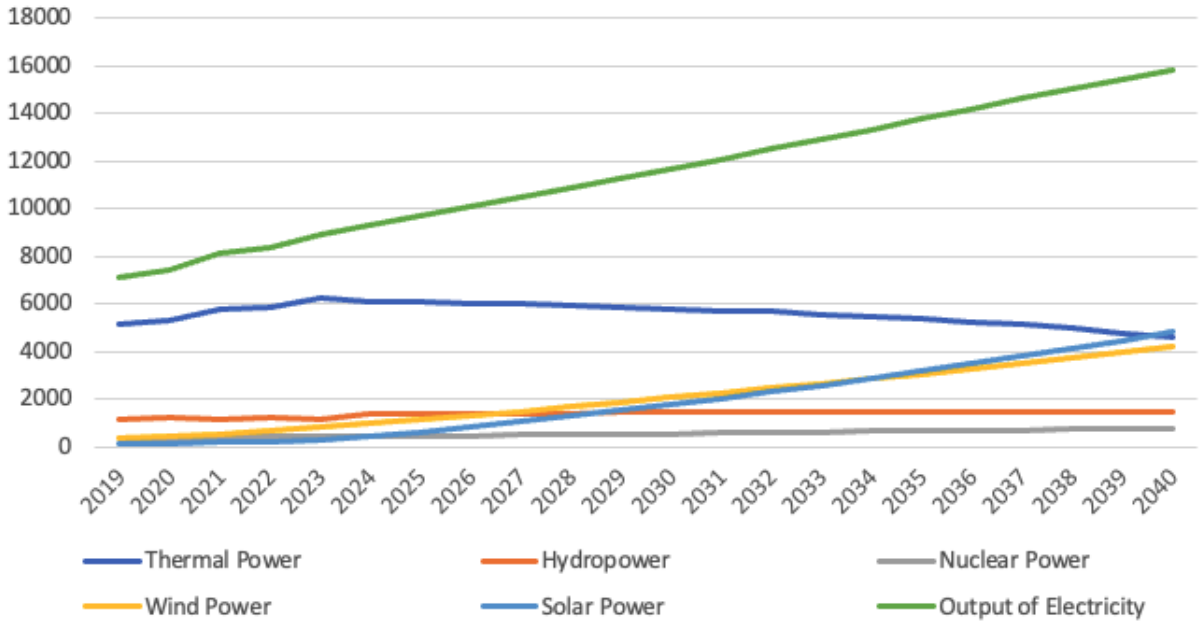


Source: China NEA; Calculated by CEF

Figure 2.1.2 depicts the forecasted installed capacity additions by fuel types until 2040, highlighting solar as the primary driver of new capacity additions over the next two decades, due to the price drop in the solar industry.

CEF estimates that the solar capacity addition will increase to 260GW by the end of CY2024, and 330GW by the end of 2027, and plateaus until 2040. Wind capacity addition will increase to 80GW by the end of 2024, and plateaus until 2040. Nuclear power capacity addition will increase to 3GW and remain at 3GW p.a until 2040. Hydropower capacity addition will decrease to 3.6GW by the end of 2024, and decrease to 0.5GW by the end of 2030, and no more new hydropower additions moving forward from 2030. Thermal power additions will drop to 19.4GW in 2024, and 0.5GW by the end of 2030, and no more thermal power additions from 2030 onwards.

Figure 2.1.3 China's Power Generation by Fuel Types Forecast till 2040 (TWh)



Source: China NEA; Calculated by CEF

Figure 2.1.3 presents the forecasted power generation by fuel types until 2040, indicating continuous growth in electricity demand driven by economic expansion and electrification trends.

CEF forecasts that China's electricity demand will keep climbing to 11,672.9TWh in 2030, a 31% increase from 2023, and reach 15,855TWh by 2040, a 78% increase from 2023. Thermal power generation in 2030 will reach 5,806TWh, and plateaus thereafter. Solar power generation will surpass wind power generation in 2034, and increase to 1,790TWh in 2030, and 4,810TWh in 2040. Wind power generation will increase to 2,068TWh by 2030, then 4,186TWh by 2040. Hydropower generation will increase to 1,436TWh by 2030, then stay around 1,438TWh from 2031 to 2040. Nuclear power generation will continue to rise, reaching 569TWh by 2030, then 792TWh by 2040.

Based on China's current speed in adding more renewable energy in the grid, it is entirely achievable for China to peak coal use before 2030, and plateau thereafter. Moreover, China can even reach its 1,200GW installed solar and wind total capacity goal by the end of this year, if the current pace of installing new solar and wind capacity during the first 2 months of 2024 continues. Section 4 will further explore the outlook for each aspect of China's electricity market categorised by fuel types, and identify the opportunities and challenges for China on its way to carbon neutrality.

2.2 China's Electricity Market: Modelling Sensitivities

At 8,909TWh of annual generation in 2023, the Chinese electricity sector is the largest in the world, more than double the US at 4,178TWh. China's electricity demand has also continued exceptionally strong rates of growth, up 25% in just the last four years, reflective of the sustained strength of GDP growth and progress in electrification of everything.

Up till 2023, annual zero emissions capacity additions in China have been insufficient to fully cover total electricity demand growth, particularly given the ongoing increased share of electricity in terms of total energy system demand. But with a 92% y-o-y growth in zero emissions capacity additions to 302GW in 2023, China is close to a tipping point. Even with a significant slowdown in the rate of new capacity expansions, the forecast progressive slowdown in rate of economic growth and changing economic composition away from heavy industry and construction to more services, technology and consumer focus could see an approaching peak in coal-fired power generation in China. This could be evident as soon as 2024, if China's 442GW of hydro-electricity capacity returns to its historic average utilisation rate after the 5% y-o-y decline in annual hydro generation as a result the extended 2023 drought. This is globally critical, given China is by far the largest producer, importer and consumer of coal globally.

We note the pending peak in China's coal consumption has been previously wrongly forecast, and that this failed to materialise, given the ongoing strength of Chinese economic activity, particularly in high energy intensive construction and infrastructure sectors.

We forecast China's electricity demand will grow by 78% to 15,855TWh pa by 2040. This assumes electricity demand to grow at a CAGR of +3.5%, slightly below our forecast for an 87% increase in GDP (a CAGR of +3.7%), with electricity rising from 19% of China's total energy mix in 2023 to 25% by 2040.

For each 0.1% pa lower (or higher) GDP growth assumed over the next 17 years to 2040, electricity generation would be 1.7% or 260TWh lower (higher), and hence coal fired power generation in 2040 would be 260TWh pa or 5.6% lower (higher), all else equal.

For each 0.1% pa improvement in the rate of energy efficiency assumed over the 17 years to 2040 (1.7% in aggregate), electricity generation would be 1.7% or 260TWh lower, and hence coal fired power generation in 2040 would be 260TWh pa or 5.6% lower, all else equal.

We assume 80GW pa of wind installs to 2040. For every 10GW pa higher wind, 2040 wind generation would rise by 393TWh, and coal generation would decline by the equivalent (all else being equal), a 7% cumulative decline vs our base scenario. This is significantly higher than for solar, given the higher capacity utilisation rates, particularly offshore wind.

We assume 320GW pa of solar installs to 2040. For every 10GW pa higher solar China installs, 2040 solar generation would rise by 170TWh, and coal generation would decline by the equivalent (all else being equal), a 4% cumulative decline vs our base scenario.

We assume China installs 3GW pa of net new nuclear capacity to reach 108GW by 2040. Increasing this forecast to 4GW pa would see nuclear generation rise by 123TWh by 2040, and coal generation would decline by the equivalent (all else being equal), a 2% cumulative decline vs our base scenario.

3. Energy Efficiency

Improving energy efficiency needs to play a key role in China delivering on its net-zero aspirations. China is falling behind to achieve its energy efficiency targets set in the 14th FYP, as it has only reduced energy intensity by 0.5% during CY2023. During the 'two sessions' in 2024, Beijing announced a 2.5% energy intensity reduction target after failing to set one for both 2022 and 2023.

China excluded non-fossil energy from the total energy consumption and intensity regulation earlier this year. CEF's model assumes China's energy consumption growth will return to lower than the GDP growth from 2024 onwards. The increasing energy consumption will not necessarily lead to more fossil fuel consumption with the electrification of everything and the increasing share of renewable energy generation in the national grid. Whether China achieves its 14th FYP energy efficiency targets or not, its energy policy is going in the right direction.

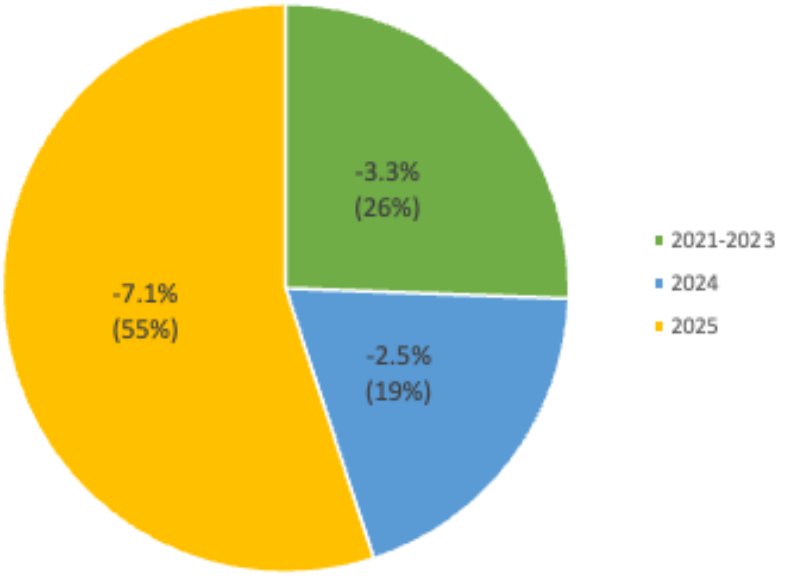
During China's '13th FYP' period from 2016 to 2020, significant strides were made in energy efficiency, with a commendable reduction of energy consumption per unit of GDP by 13.2%.[78] However, as China embarked on its '14th FYP' (2021-2025), setting ambitious targets to further enhance energy efficiency by reducing energy consumption per unit of GDP by 13.5%,[79] challenges emerged.

During 2023, China's energy intensity only fell by 0.5%.[80] This comes after China failed to set energy efficiency targets in both 2022 and 2023[81], which shows the importance of having directions for energy transition from the central government under the unique top-down political structure in China.

China's central government recently announced a 2.5% energy intensity reduction target for the year of 2024 during 'Two Sessions'.[82] This proactive measure aimed to recalibrate efforts and realign the trajectory towards achieving the '14th FYP' targets.

[78] 中华人民共和国国家发展和改革委员会. "十四五"规划《纲要》主要指标之14|单位GDP能源消耗降低. 25th December, 2021
[79] 中华人民共和国国家发展和改革委员会. "十四五"规划《纲要》主要指标之14|单位GDP能源消耗降低. 25th December, 2021
[80] 中国能源新闻网. 2023年全国万元国内生产总值能耗比上年下降0.5%. 29th February, 2024
[81] Rhodium Group. China 30/60: Tracking the Financing of China's Green Transition. 13th March, 2023
[82] 中华人民共和国中央人民政府. 2024年全国两会巡礼：团结一心再进发 昂首阔步向未来. 11th March, 2024

Figure 3.1 Energy Intensity of GDP Change (%) to Reach 14th FYP Intensity Target



Source: NBS; Calculated by CEF

Figure 3.1 shows China's current progress on achieving its energy efficiency target. To reach China's 14th FYP energy intensity target under the assumption that China successfully accomplished its 2.5% energy intensity reduction target for 2024, China needs to reduce its energy intensity by 7.1% during the year of 2025. China reduced its energy intensity by 2.2% during 2021-2023, completing 26% of the total FYP target. If 2024 sees a 2.5% energy intensity reduction, it will complete another 19% of the total FYP target. Leaving 55% of the 13.5% reduction target to be finished in 2025 itself.

Li Shuo and Taylah Bland from Asia Society Policy Institute argue that China needs a more ambitious energy intensity reduction target, especially after China did not set specific policy targets for energy intensity reduction in 2022[83] and 2023[84].

The progress in achieving the 14th FYP energy intensity reduction target was severely disrupted by covid. CEF reinforces the importance of sustained annual energy efficiency productivity gains over the medium term to 2030 and beyond, this is the single most important key to locking in peak carbon emissions in China.

Furthermore, recent policy changes in energy intensity measurement could impact China's trajectory, and this revised approach also offers opportunities to reevaluate strategies and incentivize greater investment in clean energy.

Earlier this year, China changed the definition of energy intensity measurement and excluded non-fossil energy from the total energy consumption and intensity regulation. And in the "14th Five-Year Plan" provincial people's government's energy-saving target responsibility assessment, the consumption of non-fossil energy such as renewable energy and nuclear power is calculated from the total energy consumption of each region. The energy consumption intensity reduction indicators of each region are calculated

[83] Asia Society Policy Institute. Two Sessions: China's Latest Climate Directives. 7th March, 2024
[84] Rhodium Group. China 30/60: Tracking the Financing of China's Green Transition. 13th March, 2023

accordingly.[85] This new development is from a joint notice by China's National Development and Reform Commission, NBS and NEA on 'Strengthen the connection between green electricity certificates and reducing energy consumption and carbon emissions policies to vigorously promote non-fossil energy consumption'.

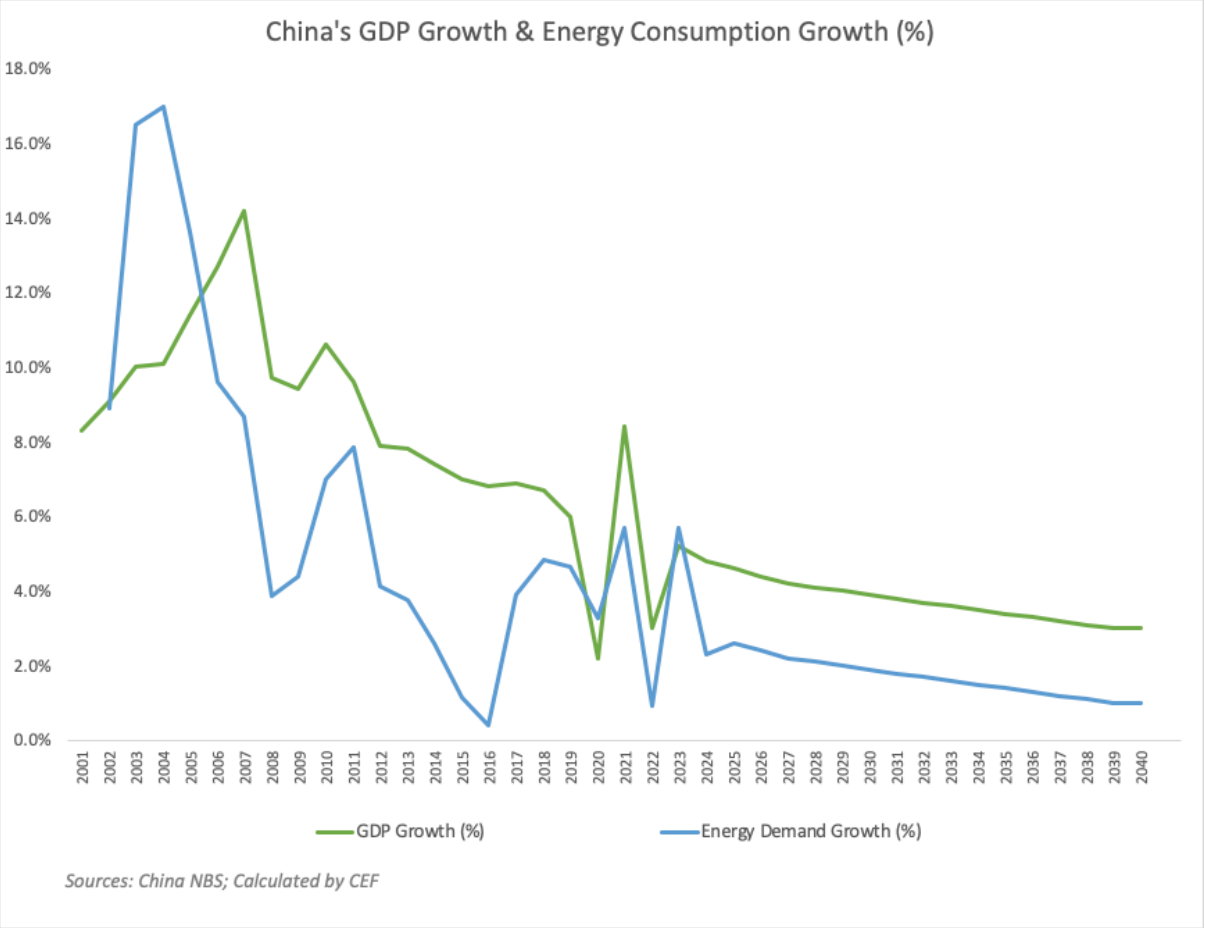
Lauri Myllyvirta from CREA says that under this new policy update, China will only need to reduce energy intensity by 9% by 2025 instead of 13.5%, if only fossil fuel energy is included in the total energy consumption.[86] In this case, if China successfully reduces its energy intensity by 2.5% in 2024, China will need to reduce 3.2% energy intensity in 2025 to achieve its energy efficiency goal during the 14th FYP period.

Although achieving the targets is feasible, Myllyvirta argues that China's new refined energy intensity target shows less ambition, it leaves room for more fossil-fuel consumption.

Nevertheless, China's call for less fossil-fuel consumption could be a good push for the country to invest more in clean energy.[87] The country's fossil-fuel consumption comes from the power sector, and we have witnessed the greening of China's electricity grid in 2023 - adding a world record high of 302GW of zero-emissions new capacity to the grid, with the manufacturing capacity now in place to sustain or accelerate this further in 2024 and beyond.[88]

[85] 中华人民共和国国家发展和改革委员会. 国家发展改革委 国家统计局 国家能源局 关于加强绿色电力证书与节能降碳政策衔接 大力促进非化石能源消费的通知. 27th January, 2024
[86] 中外对话. 解读两会 2024：四大绿色看点. 11th March, 2024
[87] China Dialogue. How China completely redefined a key energy target. 19th March, 2024
[88] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review| Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024

Figure 3.2 China's GDP Growth & Energy Consumption Growth (%)



Source: China NBS; Calculated by CEF

CEF's model - Figure 3.2 - assumes China's energy consumption growth will return to lower than the GDP growth from 2024 onwards, supported by a progressive reduction in energy intensity.

If China continues at its current pace or accelerates the greening of the national grid, the increasing energy demand will not necessarily lead to increasing fossil fuel consumption. This will come with control on fossil fuels energy consumption, and the increasing energy demand as a result of China's sustained strong GDP growth. As section 1.4 mentioned, the share of electricity demand in energy demand is increasing as a result of the national electrifying everything strategy. Under this context, this new target will encourage the deployment and usage of renewable energy sources generated electricity. It can also encourage more investment into clean energy, which was the number one stimulus for China's GDP growth in 2023. This nuanced approach could well accelerate the expansion of renewable energy in China while continuing to stimulate the Chinese economy and offset the property construction sector slowdown.

3.1 Heat Pumps

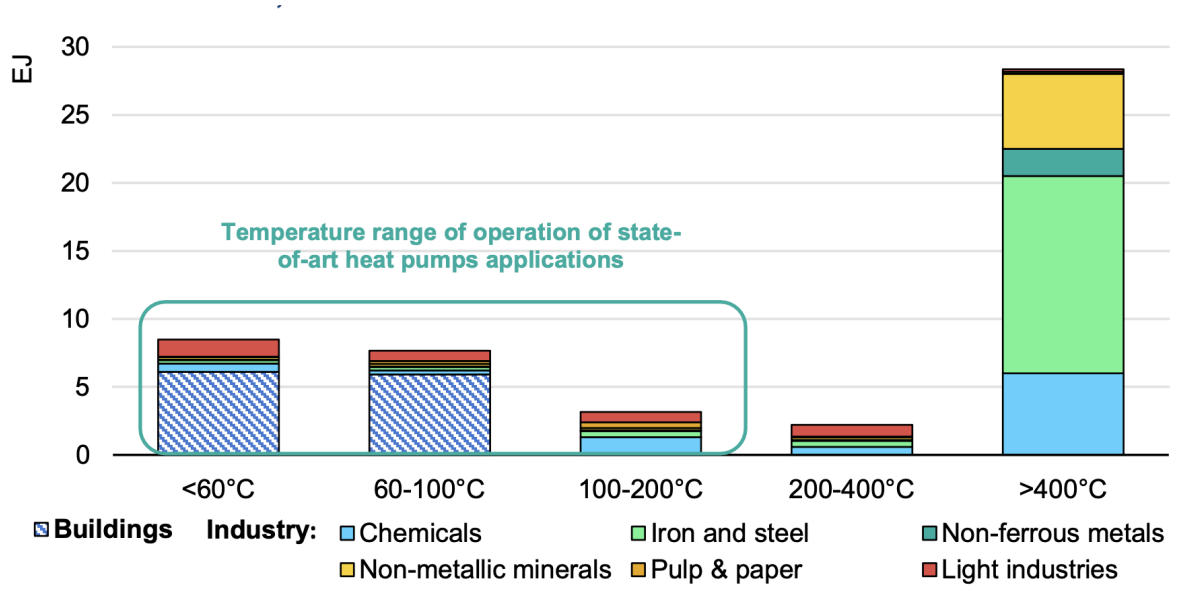
The deployment of heat pumps is one example of how electrification of everything can dramatically improve energy efficiency and drive decarbonisation, in alignment with the expansion of renewable energy in the electricity system. China leads the world in heat pump deployments, but has a huge opportunity to accelerate deployments manyfold.

According to the Energy Efficiency Council, a heat pump can deliver heat at 600% efficiency, while the efficiency of a gas heater is at 50% to 95%.[89] And if electricity provided for heat pumps are generated from zero-emissions energy resources, it will reduce the emissions from the buildings and heating system.

China is currently the world's largest market for heat pumps for buildings with a global share of >25% of installed volumes. The IEA notes that in 2023 China was the only major market where heat pump sales grew, by a robust 12%.[90]

Decentralised heat pumps installed in China have a combined capacity of >250 GW, covering around 4% of heating needs in buildings. The IEA models that to reach China's carbon neutrality target, this capacity reaches 1,400GW by 2050, meeting 25% of heating needs, meaning 100GW of heat pumps would need to be installed in buildings every year until 2050 to meet this ambition. Large-scale heat pumps can be integrated into existing district heating systems and optimise use of waste heat. The IEA estimates 40% of current end use of heat can be replaced by heat pumps on today's technology, which in turn would expand the scope with additional RD&D.

Figure 3.1.1 The Final Energy Consumption in Heating in China by Temperature Band and End Use Sector, 2022



Source: IEA, The Future of Heat Pumps in China, March 2024[91]

[89] Energy Efficiency Council. BACK TO BASICS: HEAT PUMPS.
[90] IEA. The Future of Heat Pumps in China, March 2024
[91] IEA. The Future of Heat Pumps in China, March 2024

According to the IEA, in parallel with the ongoing decarbonization of power generation, heat pumps present a viable solution for transitioning away from fossil fuels. With energy consumption significantly lower - typically three to five times less - than alternative equipment, heat pumps play a crucial role in reducing overall energy demand for heating purposes - Figure 3.1.1. Moreover, when integrated with thermal or electric storage systems, heat pumps enhance the flexibility of electricity grids and district heating networks. Although the utilisation of heat pumps for industrial heat production remains minimal in China, they are more commonly employed for space heating and domestic hot water generation. Presently, state-of-the-art heat pumps operate within temperature ranges below 200°C, while those designed for higher temperatures are still undergoing technological advancements and readiness assessment.[92]

Expanding the deployment of heat pumps represents a pivotal strategy in reducing China's energy intensity and accelerating the nation's progress towards achieving its energy efficiency targets. By embracing widespread adoption of heat pumps, China can significantly enhance its energy efficiency, contributing to a more sustainable and environmentally friendly energy landscape.

[92] IEA. The Future of Heat Pumps in China, March 2024

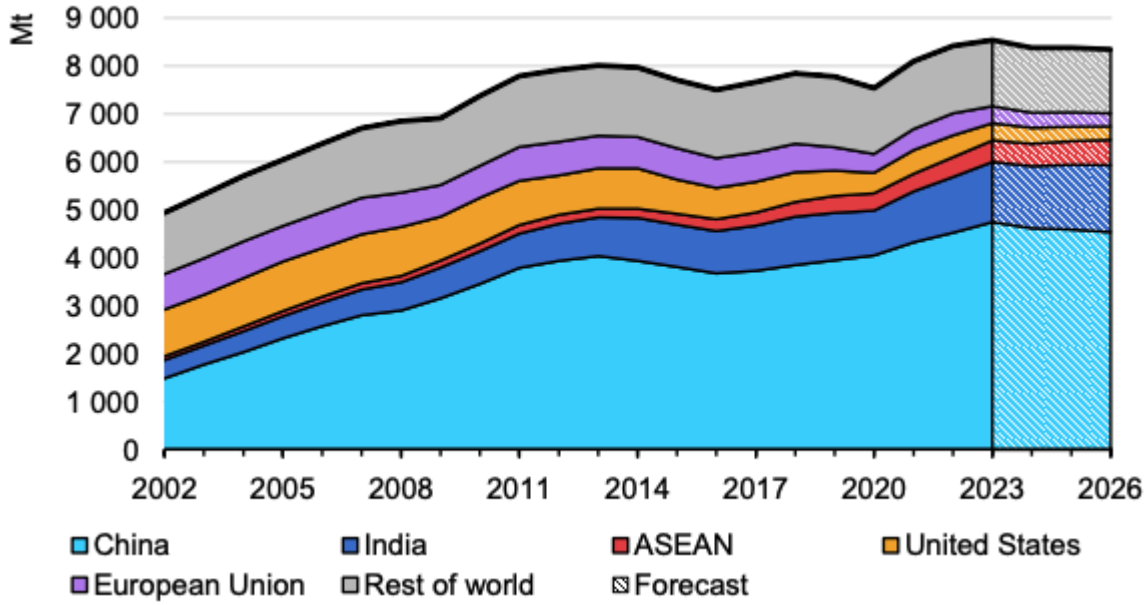
4. Aspects of electricity market

China has the world's largest power system, and it is continuing to undergo a significant transformation - from traditional coal-reliant power system to renewable and nuclear-led power system, backed up by PHS and BESS. The IEA and CREA forecast that China will peak coal-use in 2023. CEF forecasts that China can peak then plateau in coal use over the six years to 2030, followed by a slow continued decline of 2% p.a. in coal use in absolute terms in China from 2030-2040, giving a 20% decline over the next decade.

China's electricity market is at the forefront of a transformative journey - from traditional thermal power generation to robust expansion of renewable energy installations. As the largest power system globally,[93] China's shift towards greener energy sources holds immense significance not only domestically but also in the global energy transition landscape.

By the end of CY2023, China added 302GW of zero-emissions capacity to the national grid, taking up 84% of the total newly installed capacity of the year. Over half of the national installed capacity was zero-emissions capacity, reaching 1,529GW.

Figure 4.1 Global Coal Consumption, 2002-2026

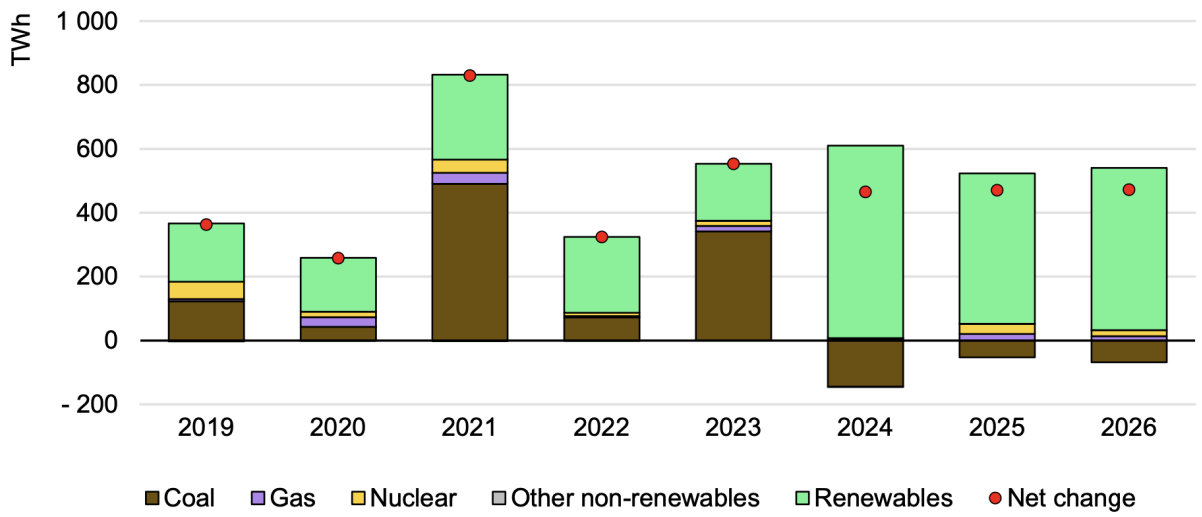


Source: IEA Coal 2023, Analysis and forecast to 2026, December 2023, page 12[94]

The IEA forecasts that China's coal demand will fall marginally in each year from 2024 through to 2026 as a result of more than half of the global renewable capacity expansions is set to occur in China - Figure 4.1.

[93] IEA. Building a Unified National Power Market System in China: Pathways for spot power markets. April 2023
[94] IEA. Coal 2023 Analysis and forecast to 2026. December 2024

Figure 4.2: China's y-o-y Change in Electricity Generation, 2019-2026



Source: IEA Electricity 2024, Analysis and Forecast to 2026 page 90[95]

While thermal power still dominates China's electricity generation, constituting 70% of the total output,[96] forecasts shown in Figure 4.2 from IEA suggest a transformative trend. From 2023 onwards all of China's electricity demand will be met by renewable energy and nuclear power thanks to the continuous strong solar PV and wind power expansion, as well as the increasing nuclear power capacity.[97] The role of coal in China's power system will change from being the pillar energy source to serve as a supportive role for renewables.

The Centre for Research on Energy and Clean Air's forecast aligns with IEA's estimation that China will peak emissions in 2023.[98]

However, China's climate targets look beyond peaking coal-use.

A study conducted by the University of California San Diego and Tsinghua University in Beijing suggests that China needs 6TW of solar and wind power to reach its net-zero target by 2060.[99] CEF suggests that this is entirely doable for China if the speed of installation of wind and solar during the first 2 months of CY2024 sustains - 10GW of wind and 37GW of solar capacity addition.

CEF forecasts that China can peak then plateau in coal use in the electricity sector over the six years to 2030, followed by a slow continued decline of 2% p.a. in coal use in absolute terms in China from 2030-2040, giving a 20% decline over the next decade. Any acceleration in zero emissions capacity additions beyond our current forecasts and / or sustained acceleration in energy productivity as the Chinese economy continues to shift away from secondary manufacturing and construction towards tertiary sectors would mean

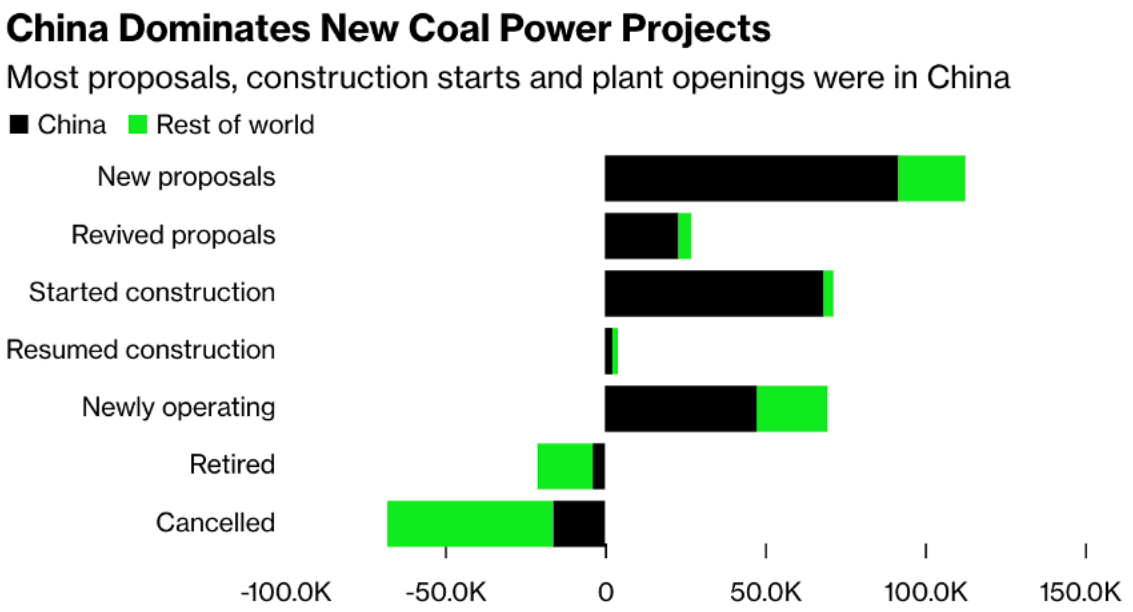
[95] IEA. Electricity 2024: Analysis and forecast to 2026. January, 2024
[96] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024
[97] IEA. Electricity 2024: Analysis and forecast to 2026. January, 2024
[98] Carbon Brief. Analysis: China's emissions set to fall in 2024 after record growth in clean energy. 13th November, 2024
[99] South China Morning Post. China needs 10 times its solar and wind power to be carbon neutral, study finds. 3rd March, 2024

that China could well deliver well in advance of its ‘double carbon’ targets - peak carbon emissions by 2030 and reach carbon neutrality by 2060. In this section, CEF will deepdive into each energy source, explore its trend, restraint, and opportunities.

4.1 Coal-fired Power Plant

With the drastic increase in the buildout of renewable energy capacity, China is expected to show a decline in coal-fired power plant generation. Although in 2023, thermal power still accounted for 70% of the total power generation (down only marginally from 72% in 2019), CEF forecasts that China will peak then plateau coal-use well before 2030 as a result of massive renewable energy scale-up. Coal will progressively decline as the central pillar of China's power generation, and continue to shift towards a more backup role in ensuring national energy security. However, CEF notes that this scenario will require a substantial shift to cease building new coal-fired power plants, so that China can deliver its 'dual carbon' targets and take the responsibility as the world leader in all front renewables.

Figure 4.1.1 China's New Coal Power Projects



Souce: Global Energy Monitor via Bloomberg[100]

According to data from Global Energy Monitor, China has 96% of the world's new coal power under construction - Figure 4.1.1. China has been permitting 2 new coal-power plants per week in 2022.[101] While this trend has proven necessary in light of the strong sustained electricity system growth of recent years and the significant underperformance of hydro during the 2023 drought, such development is considered as a major ongoing headwind to the critically important goal of China reducing coal use will have a significant impact to the global energy transition progress.

The IEA, however, indicates that the coal-fired power generation will decline through 2026 as shown in Figure 4.2 despite new coal plants having been permitted or commissioned since 2022. This is thanks to China's renewable energy expansion, and the increasing share of renewable energy in the electricity mix.[102]

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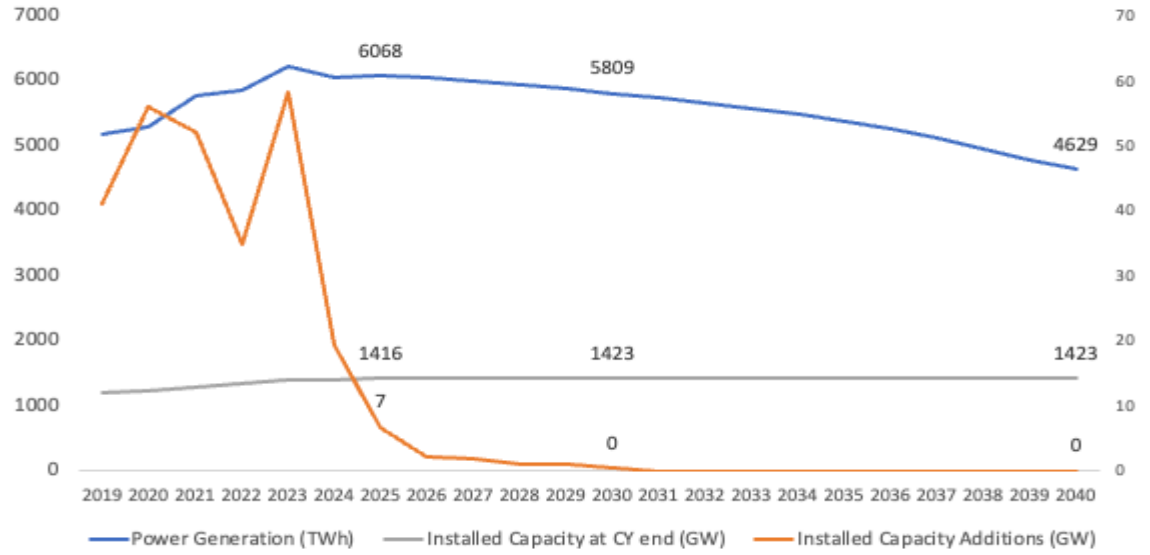
[100] Bloomberg. China Is Dominating the World's New Coal Power Plant Pipeline. 6th February, 2024
[101] Global Energy Monitor. China permits two new coal power plants per week in 2022. February 2023
[102] IEA. Electricity 2024: Analysis and forecast to 2026. January, 2024

Figure 4.1.2 China Thermal Power Forecast to 2040



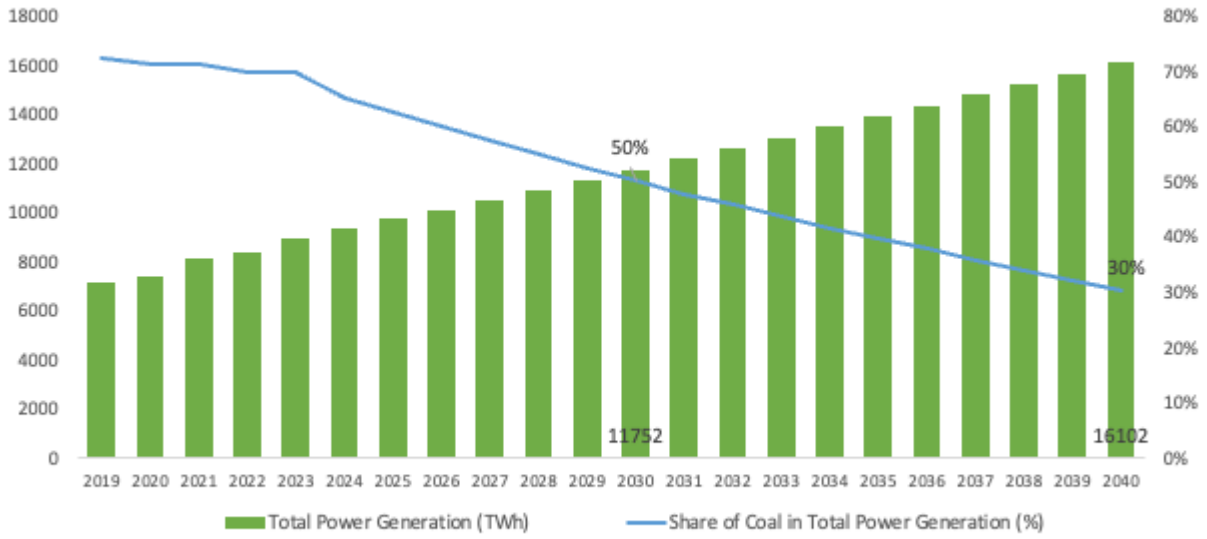
Source: China NEA; Calculated by CEF

CEF's model shows a similar trend as the IEA. CEF forecasts that under the current speed and scale of China's renewable energy deployment, it is entirely possible that China will peak then plateau its coal use well before the end of this decade, and then progressively reduce absolute coal use by some 2% p.a. over the 2030-2040 period, delivering a forecast 20% decline next decade.

As shown in Figure 4.1.2, China's thermal power generation peaks and plateaus before 2030, then declines to 4,629TWh by 2040. China's total installed thermal power will increase to 1,423GW by 2030, then plateau thereafter. It is worth noting that this scenario will happen if China has peaked new thermal power addition in 2023, and new addition in thermal power capacity will decline to 19GW p.a. in 2024 and 7GW in 2025, then zero thermal power additions from 2030 onwards. Based on data from NEA for the first 2 months of CY2024, China has already added 5.1GW of thermal capacity. It is urgent for China to drastically slow down new thermal power additions to reach its 'dual-carbon' targets.

Or, in another scenario, China will keep building new coal-fired power plants as backup power generators for the purpose of energy security. These coal plants will have low utilisation rates, or be idled as renewable energy transitions to become the major energy source. Building more new coal-fired power plants in this context will not be economic and is a waste of resources, a lose-lose situation for China.

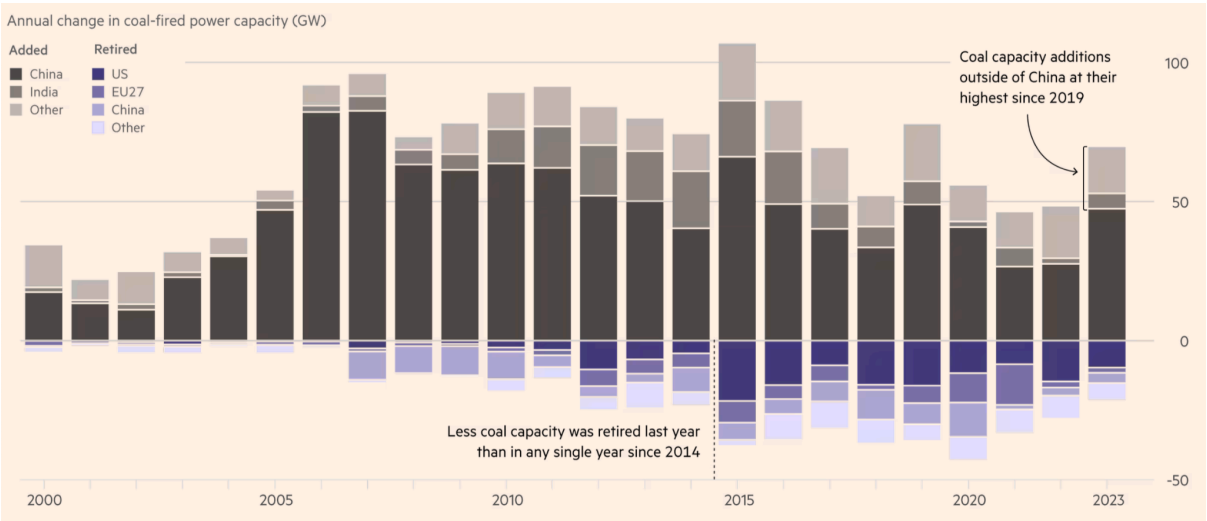
Figure 4.1.3 Total Power Generation and the Share of Thermal Power in Total



Source: China NEA; Forecasts generated from CEF's national electricity model

In our CEF national electricity model, the absolute coal use peaks in 2023, and slowly but progressively declines there-after. China's total power demand will continue to rise through 2040, due to China's continued economic growth and electrification efforts. However, the share of thermal power in total power generation will drop significantly in the next 16 years, reaching only 30% in the electricity mix in China by 2040 vs the 70% witnessed in 2023 - this is a staggering trajectory of profound global importance, if it can be delivered.

Figure 4.1.4 Global Coal Plant Additions and Closures, Annually, by Major Country

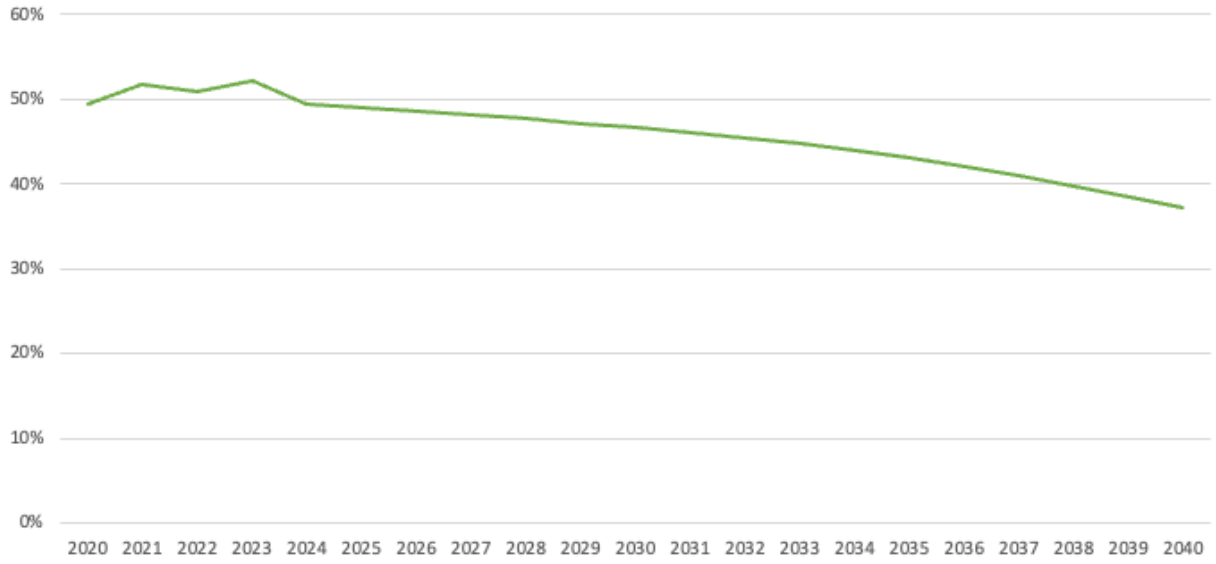


Source: FT graphic using Global Coal Plant Tracker data by Global Energy Monitor

Figure 4.1.4 shows that for the last two decades China alone has represented over half the world's new coal fired power plant additions.[103] Whilst China was closing an average of almost 20GW p.a. of inflexible old coal fired power plants in the four years to 2020, ongoing electrification of everything has seen China's electricity demand continue to grow strongly, and closure rates have dropped dramatically even as new coal plant builds have accelerated.

[103] FT. World coal capacity growth jeopardises peak emissions forecasts. 11 April 2024

Figure 4.1.5 Thermal Power Capacity Utilisation (%)



Source: China NEA; Forecasts generated from CEF's national electricity model

We calculate that the average thermal power plant in China has operated at just a 50% average capacity utilisation rate over the last five years - Figure 4.1.5. We forecast that this will progressively decline to a 46.6% average in 2030 and 37% by 2040, absent accelerated end of life coal plant closures by then. This is a deliberate strategy by the Chinese government to use new flexible coal fired power plants to balance the grid against ever greater share of VRE generation. BESS, AI-driven demand response management (DRM), vehicle to grid (V2G) and PHS will all serve a significantly larger role in grid balancing over time.

Muyi Yang and Xunpeng Shi from the University of Technology of Sydney argued, to transform China away from coal requires policy support. The Chinese government should work on decoupling coal power from current development paths, addressing factors like local government enthusiasm, sunk costs, and socio-economic concerns; implement market reforms centred on coal power as flexibility and backup; improve coordination between coal and electricity policies with regard to supply during demand spikes; and shift governance towards a learning-based, reflexive process to address the complexity of coal power transition.[104]

[104] Ember. 中国煤电发展的动因和转型切入点. December 2023

4.2 Solar

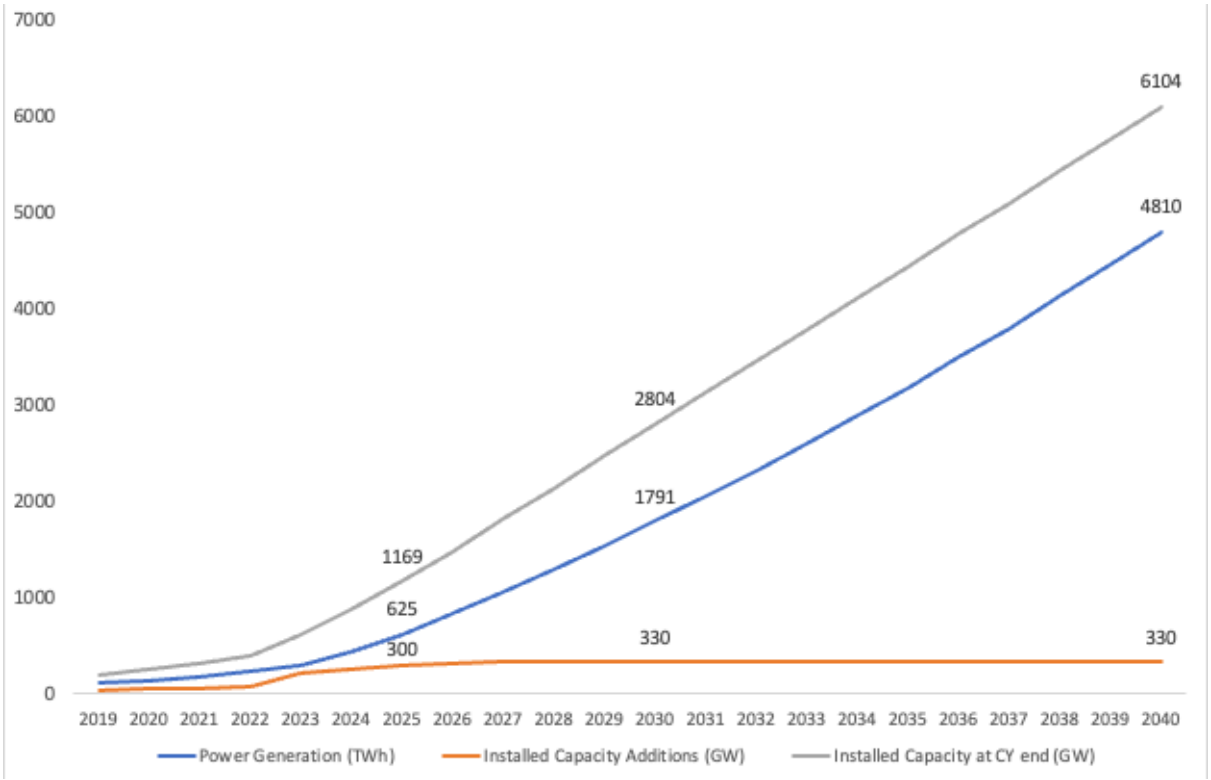
Solar power is growing rapidly in China, in both the national electricity grid and its domestic solar manufacturing and export capacities. After a record 217GW of solar installs in 2023, China installed another 37GW of solar In the first two months of 2024, 70% of net new capacity adds and growth of 80% y-o-y. Acknowledging solar is still only 3% of total Chinese electricity generation, the disruptive effect of massive new intermittent, zero emissions, low cost solar is already being increasingly felt.

With solar module prices down 50% y-o-y in the last 12 months alone, and massive new technology improvements in module efficiency still to come, CEF forecasts an average 315GW p.a. of new solar installs in China over 2024-2030.

Solar power has been China's fastest growing VRE source during the year 2023. China added 217GW of new solar power capacity into the national electricity grid last year, accounting for 60% of the total newly installed capacity during CY2023.[105]

The CEC forecasts that by the end of 2024, China's installed solar capacity will reach 780GW.[106]

Figure 4.2.1 China Solar Power Forecast till 2040



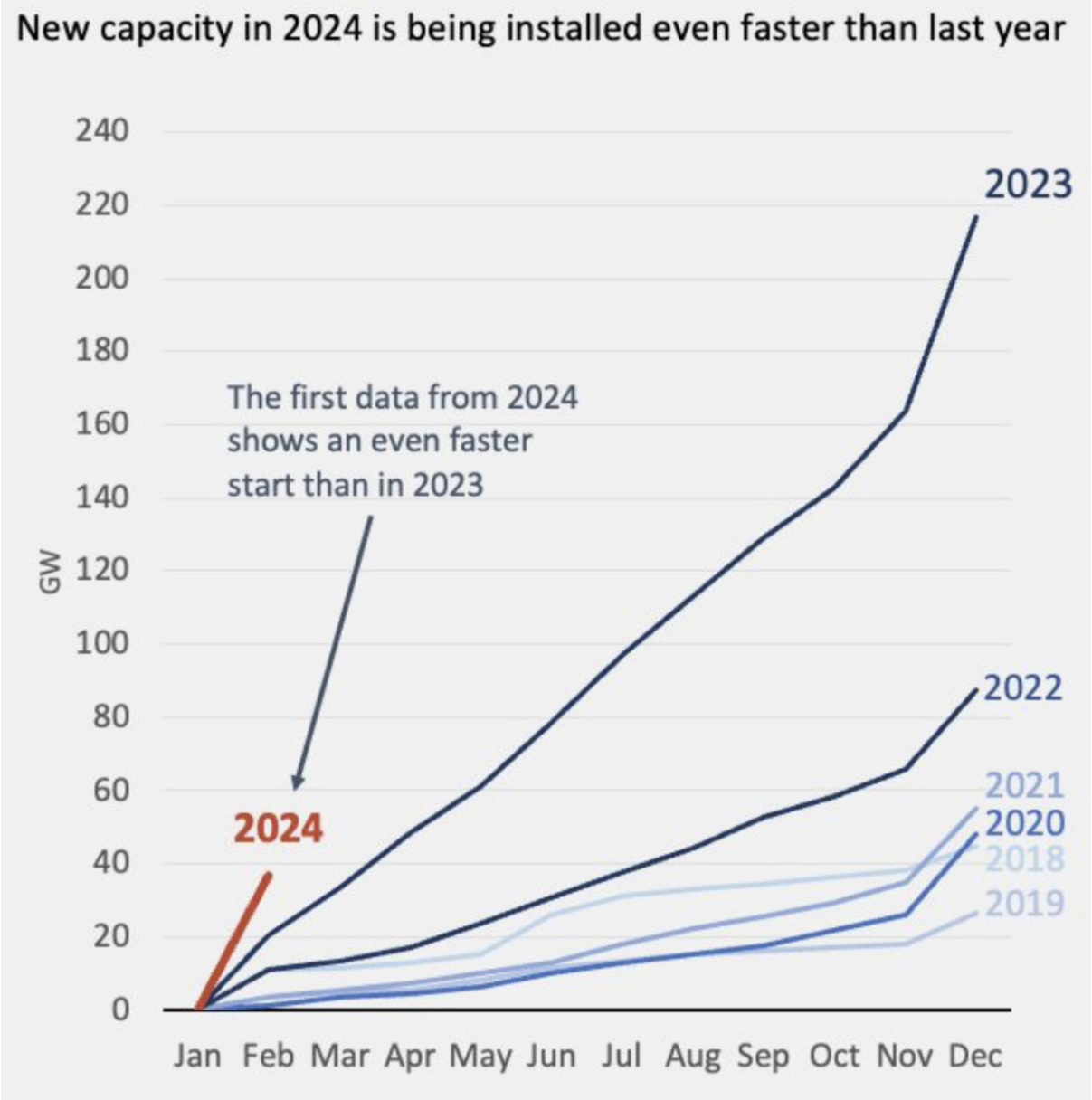
Source: China NEA; Calculated by CEF

[105] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024

[106] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024

CEF is a lot more optimistic, and we forecast 260GW of new solar capacity additions in 2024, such that China will reach 869GW of cumulative installed capacity by the end 2024 - Figure 4.2.1.

Figure 4.2.2: China's solar installation boom has continued during the first 2 months in 2024



Source: NEA via Gavin Mooney, March 2024[107]

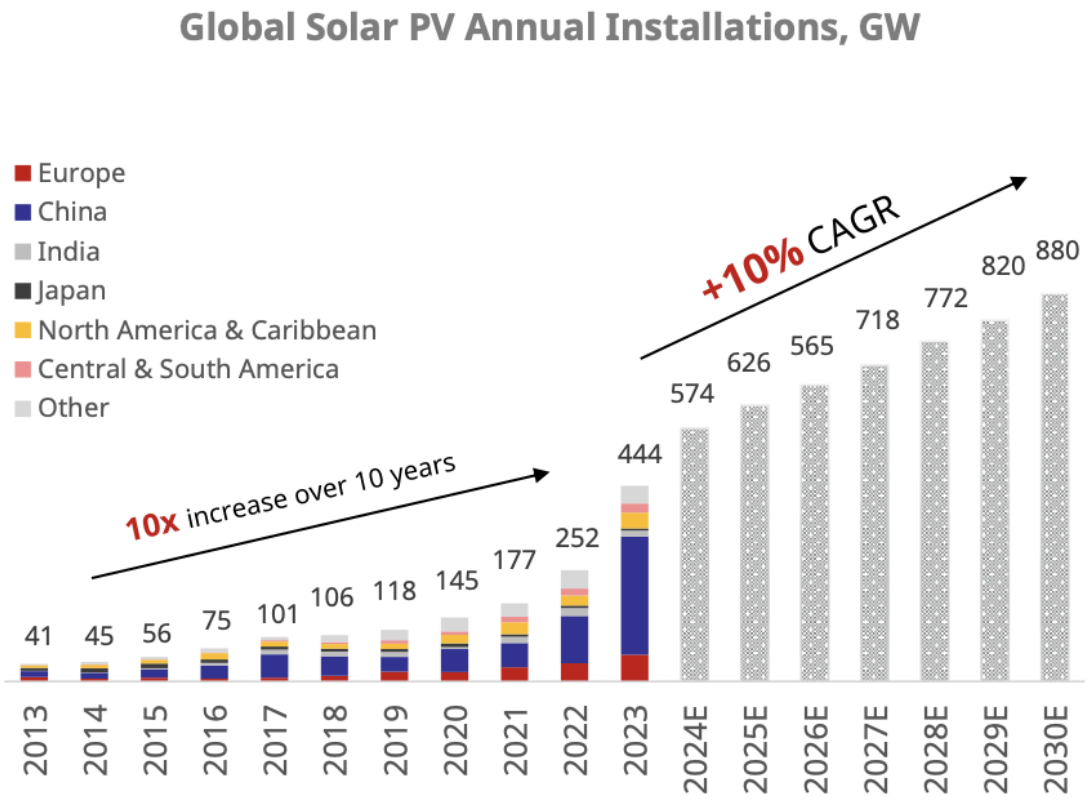
Supporting CEF's optimistic stance is not just the massive surplus solar manufacturing capacity that China has built at nearly triple the rate of domestic demand, but also the dramatically improved cost competitiveness of solar after a 50% decline in solar module prices over 2023. Further, the solar capacity installs in the first two months of 2024 are well ahead of the record 2023 year-to-date installation rate - Figure 4.2.2.

[107] LinkedIn. Gavin Mooney, March 2024

With China's fast solar power deployment, CEF forecasts that by the end of CY2030, China will have 2,804GW of solar capacity installed nationwide. By the end of CY2040, China will have 6,104GW of installed solar capacity. From 2024 to 2030, China will install 314GW of new solar capacity per annum, 330GW new installed solar capacity per annum from 2030 to 2040. As Figure 2.1.1 shows, our model indicates that China's solar capacity will surpass thermal power capacity for the first time in 2026.

By 2030, China's solar power will generate 1,791TWh of electricity, 15% of the total power generation. By 2040, China will generate 4,810TWh of electricity from solar power, accounting for 30% of the total power generation - Figure 4.2.1. Solar power generation will surpass wind power generation in 2034, and surpass thermal power generation by 2040 - Figure 2.1.3.

Figure 4.2.3: Global solar installation, GW 2013-2030

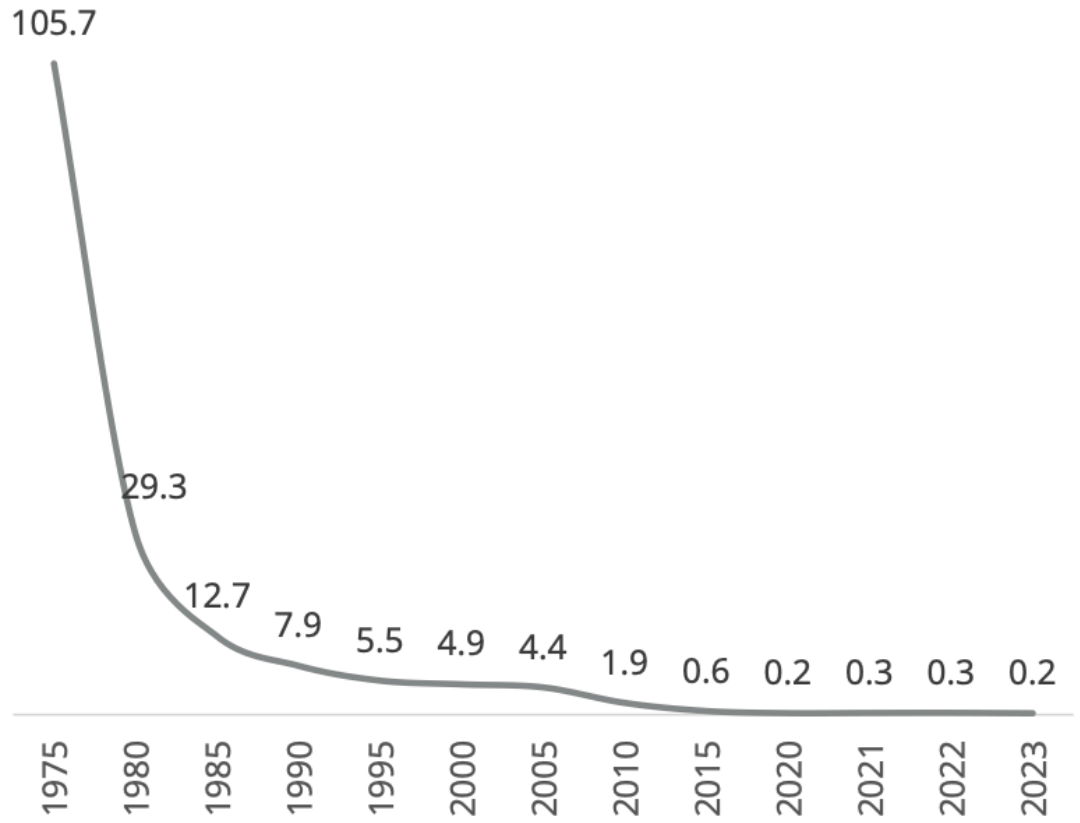


Source: Canadian Solar CY2023 Investor Presentation, BNEF, IHS Markit, March 2024[108]

China leads the world in solar with a >60% global market share of the 444GW of installations in CY2023 - Figure 4.2.3.

[108] Canadian Solar, CY2023 Investor Presentation, March 2024

Figure 4.2.4: Solar PV Module Costs, US$/W 1974-2023



Source: Canadian Solar CY2023 Investor Presentation, BNEF, March 2024[109]

The growth in the last decade has been 10x, and Canadian Solar and Bloomberg forecast at least 10% CAGR over the rest of this decade to reach 880GW p.a. by 2030. The continual dramatic ongoing decline in solar module costs is the key driver of this, and with a 50% decline over the last year to ~US12c/W, this is expected to continue - Figure 4.2.4.

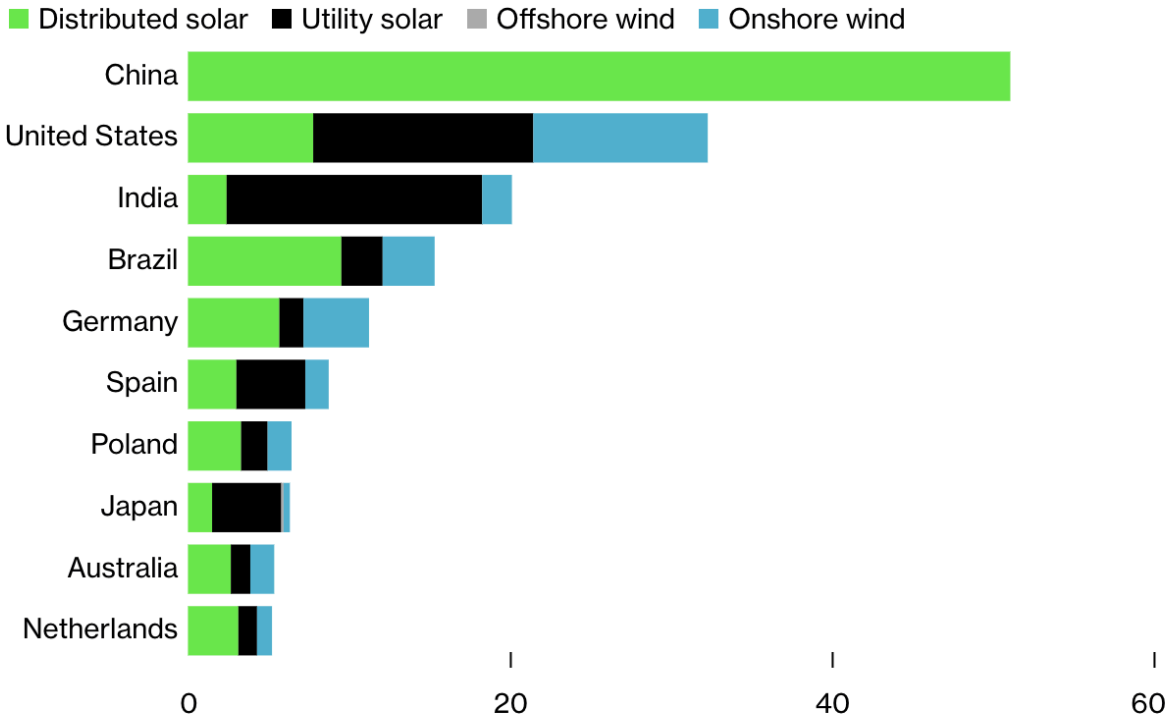
Jinko Solar notes its world leading perovskite tandem solar cell N-type TOPCon conversion efficiency has reached 32.3%, suggesting another 20-30% module efficiency improvement relative to the mass production efficiency of N-type TOPCon cells of 26% at the start of 2024 (Jinko reports this translates into a 22-23% average for its solar panels at the start of 2024). Given Jinko has 1,702 patents already granted, and employs 2,278 in its inhouse R&D team, an investment of Rmb5.6bn (US$900m) in 2022 alone (7.6% of annual revenue),[110] CEF gives considerable weight to this forecast being delivered by 2030 or earlier.

[109] Canadian Solar. CY2023 Investor Presentation, March 2024
[110] Jinko Solar. 4QCY2023 investor presentation, 20 March 2024

4.2.1 Distributed Energy Resources (DER)

Compared to the USA, where 40% of the total electricity generation is consumed by households, 35% consumed by businesses, and 25% consumed by factories, 80% of China's total power demand is for commercial and industrial sectors.[111]

Figure 4.2.1.1 Newly Added Renewable Capacity for 2022



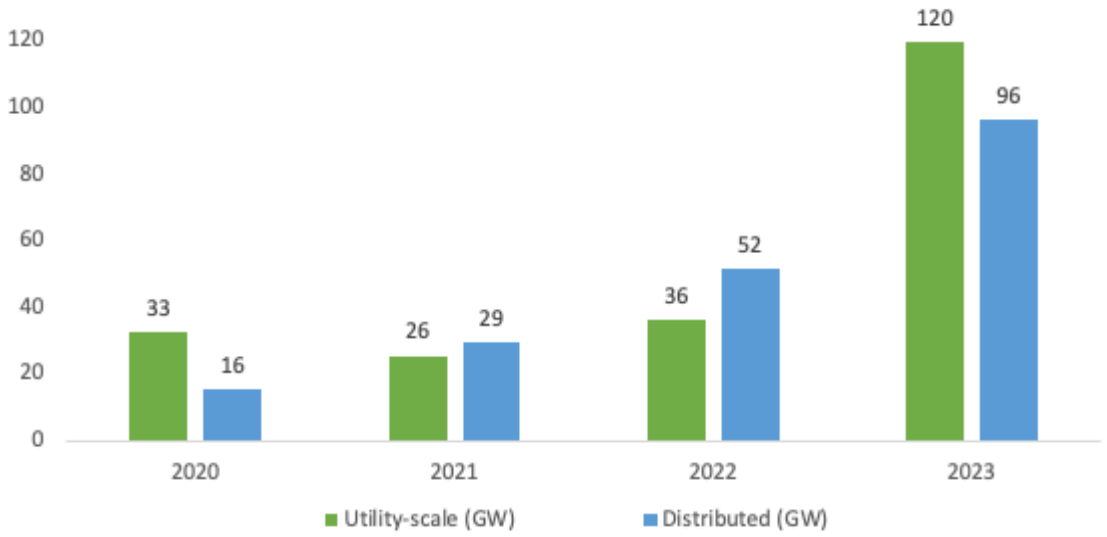
Sources: China NEA, BloombergNEF [112]

This divergence in energy consumption patterns is reflected in China's solar capacity expansion strategy.

Figure 4.2.1.1 from BloombergNEF reveals that China's solar capacity expansion, particularly during 2021 and 2022, was primarily fueled by rooftop solar installations. In 2022, small-scale solar new installations reached more than 51GW.[113] China's newly added distributed solar in 2022 alone is more than what the US has installed in distributed solar, utility solar and onshore wind additions combined in 2022.

Figure 4.2.1.2 China's Newly Installed Utility-Scale Solar and Distributed Solar 2020-2023

[111] South China Morning Post. China builds up electric power in Gobi and western deserts equal to half US capacity. 20th February, 2024
[112] Bloomberg. China Takes Its Climate Fight to the Rooftops. 28th March, 2023
[113] Bloomberg. China Takes Its Climate Fight to the Rooftops. 28th March, 2023



Source: China NEA; Calculated by CEF

However, a notable shift occurred in 2023, as utility-scale solar installations began to outpace distributed solar additions in China - Figure 4.2.1.2. The country witnessed a significant increase in solar capacity, with 120GW of utility-scale solar and 96GW of distributed solar added during the year, indicating a shift in solar deployment trends.

This transition in solar installation dynamics is further complicated by China's unique urban landscape, characterised by limited land availability, particularly in densely populated urban areas dominated by high-rise buildings and skyscrapers. Unlike countries with ample land resources like Australia, China faces challenges in deploying decentralised energy resources (DERs) in urban settings. To address this, China is prioritising the expansion of transmission infrastructure to meet rising electricity demand while minimising land use conflicts and ensuring sustainable energy growth.

4.2.2 Land Use

With the massive scale of renewable energy build-outs, land use issues come to policymakers' attention. A new study conducted by Tsinghua University in Beijing and at the University of California San Diego suggests that China will run out of land on the east coast to build more renewable energy plants. Two-third of usable land for utility-scale solar will be utilised by 2060 in the east coast provinces.[114]

CEF notes there has been a major investment program designed to avoid this limitation: by, building solar, wind and hybrid projects in China's northwest desert area, however we note this requires significant investment into building grid transmission lines and careful planning to ensure grid transmission capacity utilisation optimisation.

China has built a 1.5GW solar project in the Tengger Desert in Ningxia Province. The project has 3.5 million solar modules installed, with a land size of 42 square kilometres. The Tengger Desert has the size of 36,700 square kilometres, the solar project takes up 0.1% of the total Tengger Desert.

According to CEF's estimation, China needs to install a total of 5,405GW of new solar capacity to reach its dual-carbon targets. Under the scenario of Tengger Desert Solar PV Park, it will require a total land size of 146,736 square kilometres. The size of Gobi Desert, a neighbouring desert to Tengger, has the size of 1,294,994 square kilometres, which can provide enough land for China to build enough desert solar farms to achieve its net-zero target.

The challenge is that more transmission lines are needed. China recently started construction of a RMB28bn (US$3.9bn) ultra-high-voltage power line project, which will cover 3 provinces - Shaanxi, Hubei and Anhui. This transmission line is expected to be able to send 36TWh of electricity to Anhui per annum, and help boost renewable energy consumption by more than 18TWh per annum.[115]

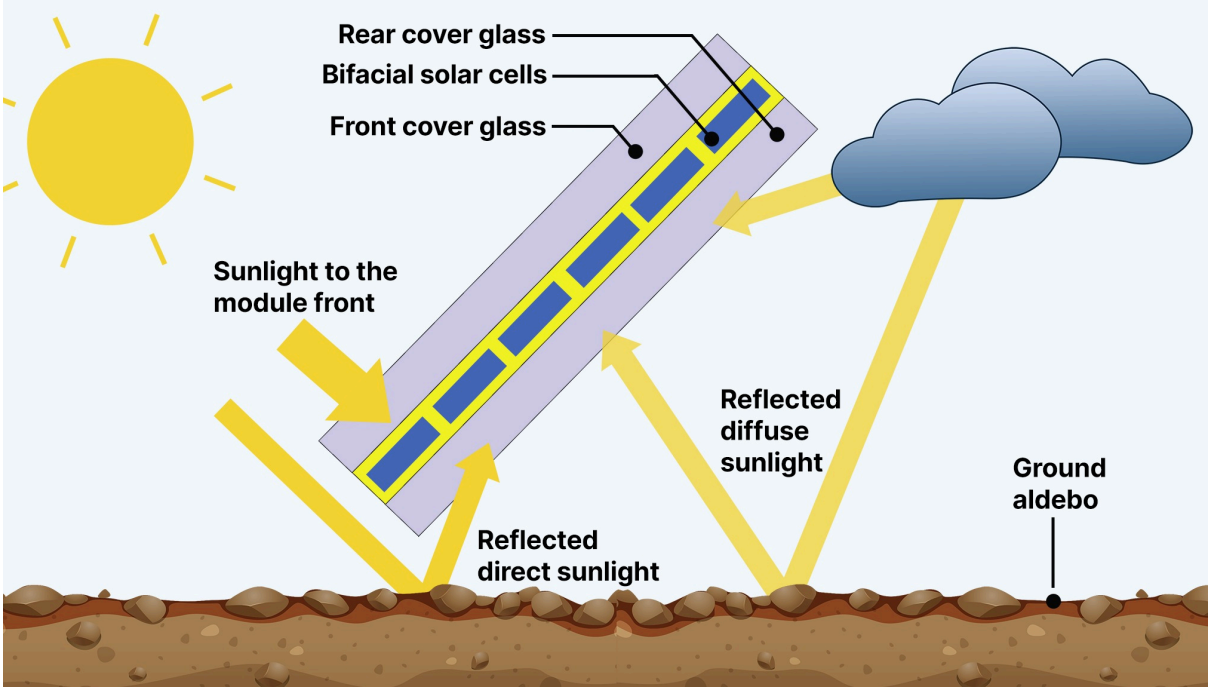
Starting from the northwest side of Shaanxi where it is close to the border of Gobi desert, this transmission line can send electricity generated from desert power stations to the city close to the east coast of China - Hefei, Anhui. And more transmission lines like this will need to be built to maximise the potential of China's desert area, and to resolve China's land use conflict in the east coast.

[114] PNAS. Spatially resolved land and grid model of carbon neutrality in China. 26th February, 2024
[115] 国家电网.【人民日报】“陕电入皖”特高压工程开工 投产后每年可向安徽输电超360亿千瓦时. 17th March, 2024

4.2.3 Technology improvement

Technology innovation in solar panels also makes building large-scale solar projects in the desert feasible.

Figure 4.2.3.1 Bifacial Solar Panel



Source: SolarReviews[116]

The Australian National University (ANU) finds that bifacial solar panels can produce 20% more energy than one-sided panels.[117] Installing bifacial solar panels can maximise the utilisation of sunlight throughout the day.

Canadian Solar developed BiKu bifacial panels which can produce up to 30% additional power from the back side.[118]

Cleaning solar panels is another logistics China needs to deal with, especially for solar panels in the desert. Longi Solar has developed HI-MO X6 Guardian Anti-Dust panel, which can reduce the impacts of dust accumulation and therefore improve power generation.[119]

[116] Solar Reviews. Bifacial solar panels: innovative and more efficient.
[117] ANU. Untapped potential: double-sided solar panels offer more energy on residential roofs. 23rd January, 2024
[118] Solar Reviews. Bifacial solar panels: innovative and more efficient.
[119] Longi. LONGi Solar Australia Unveils Revolutionary Solar PV Module: Hi-MO X6 Guardian Anti-Dust. 18th March, 2024

4.2.4 Agrivoltaics

Another innovative way of reducing the limits posed by land use conflict is agrivoltaics.

Figure 4.2.4.1 Villagers Cultivate Red Chilli Plants under Solar Panels in Guizhou Province

Source: China Daily[120]

Agrivoltaics are emerging in China's rural area, a combination of food farming and PV generation is helping local farmers to profit more while reducing land use conflicts. According to China Daily, a traditional mushroom fruiting room transitioning into a photovoltaic mushroom farm has increased yields by about 20%.[121]

Beyond farming, Chint Group has completed a 500MW solar project on top of a fish pond in Wenzhou, Zhejiang province.[122]

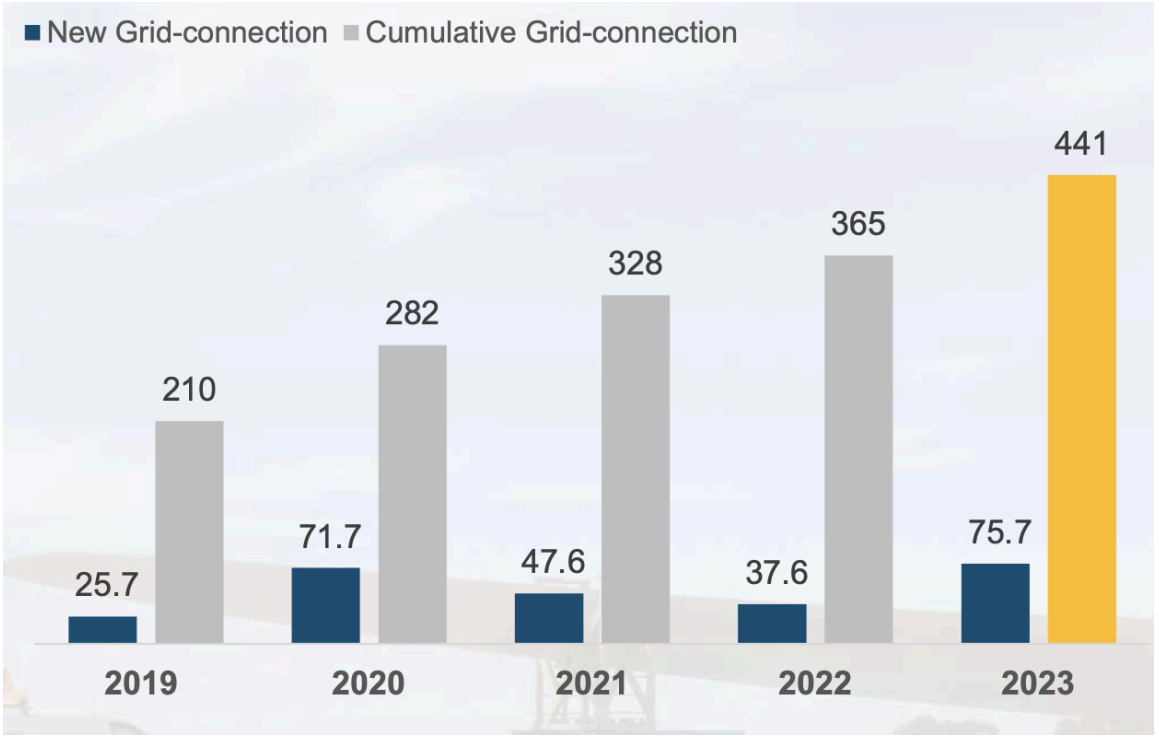
July 2023 saw Huadian New Energy Group has completed a 1GW solar project on top of a salt field, and is expected to generate 1.5TWh of clean electricity per annum.[123]

[120] China Daily. 'Agrivoltaics' lights up rural revitalization efforts. 4th January, 2024
[121] China Daily. 'Agrivoltaics' lights up rural revitalization efforts. 4th January, 2024
[122] Astronergy. Taihan 550MW fishing-solar hybrid project, 18 August, 2023
[123] PV Magazine. Huadian Energy completes 1GW solar farms on salt fields in China, 10 July, 2023

4.3 Wind

China is by far the world leader in both annual and cumulative onshore and offshore wind installations, adding a record 76GW in 2023, a 65% global share, ten times the installations in the US, #2 globally. China is also world leading in new turbine RD&D, installing in 2023 the world's largest turbine at 18MW. This starkly highlights the scale and momentum of China in the race to build zero emissions industries of the future. CEF forecasts 80GW p.a. of installs out to 2040, inclusive of offshore wind, such that wind contributes 18% of total 2030 and 26% of 2040 generation, up from 9% in 2023.

Figure 4.3.1 Global Windfarm Installation Rates (GW)

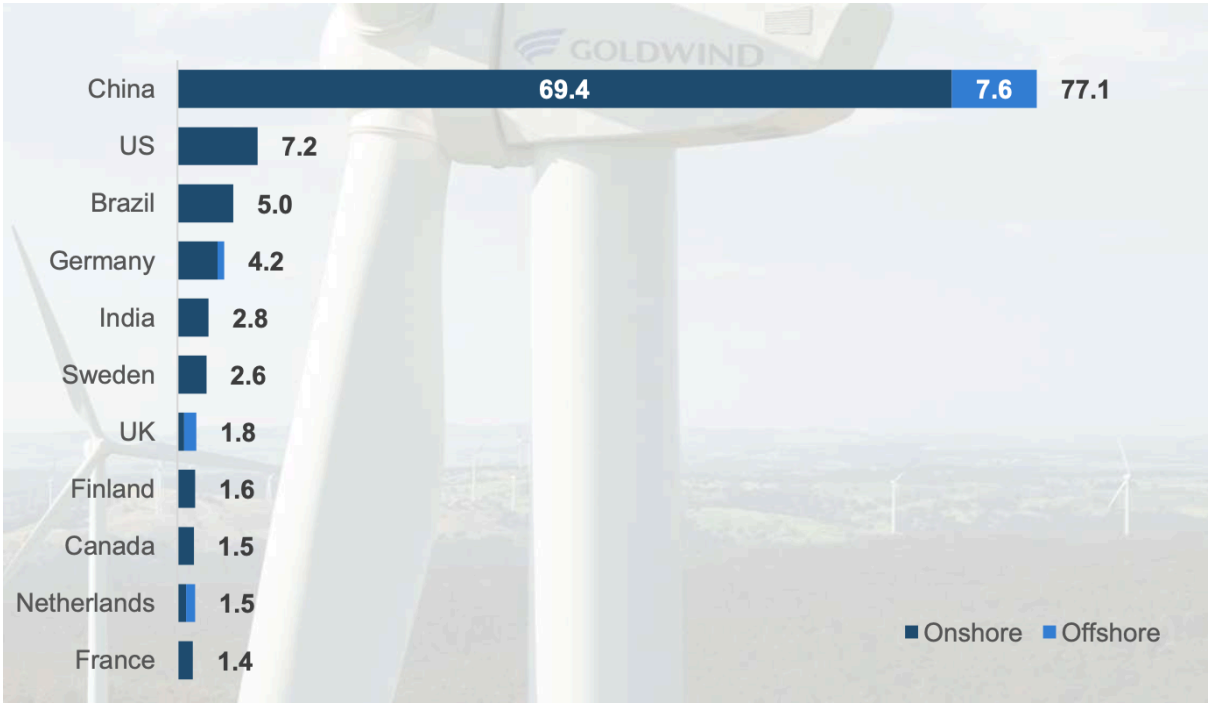


Source: BNEF, Goldwind CY2023 Investor Presentation[124]

China installed 76GW of wind during CY2023, a 102% y-o-y increase. By the end of CY2023, China installed wind capacity of 441GW - Figure 4.3.1, a 20.8% y-o-y increase. Wind generation reached 809TWh during CY2023, representing 9% of the total power generation, a 18% y-o-y increase.[125]

[124] Goldwind. CY2023 Results Investor Presentation. 2nd April, 2024
[125] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024

Figure 4.3.2 Global Windfarm Installation Rates (GW)

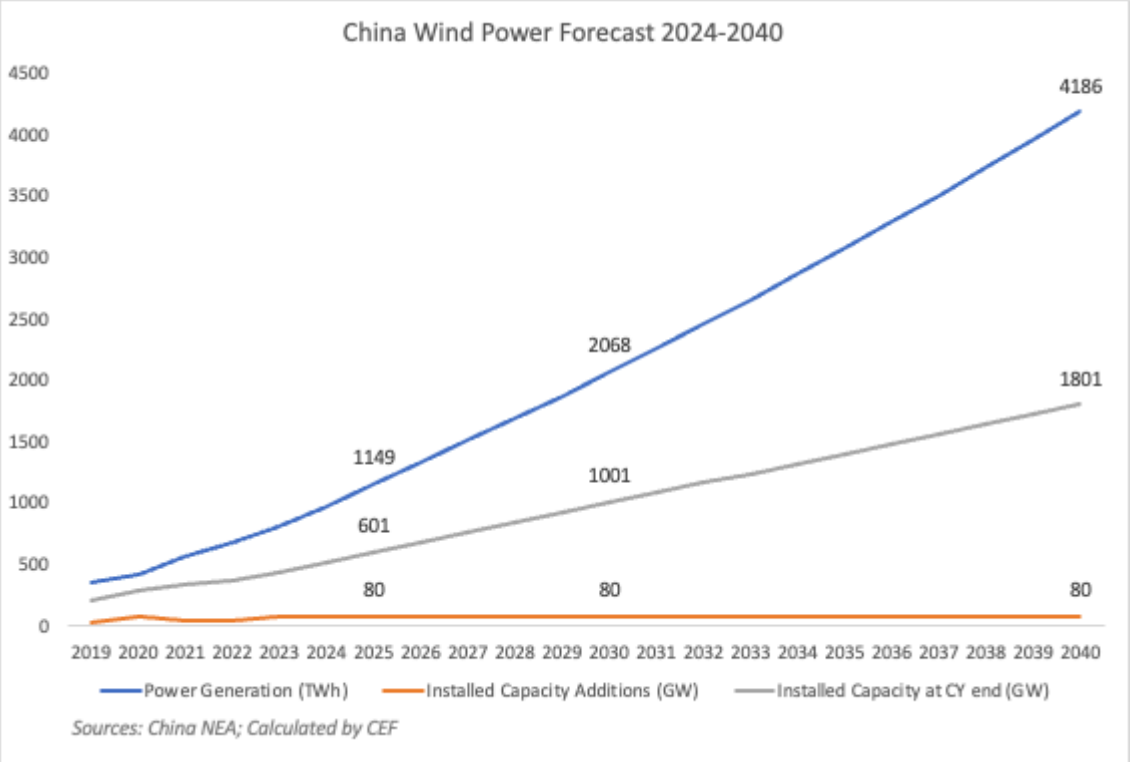


Source: BNEF, Goldwind CY2023 Investor Presentation

China's booming wind market accounted for 65% of the 118GW of global new build in 2023 (+36% y-o-y), and far exceeded investment in the second largest market, the United States (7GW). Brazil took the third place in the ranking, its installed capacity increased to 5GW in 2023, according to BNEF - Figure 4.3.2. China now hosts the top two wind turbine firms in the world - Goldwind and Envision Energy with 2023 installs of 16GW and 15GW respectively (pushing Vestas to #3 globally), and six of the top 10 firms.[126]

[126] Recharge. Two Chinese turbine giants edge out Vestas as world adds record new wind power, 27 March 2024

Figure 4.3.3 China Wind Power Forecast till 2040



Source: China NEA; Calculated by CEF

The CEC forecasts that by the end of CY2024, the installed wind capacity will reach 530GW, implying CY2024 installs of 89GW, compared to the average of 50GW p.a. added over the previous 5 years.[127]

As shown in Figure 4.3.3, CEF forecasts that China will add an additional 80GW of wind capacity per annum from 2024 to 2040. By the end of CY2030, China will have 1,001GW of installed wind capacity nationwide; wind will generate electricity of 2,068TWh during CY2030, contributing a 12% share of total generation. By the end of CY2040, China will have installed wind capacity of 1,801GW, and electricity generated from wind power will reach 4,186TWh (a 26% share).

China is also world leading in new turbine RD&D, installing 2023 the world's largest turbine at 18MW. Woodmac reports that Chinese turbine manufacturers also lead in product design and innovation. The last four years have seen 426 new Chinese turbine models released, versus just 29 new turbines outside China.This scale and technology leadership means the cost of wind farm development is world leading, both relative to other nations wind development, but also relative to high emissions fossil fuel alternatives in China, with double digit cost reductions witnessed over 2023 alone.[128]

[127] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024

[128] Reuters. Explainer: China's dominance in wind turbine manufacturing, 10 April 2024

4.3.1 Onshore Wind

Like in all zero emissions industries of the future, China is now the world leader in installations of onshore wind, adding a record 69GW in CY2023.[129]

By the end of CY2023, China nationally installed onshore wind power of 400GW and 37.3GW of offshore wind.[130]

Figure 4.3.1.1 China's Global Cost Advantage in Wind (US$/kWh, US$/kW)

Source: Goldwind CY2023 Investor Presentation, China Renewable Monitoring Platform

The levelised cost of electricity (LCOE) of China's onshore wind dropped to a very competitive level of US$0.027/kWh in 2022, reducing 53% in the past 5 years, as presented by Goldwind – Figure 4.3.1.1. China's average construction cost of onshore wind in 2022 lowered to US$1,103/kW, falling 15% relative to 2018. The global average construction cost for onshore wind in 2022 was US$1,274/kW.

A March 2024 report that the capital installation cost of onshore wind in 2023 was RMB2.15-2.70/kWh, 30-40% cheaper than 2022's lowest domestic price of RMB3.90/kWh, underpinned by a significantly lower capital installation cost in the US, wind has joined solar as the lowest cost source of new capacity in China, by far, even absent a price on carbon emissions.[131] Goldwind reports a more modest 15% capital cost reduction to RMB1,555/W over the 2023 calendar year for the industry overall. Either Figure shows the ongoing financial improvements in wind in China as a result of massive scaling up of capacity and turbine size, as well as technology improvements in utilisation rates.

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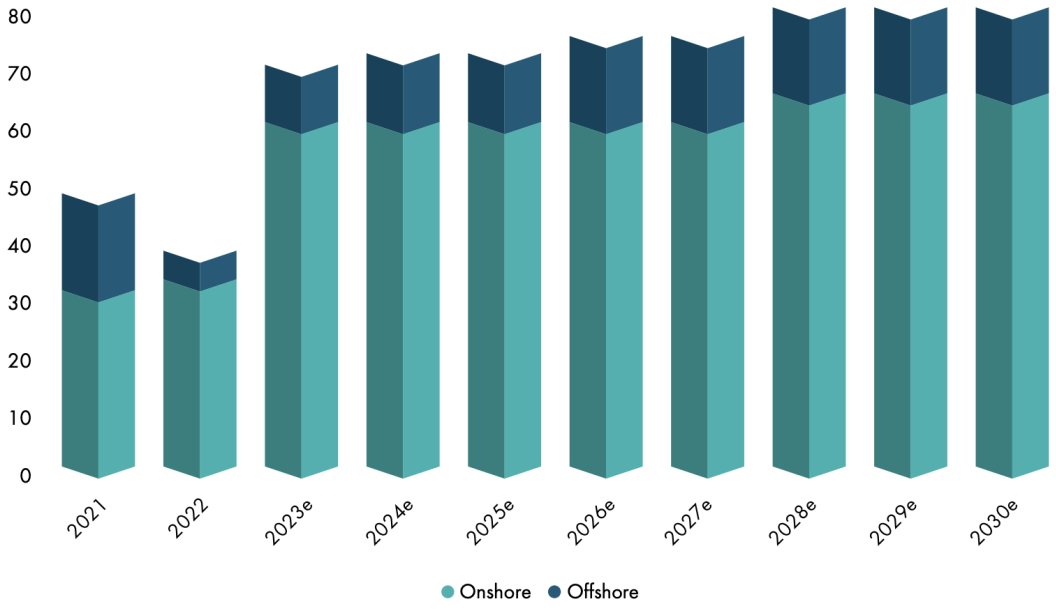
[129] 能源杂志. 2023年我国能源电力发展综述. 6th March, 2024
[130] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024
[131] SCMP. 'Historic breakthrough': China's installed wind turbine cost drops to one-fifth of the US in green energy race, 28 March 2024

Goldwind reports that of its 13.8GW of wind turbine sales in CY2023, 99% were >4MW per turbine (and 45% were >6MW), where as in CY2019, this was the reverse, with just 3% >4MW per turbine capacity.

We do note that as the leading Chinese wind turbine manufacturer, Goldwind's gross profit margins of 17.1% in CY2023 were only marginally lower than the 17.7% delivered in CY2022, the return on equity of just 3.5% p.a. in CY2023 was well below 6.4% in CY2022, and well below the firm's cost of equity (closer to 10% pa). While this is a global issue, as evidenced by the poor financial returns of Siemens and GE Vernova, China does have clear policy clarity and regulatory support, and a scale of deployment the envy of any market in the world, suggesting excessively competitive tendering practices for market share purposes are rampant in China, as in most renewable energy sectors.

We note the April 2024 warnings by Envision Energy of brutal competition coming in the wind sector, as is already evident in the solar, battery and NEV sectors in China. As Goldwind has reported, profitability has already been deprioritised behind R&D and market growth. China needs to deploy many trillions of dollars of new investment in cleantech, so CEF would advocate for more strategic planning to avoid excessive overcapacity which in turn drives excessive price competition. Ongoing technology driven deflation is great, but not if it drives too many bankruptcies of otherwise viable businesses.[132]

Figure 4.3.1.2 China Wind Market Development (GW)

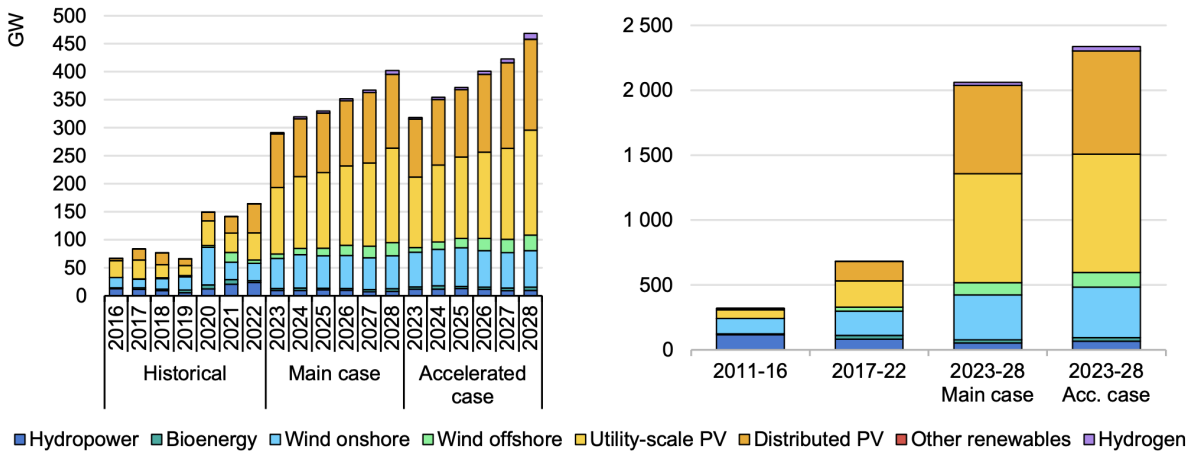


Source: Global Wind Energy Council (GWEC)[133]

The wind expansion estimation is also backed by the GWEC, who forecasts that China will add ~60GW of onshore wind per annum from 2024 to 2027, and 65GW per annum from 2028 to 2030- Figure 4.3.1.2.

[132] Recharge. Brutal price competition will kill off some Chinese turbine manufacturers, says Envision executive, 4 April 2024
[133] GWEC. Global Wind Report 2023.

Figure 4.3.1.3 China's Renewable Capacity Additions by Technology, Main and Accelerated Cases, 2011-2028



Source: IEA Renewable 2023 Analysis and Forecast to 2028, January 2024, page 28[134]

This aligns with the IEA who estimates that China will add ~60-65GW of onshore wind per annum from 2023 to 2028 under their main case scenario - Figure 4.3.1.3.

CEF forecasts that China will add 65GW of onshore wind per annum from 2024 to 2040, as well as 15GW p.a. of offshore wind (refer Section 4.3.2) - 80GW p.a. in aggregate. This is supported by the 86GW on public tenders across China in 2023, after 98GW of tenders in 2022.

China saw significant new policy support in 2023 for the deployment of green energy:

January 2023 the State Council Information Office released the white paper "China's Green Development in the New Era", proposing to promote green and low-carbon energy development and vigorously develop non-fossil energy.

April 2023 saw the NEA issue the "Guiding Opinions on Energy Work in 2023", proposing to further promote structural transformation and increase the proportion of non-fossil energy in total energy consumption.

June 2023 saw the NEA release the "Blue Book on the Development of New Power System", proposing the overall structure and key tasks of building the new power system, which includes strengthening the construction of the four major systems such as the power supply support system, the new energy development and utilization system, the large-scale layout and application system of energy storage, and the intelligent operation system of the power system, while enhancing the standards and specifications adapted to the new power system, core technologies and major equipment, and promoting the relevant policy and institutional mechanism innovation.

August 2023 saw the NDRC, the Ministry of Finance, and the NEA jointly issue the "Notice on Full Coverage of Renewable Energy Green Power Certificates to Promote Renewable Energy Electricity Consumption", proposing to issue green certificates for all the electricity

[134] IEA. Renewable 2023 Analysis and Forecasts to 2028. January 2024

produced by registered renewable energy power generation projects nationwide to achieve full coverage of green certificate issuance.

October 2023 saw the Ministry of Ecology and Environment issue the "Notice on Completing Greenhouse Gas Emission Reporting and Verification of Enterprises in Certain Key Industries from 2023 to 2025" to clarify that for key industries such as petrochemicals, chemicals, building materials, steel, non-ferrous metals, papermaking, and civil aviation, key enterprises with annual greenhouse gas emissions of >26,000tpa of CO2equivalent.

November 2023 saw the NDRC issue the "Opinions on Accelerating the Establishment of Product Carbon Footprint Management System", proposing that by 2025, about 50 key product carbon footprint accounting rules and standards will be introduced at the national level, a number of key industry carbon footprint background databases will be initially established, a national product carbon label certification system will be basically established, the application scenarios of carbon footprint accounting and labeling in the fields of production, consumption, trade, and finance will be significantly expanded, and the carbon footprint accounting rules, standards, and carbon labels of several key products will achieve international mutual recognition.

4.3.2 Offshore Wind

As shown in Figure 4.3.1.2, the GWEC estimates that China will add approximately 12GW of offshore wind per annum from 2024 to 2025, and 15GW per annum from 2026 to 2030.

As shown in Figure 4.3.1.3, the IEA estimates that China will add approximately 12GW of offshore wind per annum from 2023 to 2028 under their main case scenario.

Zhiquan Wu from State Power Investment Corporation (SPIC) said that China's offshore wind capacity could reach as high as 309GW[135] which is around 10 times more than China's current installed offshore wind capacity.

CEF forecasts that China will add 15GW of offshore wind per annum from 2024 to 2040, which means China will add a total of 255GW of offshore wind, which is entirely feasible based on the 309GW total offshore wind capacity upside proposed by SPIC. Offshore wind has a significantly higher per MW capital cost of deployment, but much larger scale, a materially higher utilisation factor, land constraints, proximity to demand centres, leveraging China's existing ship building capacities, excess steel manufacturing capacity plus low and declining interest rates in China all support the deployment in China,[136] as in Northern Europe.

China has world leading wind power technology. September 2023 saw the world's largest single-unit offshore wind power facility fully connected to the grid in Fujian. Operated by CTG, the facility has the generation power of 360GWh per annum. It consists of 11 wind turbine units, of which each wind turbine unit has 16MW capacity.[137]

China State Shipbuilding Corporation (CSSC) has developed the world's largest offshore wind turbine with a wind turbine capacity of 18MW, with a 260-metre rotor - as high as a 50 level building. Each single turbine can generate up to 75GWh of power per annum.[138]

Chinese industrial group Sany Renewable Energy has a new test facility to handle blades for 30MW wind turbines via a yet-to-be commercialised dual-axis structure. Sany told Recharge it does not have plans for a 30MW turbine, a rating even beyond the massive step-ups in capacity seen to-date. Sany also has said it aims to bring a 15MW onshore wind turbine model to market, again a massive step up from the 6MW turbines currently being deployed.[139]

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[135] 思客. 我国海上风电产业发展的思考. 26th February, 2024
[136] The Maritime Executive, Why is Offshore Wind Soaring in China When it's Struggling in the West? 24 November 2023
[137] CGTN. World's largest offshore wind power facility starts operating in Fujian. 19th September, 2023
[138] Electrek. A colossal 18 MW wind turbine is about to debut in China. 7th January, 2024
[139] Recharge,China test for 30MW wind turbines as green power 'arms race' goes on, 29 February 2024

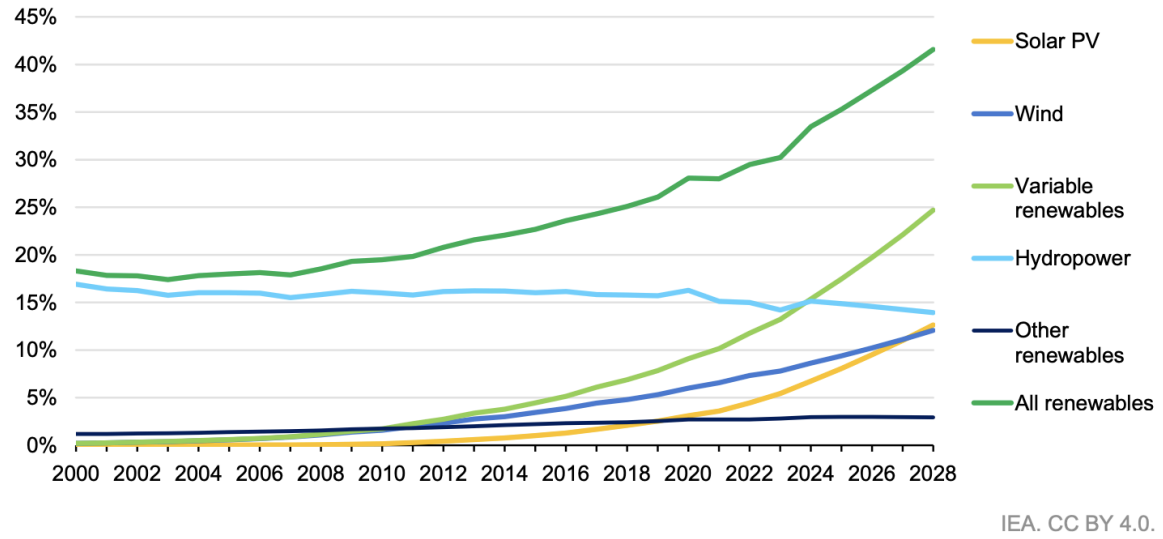
4.4 Hydro

Like in all zero emissions industries of the future, China has by far the largest fleet of hydroelectricity capacity, reaching 422GW of installed capacity by February 2024, four times the capacity installed in the US, the world's second largest hydro market. CEF expects China's new capacity installs of hydro will slow significantly to average just 2GW p.a. over the coming decade, down from the 13GW p.a. added in the last five years, given the physical limits have nearly been reached.

China's hydropower was hit severely by drought across the country in CY2023. China added 8GW of hydropower to the grid during CY2023, representing 2% of the newly installed capacity, a 66% y-o-y decrease. By the end of CY2023, China's total installed hydropower capacity reached 422GW, a 1.9% y-o-y increase. During CY2023 hydropower generated electricity of 1,141TWh, a 5.1% y-o-y decrease.[140] IEA points out that the decline in hydropower generation was a key factor in the increased use of coal-fired power generation while the electricity demand was rising in 2023.[141]

According to the CEC, in CY2023, investment in hydropower grew 13.7%. Total installed pump-hydro reached 50.9GW.[142]

Figure 4.4.1 Electricity Generation by Technology, 2000-2028



Notes: Electricity generation from wind and solar PV indicate potential generation including current curtailment rates. However, it does not project future curtailment of wind and solar PV, which may be significant in a few countries by 2028. The Curtailment section below discusses some of these recent trends.

Source: IEA Renewable 2023 Analysis and Forecast to 2028, January 2024, page 15[143]

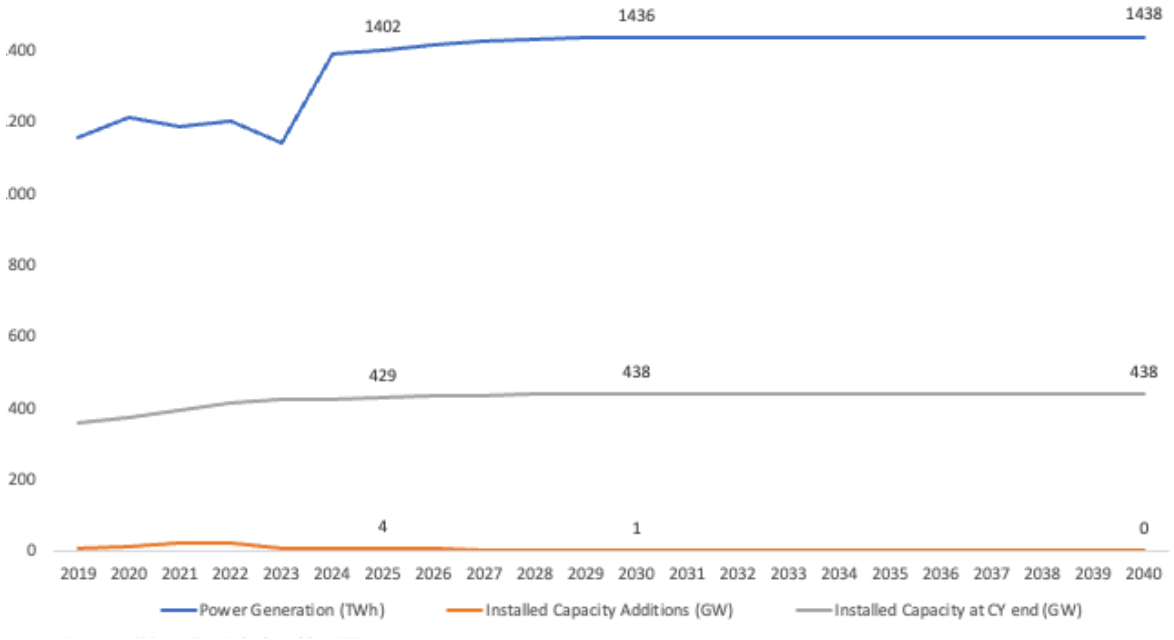
Hydropower has been the most traditional renewable energy source globally, however recent droughts in China highlighted the volatility in hydropower generation. The IEA forecasts that

[140] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024
[141] IEA. Electricity 2024 Analysis and Forecast to 2026. January, 2024
[142] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024
[143] IEA. Renewables 2023 Analysis and forecasts to 2028. January, 2024

in 2024, VRE will generate more electricity than hydropower. In 2028, hydropower will still be the number one renewable electricity source - Figure 4.4.1.

In China, CEF assumes hydropower addition starts will decelerate during 2023-2028, given the geographic capacity limitations to China's river systems.[144] Under the assumption that the weather conditions remain normal and a recovery in hydropower generation, IEA estimates that China's total renewable generation will increase by 21% in 2024.[145] However, April 2024 reports again warning of droughts in southern China highlight the system risks of over-reliance on hydroelectricity in these times of extreme weather events getting more extreme, and more frequent.[146]

Figure 4.4.2 China Hydropower Forecast till 2040



Source: China NEA; Calculated by CEF

CEF forecasts that China will add an additional 2.4GW of hydropower capacity per annum from 2024 to 2030, and no more hydropower addition after 2030, as shown in Figure 4.4.2. By the end of CY2030, China will have 438GW of installed hydropower capacity nationwide; hydropower will generate electricity of 1,436TWh during CY2030. By the end of CY2040, China will have 438GW of installed hydropower capacity, and electricity generated from hydropower will reach 1,438TWh.

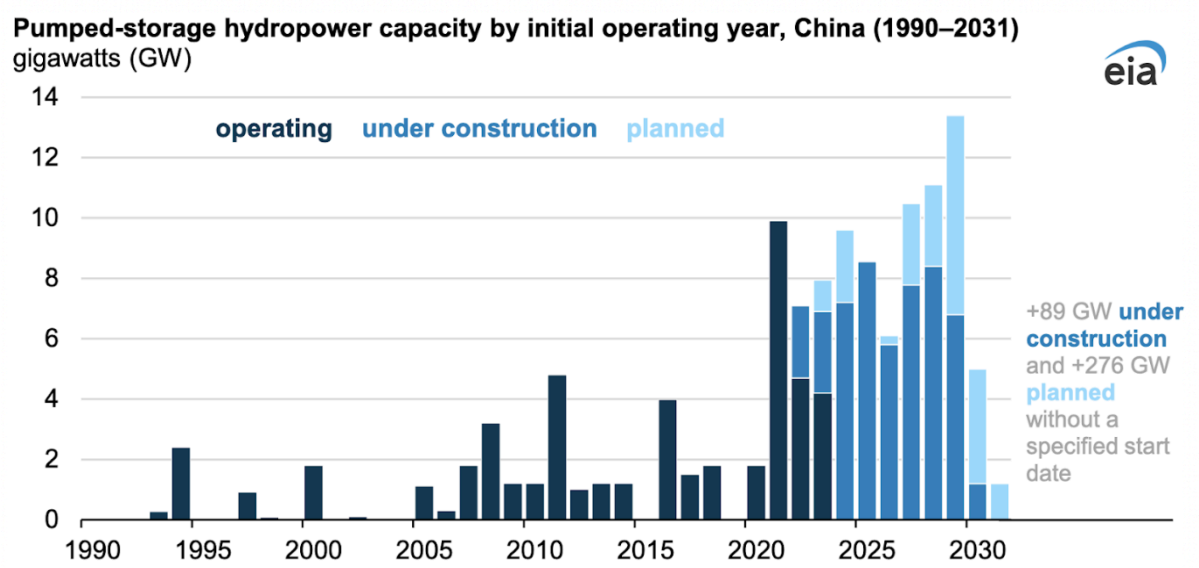
[144] IEA. Renewables 2023 Analysis and forecasts to 2028. January, 2024
[145] IEA. Electricity 2024 Analysis and Forecast to 2026. January, 2024
[146] SCMP. China wary of ripple effects as power-producer provinces combat drought, 25 March 2024

4.4.1 Pumped Hydro

In distinct contrast to hydro for generation of electricity, closed loop PHS is surging in China, with the current 8-10GW p.a. of new additions in the last few years expected to accelerate, consistent with the national target of 120GW by 2030. Along with BESS, grid modernisation, DRM and V2G, PHS will play an increasingly important role in grid reliability and balancing as ever more VRE is added to the national system.

By the end of 2023, China has a cumulative installed 50.9GW of pumped-hydro storage (PHS) capacity.[147] This puts China well on track with the NEA's 2021 plan that prioritised developing pumped storage projects to help China achieve its carbon neutrality goals with a target to have installed PHS capacity of 62GW by 2025 and 120GW by 2030.[148]

Figure 4.4.1.1 China's new pumped hydro storage capacity expansions



Sources: The U.S. Energy Information Administration (EIA), Global Energy Monitor[149]

As shown in Figure 4.4.1.1, the US EIA reports that as of May 2023, China had 89GW of pumped hydro storage under construction and 276GW more planned without a specific start date.[150] Interesting to see the EIA promoting China's massive world leadership in this area, even as the US fails to actually invest in PHS. Long duration PHS is a critically important complement[151] to ever-cheaper BESS (refer Section 4.7).

With the massive scaling up of wind and solar power in China and elsewhere, pumped-hydro storage is a good tool for a more balanced power system. In 2021, China's NEA released a

[147] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024
[148] SCMP. China breaks ground on major project that could boost renewable energy production in Gobi Desert, 10 August 2023
[149] EIA. New PHS in China is helping to integrate growing wind and solar power. 9th August, 2023
[150] EIA. New pumped-storage capacity in China is helping to integrate growing wind and solar power. 9th August, 2023
[151] National Renewable Energy Laboratory. How Mountains Could Store Mountains of Clean Energy. 5 April 2024

plan on ‘medium and long-term development plan for pumped storage (2021-2035)’, setting targets for pumped-hydro capacity to reach 62GW by 2025 and 120GW by 2030.[152]

The State Grid Corporation of China operates a 3.6GW Fengning Pumped Storage Power Station. The facility has 12 reversible pump generating sets, each of them has the capacity of 300MW, and a power generation capacity from storage of 6.6TWh.[153]

[152] 国家能源局. 抽水蓄能中长期发展规划（2021-2035 年). August, 2021
[153] PV Magazine. State Grid of China switches on world’s largest PHS station. 4th January, 2022

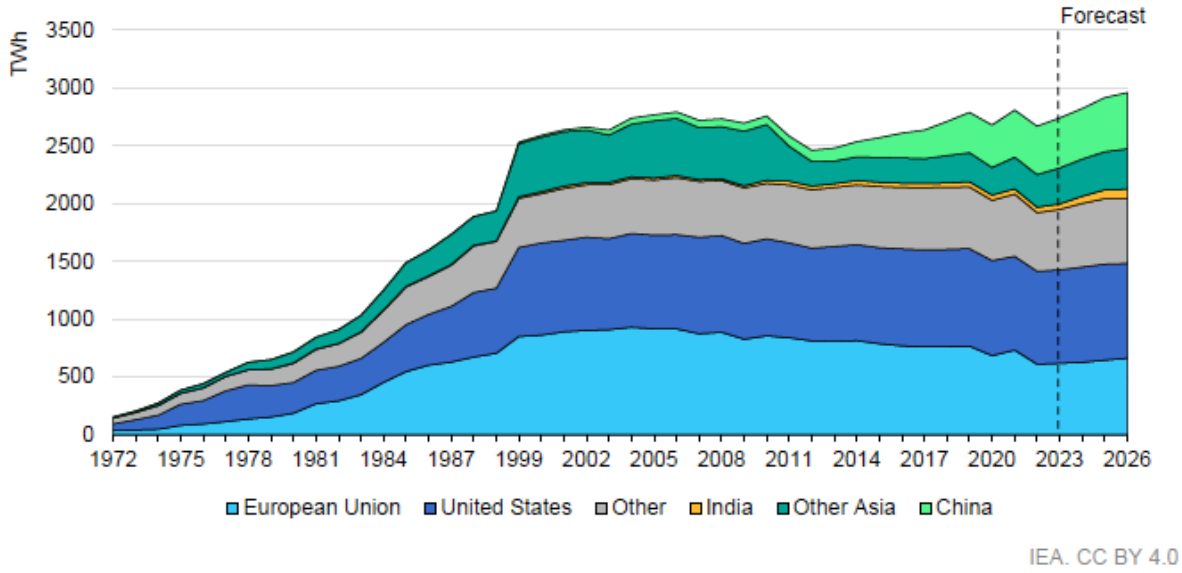
4.5 Nuclear

China led the world in deployment of new nuclear capacity over the last decade. The deployment of the world's first fourth generation pilot 211MW nuclear reactor in China in December 2023, and the prioritisation of deploying new domestic zero emissions capacity at speed and scale, means we expect China to significantly ramp up nuclear deployments. CEF forecasts 108GW of nuclear capacity by 2040, double the current 57GW. But even with an average utilisation rate of 85%, this would see nuclear contribute just 5% of total 2040 generation, a share flat on that seen in 2023.

China added 1.4GW nuclear power during CY2023, a 77% y-o-y decrease. By the end of CY2023, China's total installed nuclear power capacity was 57GW, a 2.5% y-o-y increase. Nuclear power generated electricity of 433TWh during CY2023, a 3.7% y-o-y decrease. The capacity utilisation of China's nuclear fleet CY2023 was 88%.[154]

The China Nuclear Energy Association (CNEA) says that nuclear power generation is expected to account for 10% of the country's total power generation by 2035, and 18% by 2060, reaching 400GW of capacity.[155]

Figure 4.5.1 Nuclear Power Generation by Region, 1972-2026



Note: The 2026 forecast is based on projects currently under construction and expected to be operational by the end of the period.

Source: IEA Electricity 2024 Analysis and Forecast to 2026, January, 2024, page 44[156]

According to the IEA, China and Russia lead the world in nuclear power additions, and China contributed the most to the nuclear capacity that came online since 2010 - Figure 4.5.1.[157] The IEA expects to see an additional 29GW of global nuclear capacity to come

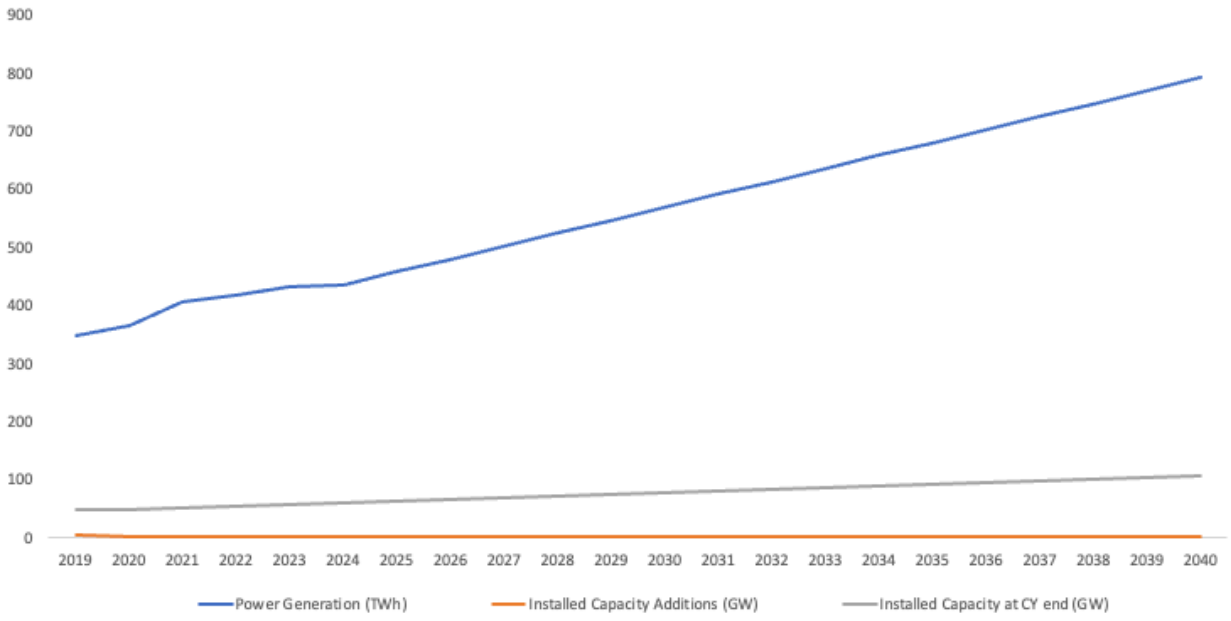
[154] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30 January 2024
[155] China Daily. China's nuclear power to generate 10% of total electricity by 2035 26 September 2023
[156] IEA. Electricity 2024 Analysis and Forecast to 2026. January, 2024
[157] IEA. Nuclear Power and Secure Energy Transitions From today's challenges to tomorrow's clean energy systems. June, 2022

online during 2024 to 2026, of which more than half of this additional capacity will come from China and India.[158]

Nuclear power will play an increasingly important role in China's process of greening the national electricity grid. The IEA forecasts that China's nuclear generation will reach 642-661TWh by 2030.[159] And China has a pipeline of nuclear power generation projects to add on top of the existing capacity. According to the World Nuclear Association (WNA), China currently has 54GW of operable nuclear power reactors, with 28GW of nuclear power reactors under construction, another 45GW in planning and 98GW proposed as of February 2024, and more proposals for building new nuclear power reactors are waiting to be approved.[160]

December 2023 saw the world's first 4th generation nuclear power plant go into commercial operation in China[161], operated by Huaneng Shandong Shidao Bay Nuclear Power - a subsidiary of China Huaneng Group. The facility has a gross capacity of 211MW.[162] The 4th generation reactors also are considered safer and more efficient than previous models.[163]

Figure 4.5.3 China Nuclear Forecast till 2040



Source: China NEA; Calculated by CEF

FIgure 4.5.3 shows that CEF forecasts China will add an additional 3GW of nuclear power capacity per annum from 2024 to 2040. By the end of CY2030, China will have 78GW of installed nuclear power capacity. Nuclear power is expected to generate electricity of 569TWh during CY2030. By the end of CY2040, we forecast that China will have 108GW of installed nuclear capacity, and nuclear power will generate electricity of 792TWh during CY2040, a 5% share of our forecast of China's total generation in that year.

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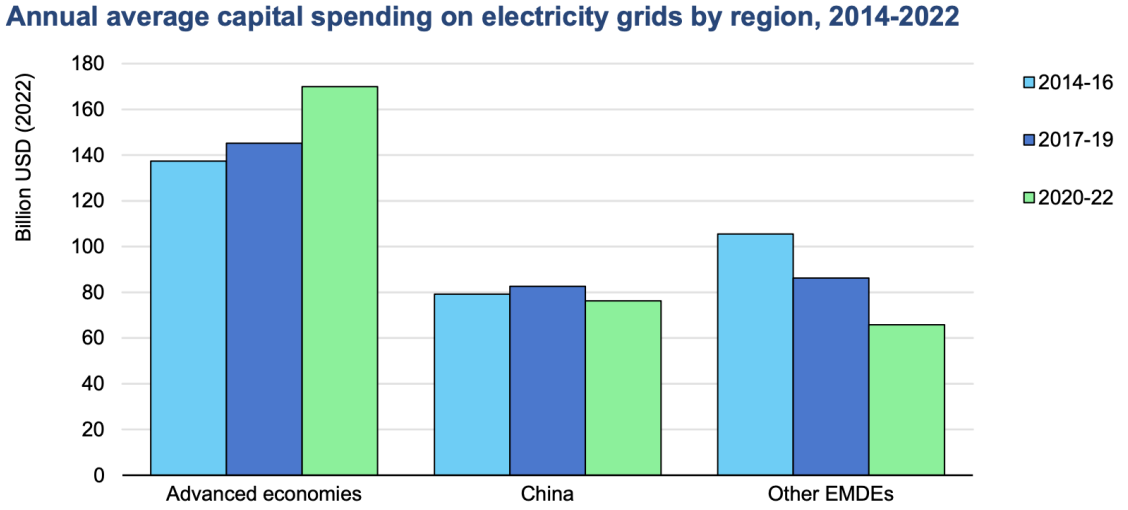
[158] IEA. Electricity 2024 Analysis and Forecast to 2026. January, 2024
[159] IEA. Electricity 2024 Analysis and Forecast to 2026. January, 2024
[160] WNA. Nuclear Power in China. February, 2024
[161] CGTN. How the world's first fourth-generation nuclear power plant works. 6th January, 2024.
[162] WNA. Shidao Bay 1, China.
[163] Oil Price. China Launches World's First Fourth-Generation Nuclear Reactor. 10th December, 2023.

4.6 A Smart Grid Transmission System

The energy system transformation is being critically enabled by a smart national grid transmission system. China's grid system has by far the highest deployment of smart meters (over 400 million), and is increasingly incorporating world leading distributed energy resources and is managing the inevitable need for flexible demand and supply to accommodate low cost but intermittent renewables. China leads the world in hybrid power developments, flexible new coal power plants, as well as BESS and PHS, and V2G is soon to be deployed nationally. All of this has been supported by some US$80bn annual investment in grid capacity expansion and modernisation over the last decade. CEF expects this ongoing investment to accelerate through to 2040 as China continues electrification of everything, including transport.

Wind and solar curtailment has been an ongoing road bump for China State Grid and Southern Grid to tackle.

Figure 4.6.1 Annual Average Capex on Electricity Grids by Region, 2014-2022



Source: IEA Electricity Grids and Secure Energy Transitions, October 2023, page 20

The IEA reports that China has been investing US$80bn p.a. for the last decade in building out and modernising its electricity grid transmission and distribution, individually well in excess of any other nation - Figure 4.6.1, giving China a far more modern and younger average grid system than any other major developed nation. China has the highest proportion of transmission lines under 10 years old, with more than 710,000km built in the past decade.

China State Grid alone has a Rmb500bn (US$70bn) grid capex target for 2024, showing this grid modernisation and expansion continues apace.[164] Wasion Group, the leading independent smart meter manufacturer in China with a 20% national market share, reports it invested 9.4% of annual revenues in R&D in 2023, a figure rarely matched in western energy competitors. Wasion alone has a total of 1,941 patents for new products and energy saving

[164] Wasion Group. 2023 Annual Report

services plus 1,707 software copyrights, adding 230 patents for new products and energy saving services and another 94 software copyrights in 2023 alone.[165]

New policy developments are a feature in support of the ongoing grid modernisation investments in China.[166]

June 2023 saw the NEA issue the “Blue Book on the Development of New Power Systems”, implementing the "three-step" development strategy to promote the construction of new power systems. In the accelerated transformation period from this year to 2030, renewable electricity as the main power source will be key.

June 2023 saw State Grid issue the "Green Procurement Guidelines" to vigorously promote environmental protection, resource conservation, safety and health, recycling and low-carbon practices, and recovery and promotion and to establish a system for recycling.

September 2023 saw State Grid release the "New Power System and Emerging Energy System", highlighting that the form of the grid will evolve towards a diversified, bidirectional, and hierarchical network with hybrid layers while its operation will shift towards source-network-load- storage multi-source, collaborative interaction.

November 2023 saw the NEA release the "Notice on Promoting New Energy Storage Integration and Dispatching and Allocation (Consultation Draft)", which seeks to promote the allocation of new energy storage through market-based approaches and proposes a "multi-purpose, time-sharing multiplexing" business model.

November 2023 saw the release of the “State Grid Corporation of China Report on Promoting the Action for Green-oriented Transition of Energy”, showcasing innovative measures, practices and cases, and achievements and performance in five areas: "Broad Area Energy Allocation", "Clean Energy Production", "Electrification of Energy Consumption", "Integration of Energy Innovation", and "Digitalization of Energy Business Formats".

[165] Wasion Group. CY2023 results briefing, 15 March 2024
[166] Wasion Group,. CY2023 results briefing, 15 March 2024

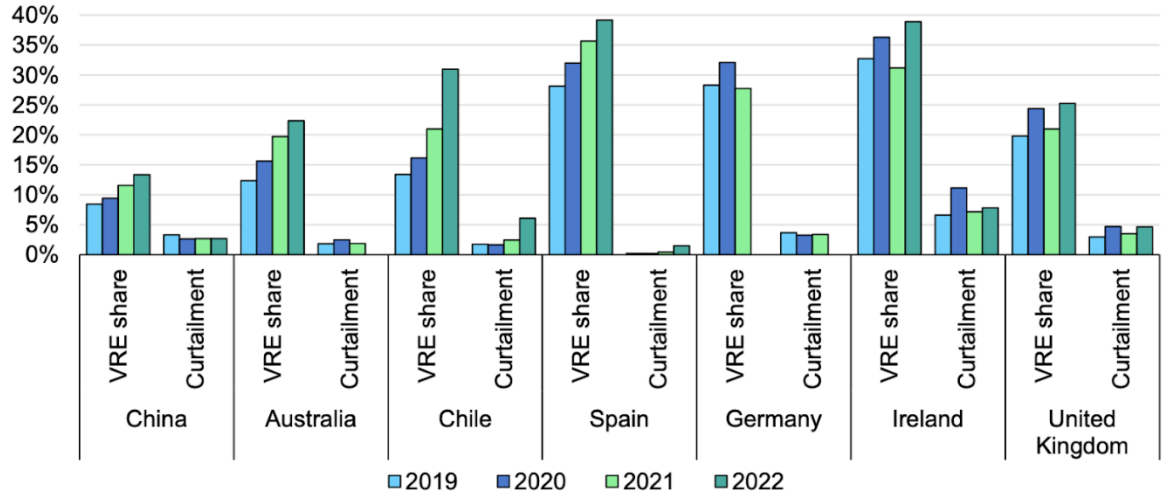
4.6.1 Grid Curtailment of Renewables

Historically, China built its wind and solar farms in the northwestern region, such as Shaanxi, Gansu, and Ningxia with abundant natural renewable resources. With strong GDP growth and climbing electricity demand elsewhere in China, power generated by wind and solar from afar was curtailed due to the lack of grid connection. Wind curtailment rate peaked in 2016 reaching 50TWh.[167]

China's massive deployment of solar and wind power has been a world-record in 2023. With 76GW of wind and 217GW of solar capacity addition in 2023 alone, representing 102% and 148% y-o-y increase respectively.[168]

Building such a significant amount of new capacity a long way from the central demand precincts in East China on top of keeping up with strong ongoing electricity demand growth in the national grid has led to challenges in higher wind and solar curtailment.

Figure 4.6.1.1: Annual technical curtailment of VRE in selected countries, 2022

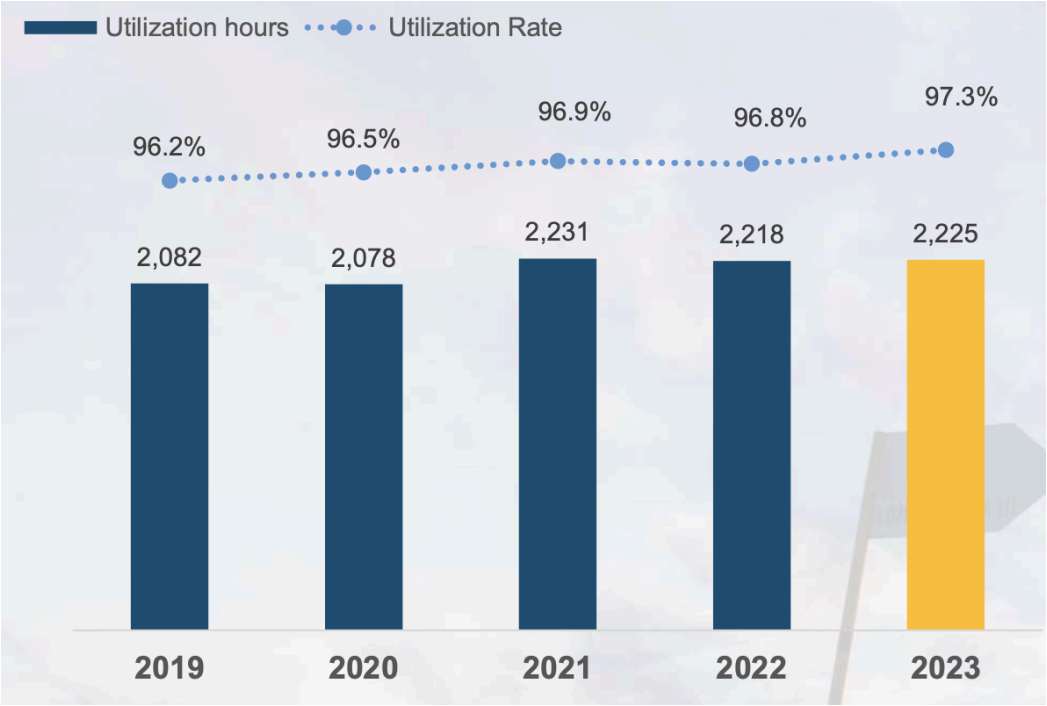


Source: IEA Electricity Grids and Secure Energy Transitions, October 2023, page 48

China lowered its curtailment rate from 20% in 2016 to 2-3% in 2022 - Figure 4.6.1.1, however concerns from a manager at China's State Grid indicate the solar and wind installation boom makes it harder to sustain or lower the curtailment rates.[169]

[167] 中国电力网. 可再生能源电量消纳,到底该由谁负责? 25th March, 2024
[168] Climate Energy Finance. MONTHLY CHINA ENERGY UPDATE | 2023 China Electricity Mix Yearly Review | Massive Decarbonisation Progress is Key Economic Stimulus. 30th January, 2024
[169] The Economic Times. Why is China increasing restrictions on renewable power plants? 6th February, 2024

Figure 4.6.1.2 Goldwind's Utilisation (hours) & Utilisation Rate (%)



Source: Goldwind CY2023 Investor Presentation

Goldwind reports its wind utilisation rate in CY2023 was a record high 97.3%, up from 96.8% in CY2022 - Figure 4.6.1.2, flagging the curtailment issues of a decade ago have been largely resolved with the ongoing massive investment in grid modernisation and expansion.

To utilise the excessive power generation in the northwest region, better grid connectivity to send the power through transmission lines to China's east coast is essential. As well as more distributed energy to ease the pressure on China's transmission lines.

Moreover, the volatility of wind and solar energy resources is also impacted by weather. When it's windy and sunny, wind and solar power generation goes up, and vice versa. Under this context, having BESS stored next to the wind and solar farms can store excess power generated during good weather days.

Another way of resolving the curtailment is to build more hybrid projects. By far the largest of these to-date is the multi-phase 100GW hybrid hydro-solar Kela project proposed by the State Development & Investment Corp. Ltd (SDIC). This project phase 1 of 1GW[170] of solar capacity and 3GW[171] hydropower capacity is now online.

A second example is the 16GW hybrid project integrating wind, solar, energy storage and coal-fired power generation by China Three Gorges (CTG) is currently under construction. The project will have 8GW of solar power capacity, 4GW of wind power, 4GW of coal-fired power, and additional energy storage once finished.[172]

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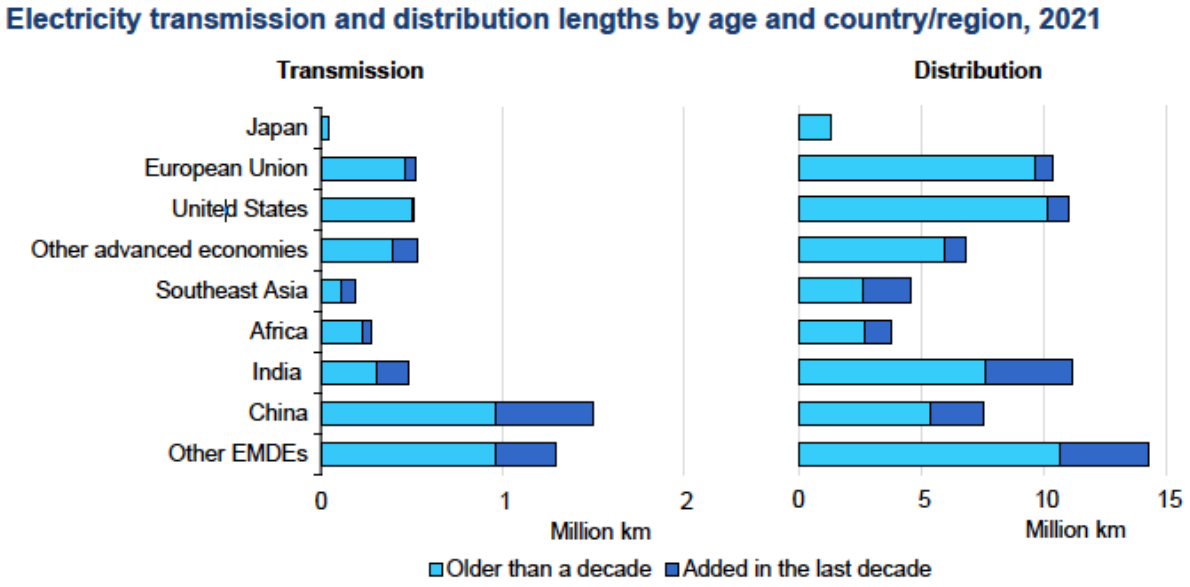
[170] SDIC. Yalong hydro drives development - new model of integrated development of Kela photovoltaic power station. 7 August, 2023
[171] Power. First phase of 100-GW China hydro/solar project enters service. 26 June, 2023
[172] 三峡能源. 库布其｜全球最大规模"沙戈荒"风电光伏基地项目开工纪实. 4 January, 2023

4.6.2 Grid Firming

Figure 4.6.2.1 Electricity Transmission and Distribution Lengths by Age and Country/Region, 2021



Source: IEA Electricity Grids and Secure Energy Transitions, October 2023, page 17

The IEA reports that China represents more than one third of the world's transmission lines expansion in the past 10 years. - Figure 4.6.2.1[173]

According to the CEC, during CY2023, investment in power grids of 100kV and below accounted for 55% of the total investment in power grid projects. 38,100 kilometres of transmission lines of 220kV and above were added. A total of 850GWh of cross-regional power transmission was completed, a 9.7% y-o-y increase.[174]

With the rapid expansion of solar and wind power across the country, the development of grid connectivity and stability become more important than ever to ensure energy security in China.

China is currently facing challenges in grid bottlenecks. Some installed renewable energy capacity is not being connected to the grid as a result of lack of grid facilities. And some renewable generated power is facing curtailment due to the limit of how much electricity can be absorbed by the grid.[175]

Liu Zhenya, former chairman of the State Grid Corp. of China advocates the country to build denser transmission network to connect the northwest - where has rich coal and renewable power resources, and the southwest - where is highly relying on hydropower and suffered from power shortage due to droughts across the country.[176]

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[173] IEA. Electricity Grids and Secure Energy Transitions. October 2023
[174] 中国电力企业联合会. 中电联发布《2023-2024年度全国电力供需形势分析预测报告》. 30th January, 2024
[175] ISS. Grid Bottlenecks and the Clean Energy Transition: Lessons Learned from China. 19th February, 2024
[176] Bloomberg. China Grid Giants Seek Solutions for a System Flooded With Solar. 27th March, 2024

March 2024 saw the State Grid start construction of a 1,069 km UHV transmission line project, which costs RMB28bn (US$4bn). This transmission line runs from north of Shaanxi to Hefei City, Anhui.[177] This is one of a growing number of new grid transmission lines, with June 2023 seeing the commencement of the 1,634km ±800 kV 8GW Ningxia-Hunan transmission project by State Grid Corporation of China with a capex cost estimated at RMB28bn (US$4bn).[178]

The Changji-Guquan ultra-high-voltage direct current (UHVDC) transmission line in China is the world's first transmission line operating at 1,100kV voltage. Owned and operated by State Grid Corporation of China, this project is also the world's longest transmission distance, traverses for a total 3,324km and is capable of transmitting up to 12GW of electricity. Construction on the US$5.9bn project commenced in 2016 and was completed by December 2018, just three years later.[179]

China's Virtual Power Plants (VPPs) are experiencing significant growth, driven by the imperative to address challenges posed by the integration of renewable energy sources into the grid and to advance China's decarbonization objectives. VPPs, which aggregate small energy-generating or storage devices like rooftop solar panels and batteries, offer a solution to the intermittency of renewable sources by providing controllable loads and distributed energy storage. The development of VPPs aligns with China's commitment to green energy, as highlighted by the government's policy support and investment forecasts indicating an estimated RMB80bn (US$11bn) investment in VPPs by 2025.[180] Moreover, the outlined development path indicates a promising future role for VPPs in energy trading markets and the incorporation of a wider range of power generation and storage resources, including hydrogen, demonstrating their potential to contribute to a more flexible and sustainable energy landscape.

China's large policy-driven support for solar and wind industry has led to overcapacity and oversupply in wind and solar manufacturing, causing manufacturing glut globally and driving prices for solar and wind components down significantly. Now it's time for the Chinese government to maintain the momentum on zero emissions capacity expansion, leveraging wind and solar as the least cost solutions that can continue to be deployed in smart hybrid configurations at massive scale to enhance China's energy independence and showcase its zero emissions global leadership.

[177] 国家电网有限公司.【人民日报】“陕电入皖”特高压工程开工 投产后每年可向安徽输电超360亿千瓦时. 17th March, 2024
[178] Xinhua,China starts construction of cross-regional power transmission project, 12 June 2023
[179] NS Energy, Changji-Guquan UHVDC Transmission Project,
[180] China Daily. Virtual power plants poised for big, green growth. 30th November, 2024

4.7 BESS

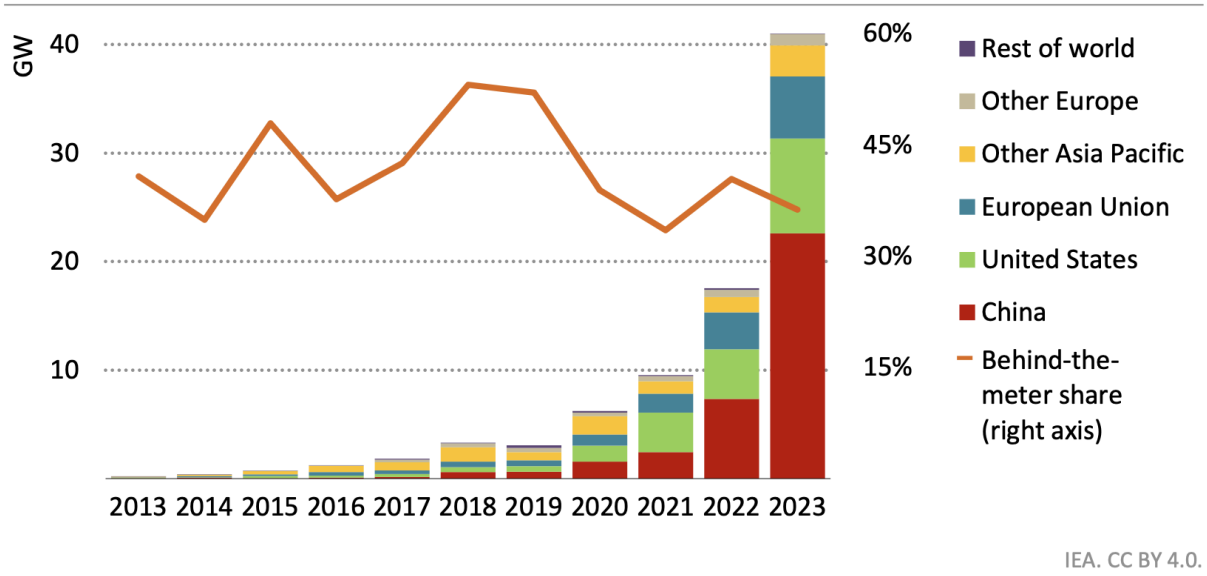
With China's world leading battery manufacturing capacity, and ongoing world leadership in new battery technologies, BESS are set to play a massively scaled up role in stabilising and firming electricity grids globally as the penetration of low cost, zero emissions but intermittent renewable energy grows rapidly. China already leads the world in BESS deployments, accounting for a 50% global share in 2023. CEF expects China's BESS investments to accelerate at far more than 30% CAGR over the coming decade.

Incorporating massive VRE capacity into the Chinese national grid will remain a major engineering challenge. Leveraging the massive economies of scale, rapid cost reductions and R&D breakthroughs underpinning China's world leading NEV development, battery energy storage systems (BESS) are being rapidly deployed across China to manage the intermittency of renewables, and the vast scale and geographic dispersion of the national electricity market.

Qian Chaoyang, President of China Southern Power Grid in March 2024 estimated that China quadrupled its BESS capacity in 2023. Combined with accelerated inter-province grid connectivity and PHS, grid reliability will be sustained.[181]

The NEA reports China's cumulative installed energy storage capacity reached 31.4GW by the end of 2023, with 22GW/46GWh installed in the year.[182] The IEA reports global BESS installs doubled in 2023, with China leading with a 55% global share, double the US at number 2 - Figure 4.7.1.

Figure 4.7.1 Global battery storage capacity additions, GW, 2013-2023



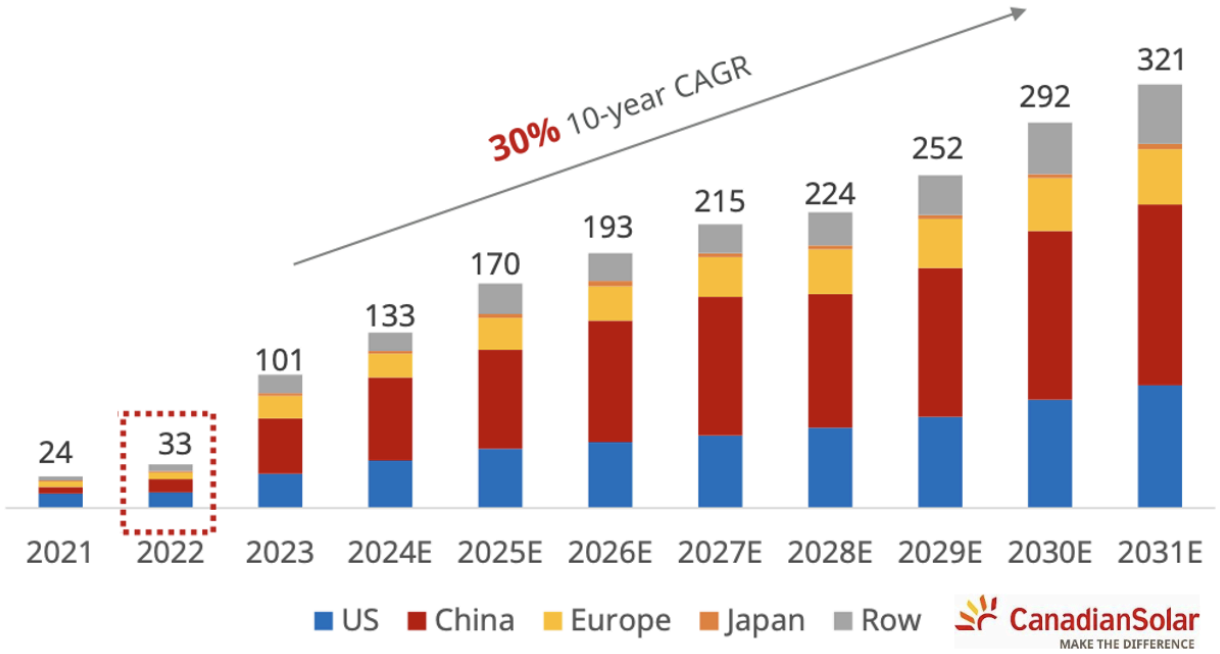
Capacity additions doubled in 2023, led by China, the United States and the European Union

Source: IEA, Batteries and Secure Energy Transitions, April 2024

[181] Bloomberg. China Grid Giants Seek Solutions for a System Flooded With Solar, 27 March 2024
[182] Best. China boosts energy storage almost four-fold in 2023, 26 Jan 2024

Wood Mackenzie forecasts global installed BESS capacity will grow at a CAGR of 30% over the coming decade, absolutely led by China with a global share of ~50% - Figure 4.7.2. In light of the rapid near 50% deflation in battery prices in the last year alone,[183] CEF would suggest this is highly conservative, given most new utility solar installs need to be matched with an associated BESS to best utilise the grid transmission utilisation, meaning the real BESS installs could be fivefold more than this by the end of this decade.

Figure 4.7.2 Global Energy Storage Capacity Growth, GWh 2021-2031



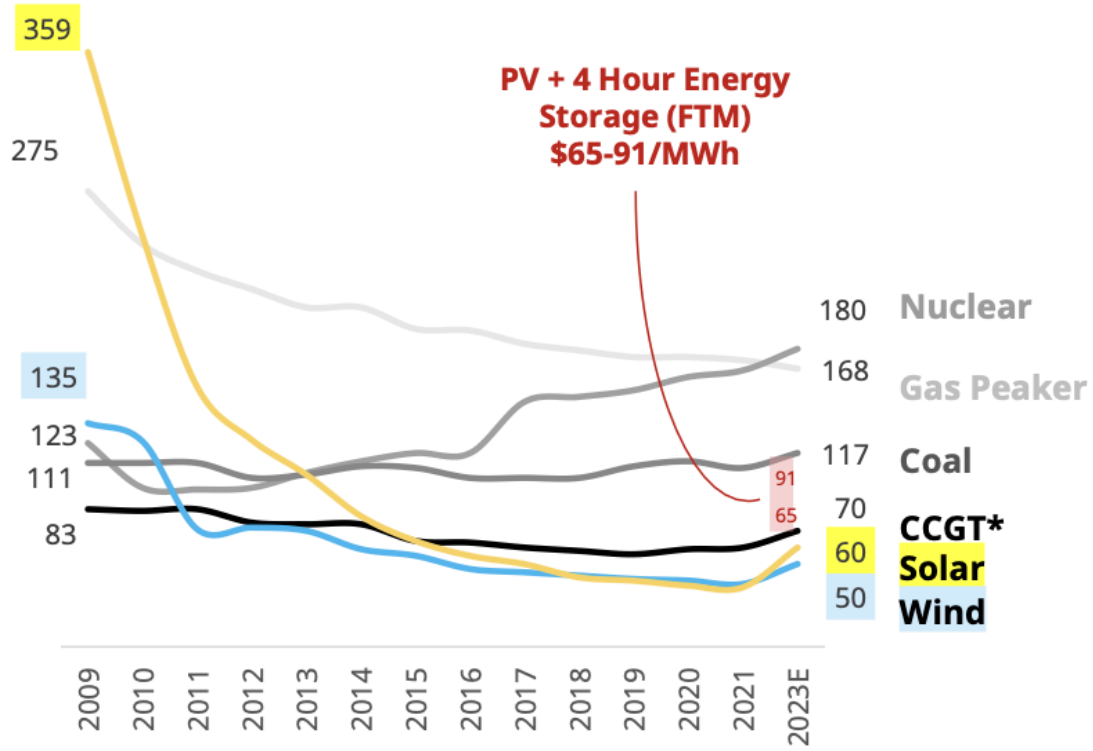
Source: Wood Mackenzie, Canadian Solar, March 2024

The implementation program for the development of new types of energy storage in the fourteenth five-year plan, jointly released by the NDRC and NEA in 2022, established key objectives for BESS development across areas including technological innovation, pilot demonstrations, scaled expansion, institutional mechanisms, policy support, and international collaboration, including a target of achieving 30 GW of new energy storage installations by the end of 2025.[184]

March 2024 saw reports China's CATL will slash the cost of its batteries by up to 50% in 2024, as a price war kicks off with the second largest maker in China, BYD, partly driven by the >80% collapse in lithium and >40% decline in nickel commodity prices.[185] CATL also announced a new NEV battery pack with a 15-year, 1.5 million km warranty. In a passenger car that would be enough for 100 years of normal driving, or 50 years and constant V2G use.[186] These two firms collectively account for more than half the world's battery supply, and each have massively expanded manufacturing capacity and invested heavily in new RD&D in extending the life and capacity, and reducing battery weight so as to expand the market globally. This dramatically lowers the capital cost of incorporating ever-more low cost, zero emissions but VRE. We are in the midst of a battery revolution.

[183] Bloomberg. China Already Makes as Many Batteries as the Entire World Wants, 12 April 2024
[184] PV Magazine, Solar giants enter the storage market, 30 March 2024
[185] The Conversation. A battery price war is kicking off that could make NEV cheaper, 20 March 2024
[186] The Driven. CATL announces electric vehicle battery with 1.5 million km warranty, 3 April 2024

Figure 4.7.3 Mean Unsubsidised LCOE & Levelised Cost of Storage (LCOS), US$/MWh



Source: Lazard 2023 LCOE and LCOS reports, Canadian Solar, March 2024

Another solution to better coordinate the electricity grid to ensure energy security and stability is to build more energy storage systems. China's technology innovation in BESS has been pushing the market forward. China's current energy policy requires renewable energy plants to have a storage of 20% of the generation capacity integrated to the plants, with at least 2-4 hrs duration.[187] This is increasingly the least cost electricity solution - Figure 4.7.3.

China leads the world in installing and scaling up new energy storage systems to assist grid firming for renewable energy.

Whilst lithium ion batteries like CATL's world leading BESS offers[188] are expected to be the mainstay of short duration grid firming technologies deployed across China over the medium term, the country is investing massively in new battery chemistries, and building battery manufacturing capacity at a globally unprecedented rate. China is also experimenting with a range of alternative BESS.

December 2023 saw China commissioned Rudong 25MW/100MWh EVx gravity BESS. A total of 3,7GWh announced EVx gravity BESS are now under construction. 2023 saw the beginning of the construction of a 17MW.68MWh gravity BESS project and a 50MW/200MWh gravity BESS project in Gansu Province.[189]

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[187] PV Magazine. Energy Vault connects commercial-scale gravity BESS in China. 7th March, 2024
[188] Electrek. CATL unveils Tesla Megapack competitor, claims zero degradation and more capacity. 12 April 2024
[189] Energy Vault. Energy Vault Announces China State Grid Interconnection of First EVx 100 MWh Gravity Energy Storage System, Groundbreaking of Three Additional EVx Gravity Storage Systems and Other China Market Expansion Milestones. 29th February, 2024

April 2024 saw China Energy Engineering Corporation deliver grid connection on its 300MW/ 1,500MWh compressed air energy storage system. Built in two years with a RMB1.95bn (US$270m) investment, it uses abandoned salt mines in the Yingcheng area of Hubei.[190]

CEF also expects that China's world leading manufacturing, domestic sales and export profile in EVs means that China's smart grid system will also leverage the massive combined battery storage, charging and discharging capacity of V2G technologies. China in March 2024 saw NEV reach a record high 41.6% share of new passenger vehicle sales. NEV sales were 709,000 units, +29.5% y-o-y.[191] BYD chairman Wang Chuanfu predicts that China could see monthly NEV penetration exceed 50% within this year.[192]

Distributed energy and storage solution are forecast to boom, including the "batterification" of tools and electronic devices such as induction stove cooktops. Ampace is a Xiamen-headquartered firm founded in 2021 as a joint venture of CATL and CATL's former parent company Amperex Technology Limited (ATL). According to data from Shenzhen Gaogong Industry Research (GGII), China shipped 20 GWh of the global total of 24GWh of residential energy storage systems in 2023. Ampace was ranked the biggest manufacturer, accounting for over 30% of China's contribution.[193]

[190] Energy Storage News, 'World's largest' compressed air energy storage project connects to the grid in China, 10 April 2024
[191] CNEVPOST. China's NEV retail rebounds to 709,000 in Mar, penetration reaches record 41.6%. 9 April 2024
[192] CNEVPOST. BYD chairman expects China's NEV penetration to exceed 50% within next 3 months. 16 March 2024
[193] SCMP, How a little known spin-off of Chinese battery giant CATL has come to dominate the global home energy storage market, 19 April 2024

5. Carbon Price in China

5.1 China's ETS

The economically rational way to solve carbon pollution is to put a price on carbon emissions, firstly in electricity generation, then progressively across the whole of the economy, including international trade. Ratcheting the price expectation up over time makes clear to all the direction of travel, and finance will quickly pivot investment to zero emissions options. This is particularly so in China where the manufacturing scale and rate of price deflation of solar, wind and batteries is staggering.

China now operates the world's largest ETS by volume, and this is progressively set to extend to selected heavy industry sectors. A progressively higher price is needed.

China launched the national emissions trading system (ETS) in 2017, officially put into operation in 2021, is the world's largest emissions trading program in terms of CO_2 emissions covered.[194] China's ETS oversees more than 2,200 companies from the power sector, which covers annual emissions of more than 4.5 billion tonnes pa of CO_2.[195]

In February 2024, China State Council released new regulations for carbon emissions trading - Interim Regulations on Carbon Emissions Trading Management[196] - aiming to provide a legal framework for China's carbon emissions trading market.[197] The new regulation specified products eligible for trading, trading methods and the distribution of carbon quotas.

China has also proposed expanding its ETS from just electricity sector coverage to include seven other heavy industry sectors including cement, aluminium and iron and steel to cover 70% of the nation's annual emissions, in part to allow compliance with the EU CBAM requirements,[198] but has warned compliance and verification needs to be significantly enhanced first before this expanded policy is implemented. March 2024 saw the release of draft greenhouse gas emissions guidance for aluminium and cement open for consultation, suggesting these two sectors will be included this year, albeit initially only with 'simulation trading'. The inclusion of domestic aviation to national ETS is also highlighted in this new regulation.

April 2024 saw the Ministry of Ecology and Environment seek input on plans to address overallocation of allowances and tighten the ETS market.[199]

There is clearly a strong synergy between China's carbon and green electricity policies. We expect further policy updates to cover the third compliance period and a progressive lowering of the benchmarks for the electricity sector, reinforcing the country's overall decarbonisation plans led by electrification and the continued deployment of massive new firmed renewable energy capacity.

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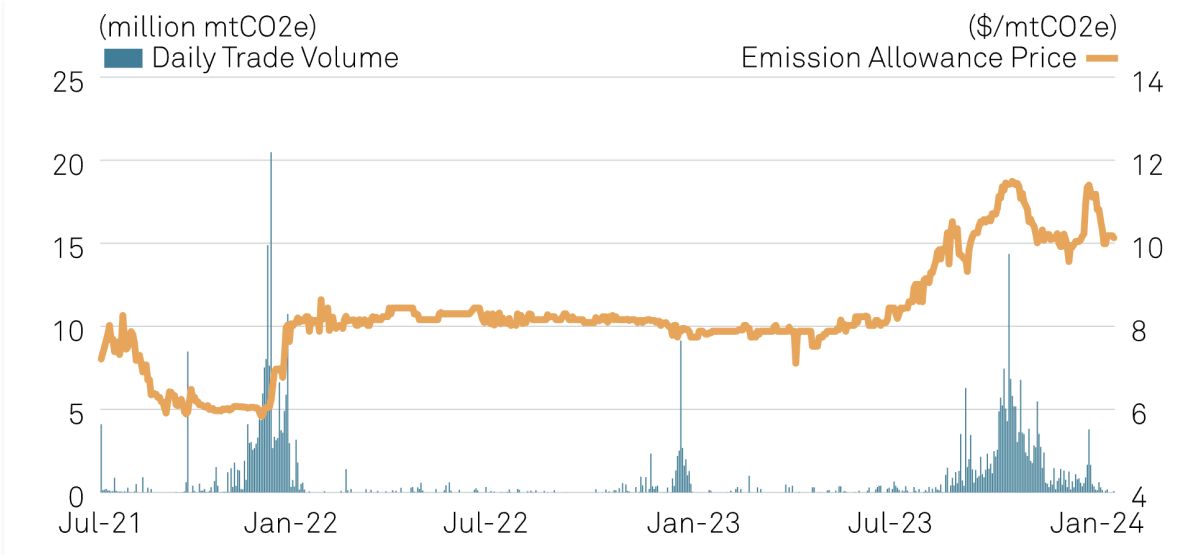
[194] Oxford Institute of Energy Studies. Guide to Chinese Climate Policy 2022
[195] International Carbon Action Partnership. China National ETS
[196] 中华人民共和国中央人民政府.《碳排放权交易管理暂行条例》. 4th February, 2024
[197] China Daily. China releases carbon emissions trading regulations. 4th February, 2024
[198] S&P Global China's compliance ETS to accelerate coverage of CBAM-eligible sectors. 9 May 2023
[199] Bloomberg, China Plans Biggest Changes Yet to Lift Carbon Market Impact, 15 April 2024

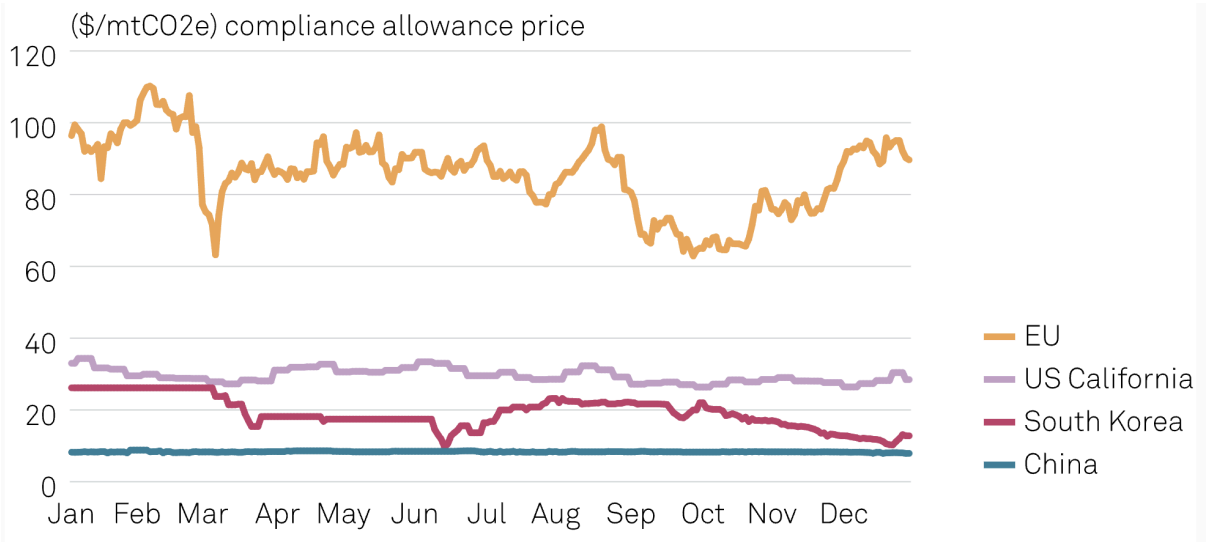
Figure 5.1.1 Price and Trade Volume in China's Compliance Carbon Market



Source: Shanghai Environment and Energy Exchange Co., Ltd.

Figure 5.1.1 shows that China's Emission Allowances (CEAs) demonstrated an overall increase from July 2021 to January 2024. According to S&P Global, China's average trading price for China Emission Allowances (CEAs) reached RMB68/tCO_2e (US$9.6/t$CO_2$e) in 2023, a 23% y-o-y increase, and RMB90/t (US$13/t) in April 2024. The CEA trade volume reached 212Mt CO_2e, jumping 316%.[200]

Figure 5.1.2 Cross-Comparison of China and Global Compliance Market Prices



Sources: S&P Global Commodity Insights, Shanghai Environment & Energy Exchange, Korea Exchange.

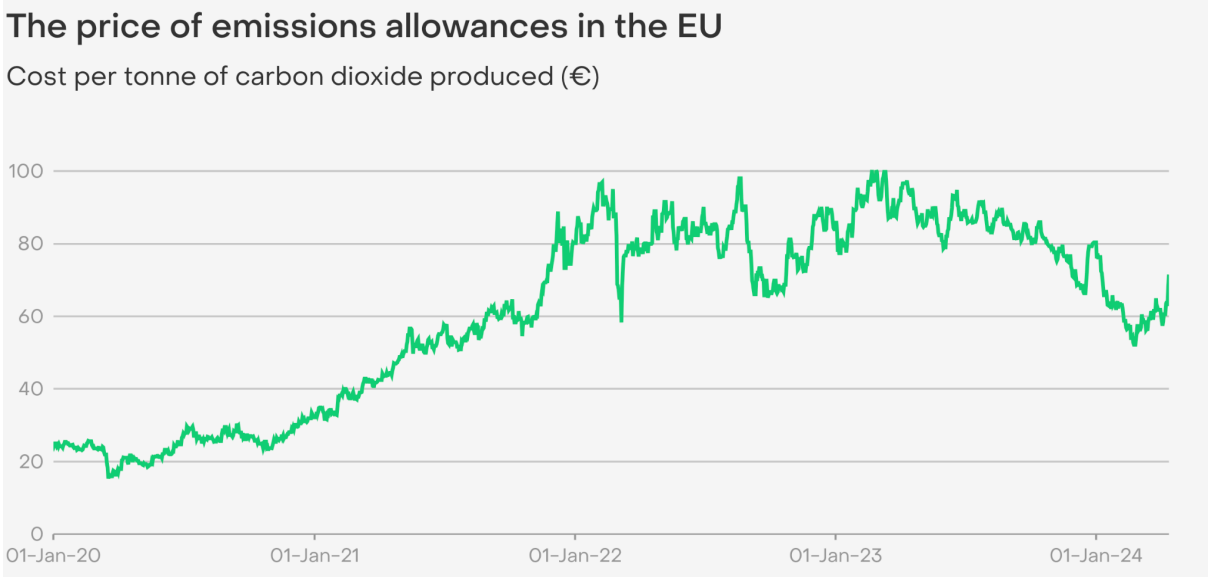
However, China's current carbon price is significantly lower than other developed countries and regions, such as the EU, USA, and South Korea - Figure 5.1.2. A Beijing-based consulting company ICF forecasts that China's average carbon price will rise to RMB87/tCO_2e (US$12/t$CO_2$e) in 2025, RMB130/t$CO_2$e (US$19/tCO_2e) in 2030, and

[200] S&P Global. Commodities 2024: China's domestic carbon market set for revamp; Article 6 in limbo. 17th January, 2024.

RMB239/tCO_2e (US$34/$tCO_2e$) in 2050.[201] In CEF discussions with Chinese officials, there is a clear acknowledgement that a progressively rising carbon price is needed to reach net zero emissions.

In the meantime, we should also place China's deflation into consideration, as the cost of living in China is generally lower than the rest of the world. Nevertheless, higher carbon prices to keep up with the global standard can only benefit China's energy transition progress, and the global battle with climate change.

Figure 5.1.3 Cost per Tonne of Carbon Dioxide Produced (€)

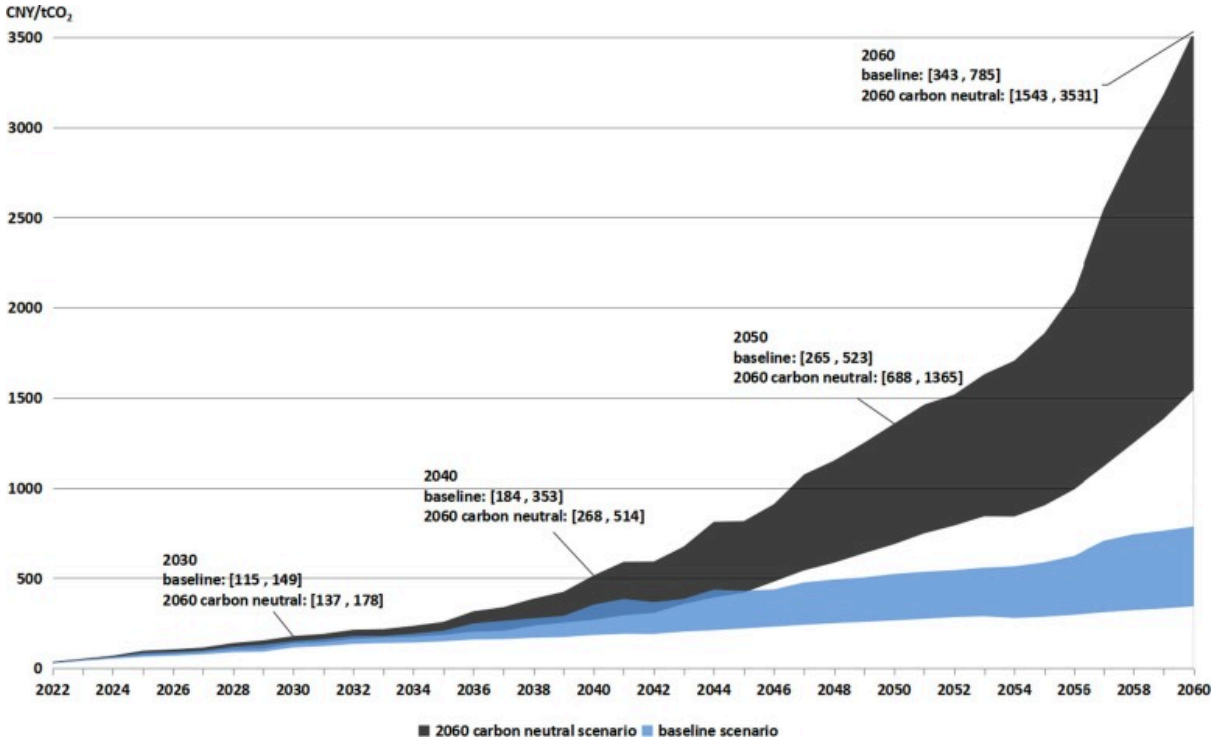


Source: Montel via Ember.

The biggest difference between China's ETS and the EU ETS is that China's ETS has not yet specified an absolute cap. Instead, China's ETS adopted a bottom-up method, all companies included by ETS will be allocated their emission allowances free of charge based on China's own national benchmarking method.[202] While in the EU, the emission allowance is €72/t (US$77/t) as of 12th April 2024 - Figure 5.1.3.[203]

[201] S&P Global. Commodities 2023: China's carbon market to slow in 2023 as energy security, economy take priority. 12th January, 2023
[202] Energy Monitor. Carbon trading the Chinese way. 5th January, 2022
[203] Ember. Carbon Price Tracker.

Figure 5.1.4 Prediction of carbon price range of China under the carbon neutrality



Source: Predicting China's carbon price based on a multi-scale integrated model, Applied Energy, Volume 324, October 2022.

Shaozhou Qi from Wuhan University predicts future carbon price trends in China under the baseline and the 2060 carbon neutral scenarios - Figure 5.1.4. China's carbon price range in 2060 will reach RMB343-785/tCO_2 under the baseline scenario, and reach RMB1,543-3,531/tCO_2 under the 2060 carbon neutral scenario.[204]

This is an area where collaboration between China and the EU could be established as China could learn from the EU ETS to better mature the Chinese ETS. One avenue for improvement is for China to increase its carbon price, which could provide stronger incentives for companies to invest in emissions reduction measures and transition to cleaner technologies. A higher carbon price would also more accurately reflect the environmental cost of carbon emissions, encouraging greater accountability among emitters and driving further innovation in low-carbon solutions.

Moreover, introducing an absolute cap on emissions within China's ETS framework could provide greater certainty and transparency for market participants. By setting clear limits on the total amount of emissions allowed within the system, China can create a more stable and predictable regulatory environment, facilitating long-term planning and investment decisions.

Implementing these enhancements to China's ETS aligns with the country's broader climate goals, including its commitment to achieving carbon neutrality. By strengthening its carbon pricing mechanisms and establishing emission caps, China can accelerate progress towards its climate targets while fostering a more sustainable and resilient economy. Additionally,

[204] Applied Energy. Predicting China's carbon price based on a multi-scale integrated model. 15th October, 2022

these measures would demonstrate China's leadership in global climate action and contribute to collective efforts to address the pressing challenges of climate change.

Any positive reforms within China’s carbon trading market would accelerate the global energy transition progress due to it covering a significant portion of the total carbon emissions of the world. As the world’s biggest CO2 emitter, China needs to put in more substantial ambitions on carbon price in ETS.

5.2 Carbon Border Adjustment Mechanism (CBAM)

A China CBAM working in collaboration with the EU CBAM would be a great signal for world trade to accelerate investment in decarbonisation, driving global solutions at scale, leveraging the buying power of two of the largest markets in the world. Extending the China CBAM to a developed North Asia CBAM would be even better!

The growing need for a carbon price for China comes from more than just domestic regulation.

China's lead climate negotiator Su Wei said in an interview that "Some developed countries are imposing additional tariffs and conducting countervailing investigations on photovoltaic products, renewable energy equipment, etc. These measures run counter to the goal of tripling the installed capacity of renewable energy."[205]

The EU has been pushing the CBAM in order to leverage its collective trade buying power to encourage other countries to lift their climate ambitions towards alignment with the EU. CBAM is designed to apply import charges on carbon intensive import goods such as cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. It aims to capture more than half of the emissions in EU's ETS covered sectors[206] The EU aims to apply CBAM in practice starting from 2026 in the designated regime.

A recent study from Asian Development Bank (ADB) indicates that due to the fragmentation of carbon pricing initiatives around the world, CBAM will likely reduce global carbon emissions by less than 0.2% with a carbon price of €100 (US$108) per metric ton and no carbon tariff. CBAM charges could potentially reduce global exports to the EU by 0.4% and exports from Asia to the EU by 1.1%.[207] CEF would counter this narrative to suggest that the leading developed economies of north Asia collaborate with the EU to collectively lift developed world decarbonisation ambitions and tools, and then jointly provide clear finance support to developing nations - as per the Paris Agreement in terms of the 'common but differentiated responsibilities' to get the collective global decarbonisation momentum underway in alignment with the climate science.

CBAM is a positive incentive that will encourage EU's trade partners to start to reduce their emissions in terms of their exports, and in doing so put their domestic economies on a decarbonisation pathway, so as to boost energy transition in the global supply chain.

Disagreement from some in China has seen the EU's CBAM called a new trade barrier for Chinese exports.[208] However, if China's own price on carbon and ETS scheme keeps up with science-based standards, transforming the carbon-intensive industries can minimise the effects of CBAM on Chinese exports, as well as be beneficial for the global environment. Ideally, we would call on China to work with other developed Asian leaders to introduce a North Asia CBAM as well, to provide a clear policy and price signal for all to accelerate investment in zero emissions industries of the future.

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[205] 中国新闻周刊. 重磅专访 中国气候谈判首席代表苏伟谈能源转型. 8th January, 2024
[206] European Commission. Carbon Border Adjustment Mechanism.
[207] Asian Development Bank. EU Carbon Tariff Likely to Have Limited Impact on Emissions Without Global Efforts. 26th February, 2024
[208] Reuters. China steel association says EU carbon tax a new trade barrier, calls for more talks. 3rd November, 2023