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Software versus hardware:

how China's institutional setting helps and hinders the clean energy transition

CHINA

ENERGY TRANSITION

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Anders Hove, Research Associate, OIES
Michal Meidan, Senior Research Fellow, OIES
Philip Andrews-Speed, Senior Research Fellow, OIES

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Abstract

The global low-carbon energy transition will require major changes to institutional practices and energy industry paradigms – and will have implications for non-energy industries, consumers, and society writ large. Considering the scope of the energy transition, a country's existing institutional pattern inevitably shapes the transition, and helps or hinders its progress. This is perhaps especially so in state-dominated systems such as China, which have historically considered energy as a strategic field for state dominance and control, for reasons of both security and economic development.

China has already taken steps to embrace clean energy, even as it remains the world's largest consumer of fossil fuels: Indeed, it is the world's leading producer and consumer of renewable energy in absolute terms today, and the country's leaders speak of encouraging a revolution in energy consumption and production, in line with new targets announced in 2020 to achieve carbon neutrality by 2060. But how successful will China be in introducing the sweeping changes that are commonly assumed to be required? At the technological level, such changes could include not only replacing fossil fuels with renewable energy sources, but shifting from centralized to distributed forms of production, greatly improving energy efficiency and consumption flexibility, and adopting digital technologies throughout the sector. At the institutional level, these shifts could entail major market reforms and changes to the structure of the Chinese energy sector, dominated now by SOEs and administrative planning.

This paper examines how China's institutional setting both contributes to and hinders the energy transition, with a particular emphasis on the energy sector. It also aims to dispel the binary view of China's governance and the energy transition, in which central government commitment is portrayed as the sole determinant of success. Finally, it sets out a preliminary framework for analysing the areas where technological and institutional factors make change more likely to be lasting and transformative, versus areas in which resistance will likely remain strong.

Historically, China has been better at building out energy supplies and adding the 'hardware' of energy infrastructure, while having greater difficulty adjusting the 'software' of institutional and societal change or practices related to energy demand and energy efficiency. We would argue that China is likely to continue to expand the hardware, given its strong institutions devoted to investing in supply. But China will struggle with the software as this relies on a demand pull, market incentives, and greater coordination among stakeholders and between sectors.

When considering innovation for the energy transition, the paper makes a similar argument: China's technology innovation system has enabled innovation in first generation technologies. But will China's strong incumbent industries impede the transformational change required for the more modular technologies that are less capital intensive and require greater societal involvement and coordination? China has come to dominate global supplies in manufacturing-intensive technologies – solar photovoltaics and batteries – which have also seen the most rapid cost declines due to scale. For design-intensive technology – such as wind, concentrating solar power plants, or advanced coal plants – cost declines have not been as pronounced. For those technologies that are less modular and more design-intensive, state-owned enterprises may play a larger role and the potential for transformative technological change could be slower to emerge.

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Introduction

The global low-carbon energy transition will require major changes to institutional practices and energy industry paradigms – and will have implications for non-energy industries, consumers, and society writ large. Considering the scope of the energy transition, a country's existing institutional pattern inevitably shapes the transition, and helps or hinders its progress. This is perhaps especially so in state-dominated systems such as China, which have historically considered energy as a strategic field for state dominance and control, for reasons of both security and economic development. Moreover, other strategic areas – including industrial manufacturing, heavy industry, and transportation – are also heavily dominated by the state, and since these industries tend to function in political and bureaucratic silos, the country's institutional patterns are critical when thinking about economy- and society-wide change. Can a state-dominated system reshape its institutional and industrial structures to enable the systemic change that the energy transition implies?

China has already taken steps to embrace clean energy, even as it remains the world's largest consumer of fossil fuels: Indeed, it is the world's leading producer and consumer of renewable energy in absolute terms today, and the country's leaders speak of encouraging a revolution in energy consumption and production, in line with new targets announced in 2020 to achieve carbon neutrality by 2060. But how successful will China be in introducing the sweeping changes that are commonly assumed to be required? At the technological level, such changes could include not only replacing fossil fuels with renewable energy sources, but shifting from centralized to distributed forms of production, greatly improving energy efficiency and consumption flexibility, and adopting digital technologies throughout the sector. At the institutional level, these shifts could entail major market reforms and changes to the structure of the Chinese energy sector, dominated now by State Owned Enterprises (SOEs) and administrative planning.

China's present institutional settings simultaneously hold elements of regime resistance and impetus for change: China's fossil fuel-dependent energy system is uniquely tied to the country's economic development model, which emphasizes state-led investment in heavy infrastructure owned by powerful state-owned entities and monopolies. Will this impede the change in scale, use, and ownership of energy that could be realized in some regions as distributed energy technologies continue to fall in cost? Or will rapid institutional changes, such as those relating to adoption of alternative energy, now that it is cost effective in many fields, have the potential to overcome long-existing barriers to the energy transition. Does the high-level commitment to the 2060 target suggest deeper change is forthcoming?

The purpose of this paper is to examine how China's unique institutional setting contributes to or hinders the energy transition – with a particular emphasis on the energy sector, to limit the scope of the analysis. In many cases, writers on China's institutions have tended to assume that certain features of China's energy sector – such interventionist management of the economy and dominance of state-owned monopolies – will primarily hinder the transition, as they limit market forces and private enterprise. Others point to China's strong central state and high-level commitments to the environment to suggest that China's institutions are better suited to addressing environmental problems than those of liberal democracies – and indeed, that China will 'save the planet'.[1]

The paper argues that China's institutional setting will both help and hinder the transition: While China's institutional settings prioritize stability, they can adapt when there is high-level commitment to change. With the Party–State now committing to the low-carbon transition, considerable resources will likely be dedicated to implementation. Yet despite the central government's resolve, the fragmented nature of governance in China remains a challenge to efficient implementation. Even though the government is introducing institutional changes, including market incentives, which could reinforce the transition, these will remain imperfect and subject to other goals related to economic growth, security policy, and technology policy. Ultimately, achieving a low-carbon energy transition will depend on the Party–State's commitment to this goal, and to the convergence or divergence of various policy goals and institutional factors.

The aim of this paper is to dispel the binary view of China's governance and the energy transition – in which central government commitment is portrayed as the sole determinant of success – while also setting out a preliminary framework for analysing the areas where technological and institutional factors make change more likely to be lasting and transformative, versus areas in which resistance will likely remain strong.

Historically, China has been better at building out energy supplies and adding the 'hardware' of energy infrastructure, while having greater difficulty in adjusting the 'software' of institutional and societal change or practices related to energy demand and energy efficiency. We would argue that China is likely to continue to expand the hardware side – it is driven by strong institutions devoted to investing in supply and can be managed through state support and policy, but China will struggle with the software as this relies on a demand pull, market incentives, and greater coordination among stakeholders and between sectors. This is especially relevant in fields that have a more distributed nature or are focused on demand-side measures – such as distributed solar, storage, electric vehicle charging, smart grids, smart buildings, or building energy efficiency. In these fields, individual consumers, building owners, management companies, and consumer product companies (such as car makers or charger manufacturers) will have a more direct role in managing and interacting with the energy sector than in the past. China's present system is biased towards investment in supply to meet energy security objectives, and this reduces the opportunities for investment in distributed energy, flexible consumption, or efficiency, and ultimately increases the cost of the energy transition.

When looking more narrowly at innovation for the energy transition, we make a similar argument: China's technology innovation system has provided consistent policy guidance and support that has enabled innovation in first generation technologies. But will China's strong incumbent industries impede the transformational change that is required for more modular technologies that are less capital intensive and require greater societal involvement and coordination? Will rising tensions with the US and other Western countries slow future gains in innovation? Patent analysis suggests that innovation in solar and battery technologies – in which China has made considerable gains – appears somewhat simpler compared to wind power and other technologies, and depends on materials and electronics-related R&D. Whereas innovation in wind power – in which China has fared less well – is dependent upon both materials and mechanical engineering innovation. The manufacturing-intensive technologies – solar photovoltaics and batteries – have seen the most rapid cost declines due to scale, and these are precisely the fields where China has come to dominate global supply. The ease of entry into manufacturing by private players, and the existence of local supply chains, has helped this process. In design-intensive technologies – such as wind, concentrating solar power, or advanced coal plants – China has also performed well, but cost declines have not been as pronounced. For those technologies that are less modular and more design-intensive, state-owned enterprises may play a larger role and the potential for transformative technological change could be slower to emerge.

This paper is organized as follows. The first section discusses China's fossil-fuel reliant industrial model and existing institutions and lays out the fundamental challenges to China's transition from an energy system, and a sociotechnical regime, based mainly on fossil fuels, to a decarbonized system. The second section then discusses the key drivers underpinning the country's 2060 carbon neutrality pledge before moving, in the third section, to assessing which elements of China's institutional makeup are likely to help or hinder the transition. In the fourth section, we argue that strong and consistent support for the energy transition can help China add new energy supplies (or the 'hardware'), but as we argue in the fifth section, there are obstacles to developing the software that is required in the transition. The sixth section looks more closely at technological innovation and examines why China leads in some clean energy technologies but not in all. Historically, China's innovation policy has favoured supply-side innovation rather than focusing on moderating energy demand. Going forward, innovation in fields that are either dominated by large, conservative, state-owned entities, or that require stakeholder interaction at multiple levels, may be inherently more difficult. Especially if China's relations with the US and other Western economies continue to deteriorate. In the final section, we discuss the impact of international relations on China's energy transition, and make concluding remarks.

1. China's fossil-fuel heavy development path and governance model

- *China's economic growth has led to a strong increase in energy consumption, with an energy mix heavily reliant on fossil fuels, and predominantly on coal. Efforts to tackle air pollution have led to increases in energy efficiency to tame demand growth, and a focus on supplies of renewable energy sources.*
- *While the country's economic structure has changed significantly since the start of the Reform and Opening period in 1978 – shifting from a predominantly agricultural economy to one dominated by industry and, increasingly, services – the industrial sector rapidly became, and remained, the largest consumer of energy.*
- *The dominance of industry in energy demand reflects the political significance of energy-intensive industries such as steel, aluminium, chemicals, and cement. The country's economic growth has been led by an investment boom in manufacturing and the associated infrastructure. Since many of these heavy industries are dominated by state-owned companies that benefit from access to cheap capital – through the country's state-owned banks – as well as cheap labour and land, they have been able to reinforce their position as pillars of economic growth and development.*
- *In this context, China's pledges to decarbonize its energy system will prove transformational not just for its energy use but also for its economy and institutional set-up. Herein also lies the challenge.*

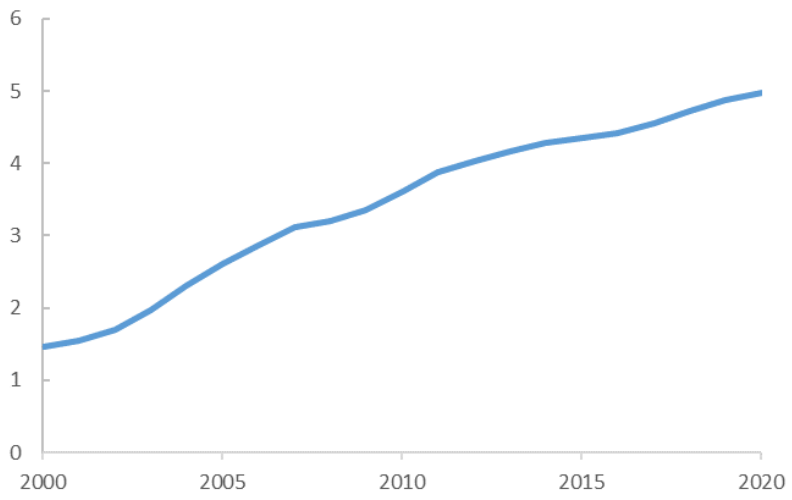
Since China's Reform and Opening up in 1978, the country has undergone a profound transformation. Its Gross Domestic Production (GDP) in 1978, according to the World Bank, was roughly half the size of the Italian economy, while it is now set to overtake the US and become the world's largest. Per capita GDP has grown by nearly 24 times and urbanization has been a defining feature; the rural population, which accounted for roughly 85 per cent of China's population on the eve of China's Reform and Opening up, is now down to around 40 per cent. Over the course of its economic transformation, China has also reached 100 per cent electrification, meaning that all its population, both rural and urban, has access to electricity.

Fuelling the country's rapid industrialization and urbanization process is a voracious appetite for energy, with primary energy consumption increasing rapidly, from 1.5 billion tons of standard coal in 2000, to 5 billion tons standard coal in 2020, according to China's National Bureau of Statistics see Figure 1), accounting for one quarter of global energy use. Domestically-produced coal accounted for 70 per cent of the energy mix in 1978, alongside oil which accounted for another 23 per cent. In the late 1970s, China consumed a mere 17 per cent of global coal, but given its importance in powering the nation's industrial growth, consumption reached 3.9 billion tons in 2019, or half of the coal used worldwide.[2] In 2018, around 49 per cent of China's coal consumption was used for generating electricity and heat.[3]

In light of China's heavy reliance on coal, since 2006 it has become the world's largest greenhouse gas emitting country, accounting for 27.9 per cent of global emissions in 2019 compared to 7.5 per cent in 1980.[4] Based on various estimates, China's emissions have grown by a factor of 4 since 1990, reaching around 13.7 billion tons of CO_2-equivalent in 2020.[5]

Similarly, China's oil consumption has grown from 212 million tons in 2000 to 696 million tons in 2019.[6] Oil supplied 19.7 per cent of primary energy consumption in 2019.[7] During this period, imports rose from 33 per cent of consumption to over 70 per cent in 2019.[8] Along with addressing urban air quality, reducing dependence on imports is one of the primary goals of policies aimed at shifting to electric vehicles. In 2020, there were around 367 million internal combustion vehicles in China, with 19.3 million sold in 2020 alone (1.1 million EVs were sold in China that year, bringing the total EV count to 4.9 million, or 1.75 per cent of the fleet).[9]

Figure 1: China primary energy demand (billion tons of standard coal)



Source: National Bureau of Statistics

In light of China's heavy reliance on coal, since 2006 it has become the world's largest greenhouse gas emitting country, accounting for 27.9 per cent of global emissions in 2019 compared to 7.5 per cent in 1980.[10] Based on various estimates, China's emissions have grown by a factor of 4 since 1990, reaching around 13.7 billion tons of CO_2-equivalent in 2020.[11]

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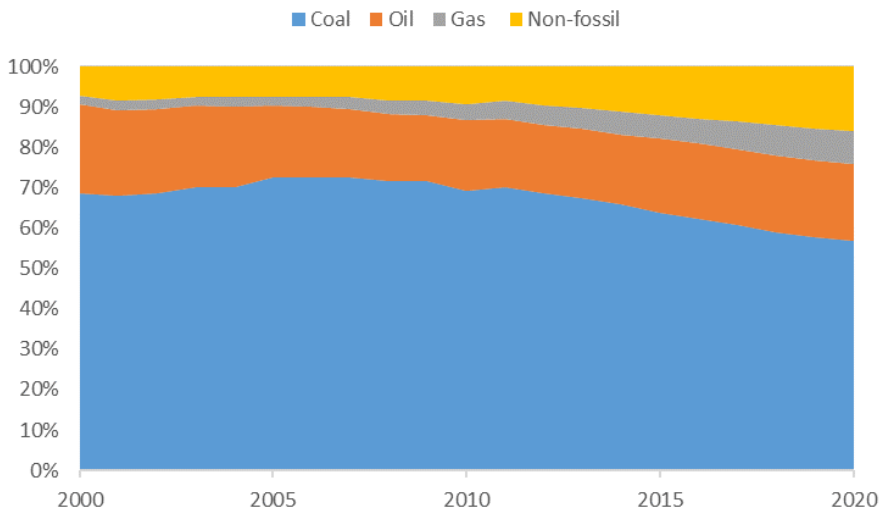
Gas use has also been growing dramatically in recent years, and it looks likely to play a major role as a transition fuel. Methane gas supplied 7.81 per cent of China's primary energy in 2020.[16] Gas consumption grew from 25 billion cubic meters in 2000 to 304 billion cubic meters in 2019.[17] Imported gas has met a large portion of China's incremental gas demand, and China's growing appetite for gas imports has led to rapid growth in the global trade in liquefied natural gas (LNG).

Yet over the years, even as coal demand has continued to rise, government efforts to tackle air pollution have led to a steady decline in its share of the country's primary energy consumption, falling from 74 per cent in 2013 to 56.7 per cent in 2020 (Figure 2).[18]

And in line with these efforts, China is also the world's largest renewable energy producing country, with the largest wind and solar capacity. The country's scale-up of manufacturing wind and solar equipment helped bring down the costs of wind and solar PV technologies worldwide. China's wind and solar capacity has grown immensely in the last decade, and by the end of 2019, solar PV and wind installations in China each accounted for 35 per cent of the world's total.[19] Wind capacity reached 282 GW at the end of 2020, solar reached 253 GW.[20] Despite this impressive growth, wind and solar accounted for just 9.4 per cent of electricity generated in 2020.[21] China's installed capacity of hydro power increased from 216 GW in 2010 to 396 GW in 2020,[22] and electricity generated by hydro power increased 509 per cent from 222 TWh in 2000 to 1355 TWh in 2020.[23] China has the world's largest dam, the Three Gorges Dam, with an installed capacity of 22.4 GW.[24]

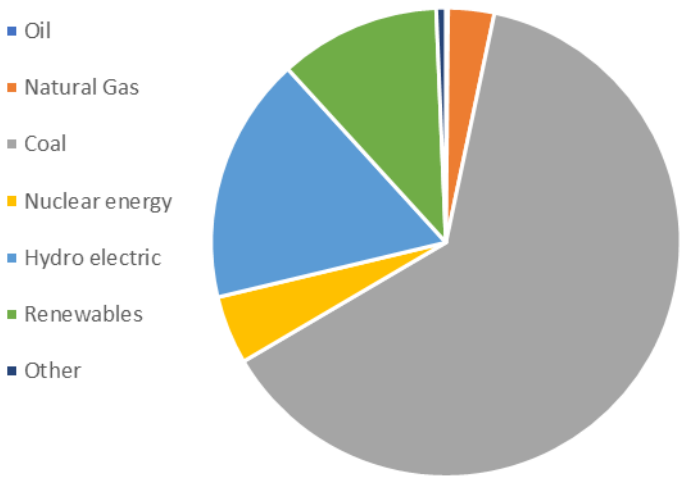
Figure 2: China's energy mix, %



Source: National Bureau of Statistics

Finally, China is also a large producer and consumer of nuclear: China's first nuclear plant, Qinshan nuclear plant, started operating in 1974. At the inception stage, China's nuclear technology wasn't sufficiently advanced and needed to rely heavily on foreign technology. Two units in Daya Bay Nuclear Power Plant (operated since 1994) were imported from France.[25] Nuclear capacity grew from 11 GW in 2010 to 50 GW in 2020 – a five-fold increase in 10 years. Electricity generated by nuclear power increased from 75 TWh in 2010 to 366 TWh in 2020 (Figure 3).[26]

Figure 3: China's electricity generation by fuel



Source: BP Statistical Review, 2021

Indeed, while the country's economic structure has changed significantly since the start of the Reform and Opening period, shifting from a predominantly agricultural economy to one dominated by industry and, increasingly, services, the industrial sector rapidly became, and remained, the largest consumer of energy. In 1980, agriculture represented a larger proportion of the Chinese economy than industry and services, but in the early 1980s, the Chinese government began gradually easing central planning and increasing the autonomy of farming collectives. Rural residents then found themselves with new-found wealth to invest in labour-intensive light manufacturing enterprises which, in turn, became the engine of China's economic growth. At the same time, the reform era led to changes within heavy industry, which had become tremendously inefficient under the planned economy. As economic

incentives were introduced alongside the traditional planned targets, the growing awareness of profitability, combined with the availability of energy efficient technologies, led to a dramatic improvement in the country's energy intensity.[27] By 2000, Chinese economic activity required two-thirds less energy per unit of output than in 1978.[28]

By then, China was on the path of gradual economic liberalization, anchored firmly by its decision to join the World Trade Organization (WTO). The country's planners were expecting strong GDP growth while maintaining the gains seen in energy efficiency, as the country's economy would transition from energy-intensive heavy industry toward light industry. But over the course of the following decade, the economy grew faster than expected, while energy intensity (energy consumption per unit of GDP) tripled.[29] The surge in economic activity and the ensuing need for energy meant that even as the economic reform agenda, of liberalization and decentralization, gathered momentum, similar changes in the energy sector were slower. Yet despite rising energy demand from consumers, industry has remained the largest end-user of energy.[30]

The dominance of industry in energy demand reflects the outsized role that heavy industry has played in China's economic development, as well as the political significance of energy-intensive industries such as steel, aluminium, chemicals, and cement. Not only has the country's economic growth been led by an investment boom in manufacturing and the associated infrastructure, but the country has also sought to localize production of the energy-intensive basic products used to construct roads, factories, and buildings. Moreover, since many of these heavy industries are dominated by state-owned companies that benefit from access to cheap capital – through the country's state-owned banks – as well as cheap labour and land, they have been able to reinforce their position as pillars of economic growth and development.[31]

In this context, China's pledges to decarbonize its energy system will prove transformational not just for its energy use but also for its economy and institutional set-up. Over the past three decades an extensive political science and economics literature has emerged about energy transitions. The concept of a low-carbon or clean energy transition generally implies a major change in sociotechnical regime.[32] A *sociotechnical regime* is dynamically constituted by a diverse set of social, regulatory, economic, and technical factors that have aligned into a dominant system. This concept also recognizes that technology and society are highly interdependent spheres. Technology can determine societal behaviour and institutional arrangements; in turn, societies can make choices concerning technology that ultimately lead to (potentially unanticipated) behavioural or institutional changes. An existing sociotechnical regime can be challenged by emerging technologies, sometimes fostered by state policy; while most new technologies stay in market niches or fail altogether, some may eventually introduce a radical discontinuity in the sociotechnical regime of the energy sector, leading to a system transition. All this sociotechnical change is set within a broader landscape of diverse political, economic, social, and environmental settings, described as a multi-level perspective (MLP) in which the transition takes place.[33]

Fossil fuel energy systems constitute a sociotechnical regime with particular institutional characteristics that tend to lock in existing patterns of energy production and consumption and resist change, even when new technology is cheaper and better.[34] Conversely, successful energy transitions require institutional adaptation at many levels.[35] Often – as in the case of China, with the adoption of wind and solar, which now account for around one tenth of electricity production – this begins with the establishment of protected industry niches, and leads ultimately to the legitimation of new technology. The development of niches and technology legitimation can bring about new sociotechnical regimes to replace the old, though this remains uncertain. The process is fraught with policy reform challenges and resistance from incumbent industries and their supporting structures in government and society. In general, countries actively pursuing low-carbon energy transition have done so with varying degrees of transition management from above and below. Yet for many energy transition scholars, the concept of an energy transition requires a broader societal transition. This includes measures focused on the 'large-scale societal transformation towards sustainability', of which low-carbon energy is one aspect,[36] as well as those emphasizing institutional, market, and spatial changes.[37]

In this context, China poses an interesting case study: it has begun to adapt to the challenges of climate change through various domestic priorities[38] and has legitimized new technologies, albeit in a largely top–down manner. At the same time, in mobility for example, several 'niches' are emerging as potential social and technical disruptors, with electric vehicles (EVs) and electric two-wheelers (E2Ws) being interesting examples.[39] Yet the institutional framework for energy governance has only undergone modest changes,[40] with reforms aimed at allowing markets to play a decisive role remaining some way off, while formal and informal administrative planning plays a growing role. Chinese scholarship on the low-carbon energy transition tend to focus on technology and macroeconomic forecasts and scenarios. Western scholars and government strategy documents have, by contrast, tended to emphasize the importance of private sector innovation and competition, market-based instruments, and a mixture of top–down and bottom-up economic and environment-related governance institutions.

This paper fits into this scholarship in two respects. First, we argue that China, in common with all countries undergoing a low-carbon energy transition, has a unique mixture of institutional advantages and disadvantages. We highlight the relationship between the advantages that have enabled China to overcome obstacles to become the largest producer of solar, wind, and batteries, with the larger obstacles that could affect whether these advantages would translate to other aspects of the energy transition, such as scaling down coal or enabling energy demand flexibility. Second, we review scholarship on China's technology innovation system through both a technological and an institutional lens. We point out areas in which China's various institutions can mobilize resources for change but which could nevertheless struggle to adapt. This could lead to a potentially inefficient or imperfect transition that over-emphasizes supply-side investment in centralized resources to the detriment of changes implied by the central leadership's Ecological Civilization or Energy Revolution paradigms. Whereas some recent scholars have focused on the quantifiable metrics of innovation – such as patent analysis and R&D spending – in fields that have experienced the greatest innovation,[41] we situate energy sector innovation within the larger frame of the energy transition, as a sociotechnical regime change that could fundamentally alter the roles of many players in the energy sector.

While we argue that several institutional characteristics in China could hinder a clean energy transition, despite strong central government support and high institutional capacity to adapt to major sociotechnical change, a more complete comparative analysis would be needed to establish that the barriers to such a transition in China are materially greater than those in other countries or regions. In Europe and North America, decades of entrenched political division, industry lobbying, and opposition from powerful local interests have hindered climate and clean energy progress. It would be unfair to call out barriers in one country without noting that unique and powerful hindrances exist elsewhere as well. But identifying potential obstacles is an important element in overcoming them.

2. Drivers behind China's environmental pledges

When taken in the context of the current energy system described above, the task at hand is tremendous. While these changes will create new areas of growth, they also require a radical transformation – if not destruction – of the economically and politically powerful hydrocarbon industry. To assess China's institutional capacity to engage in this change, it is critical to understand the motivations behind the 2060 pledge. There are five main drivers of China's low-carbon energy transition, and the increasing convergence between them suggests an ongoing and concerted commitment to change. These drivers are:

- ***Industrial development** goals and Beijing's perception that China must increase the value added to its industrial output, for the long-term sustainability of its economic model and its international competitiveness.*
- ***Energy security and geopolitics** have been a key driver of China's energy transition and innovation. Electrifying China's energy end-uses and relying on domestically produced sources of energy will reduce exposure to oil and gas import disruptions and price volatility. Moreover, by dominating the production of key minerals, China could even become a new global chokepoint for the development and deployment of wind, solar, and batteries.*

- ***Environmental quality****, and in particular, tackling local air pollution. Alleviating public concerns and social instability related to air quality has been a major driver of energy policy. That said, China's environmental and clean energy policies have mainly targeted local environmental concerns, with climate change a secondary consideration.*
- ***Climate change*** *has, however, played an increasingly central role over time. In 2021, extreme weather events highlighted the risks of climate change and their impact on China's food security. Chinese and international atmospheric scientists have shown that many of China's air quality policies have benefits for reducing greenhouse gas emissions as well.*
- ***Environmental diplomacy****: Climate and environment have been an important aspect of international relations, especially since 2007, when China became the world's largest emitter of CO_2. China is now increasingly willing to assume a global leadership role, capitalizing on its domestic strengths.*

The motivation of China's top leadership in pursuing carbon neutrality is central to whether that transition will succeed. We assess the motivation as high, and furthermore note that the state is pursuing the low-carbon energy transition for several overlapping motives which, in turn, contributes to the sustainability of this policy commitment in the face of significant obstacles.

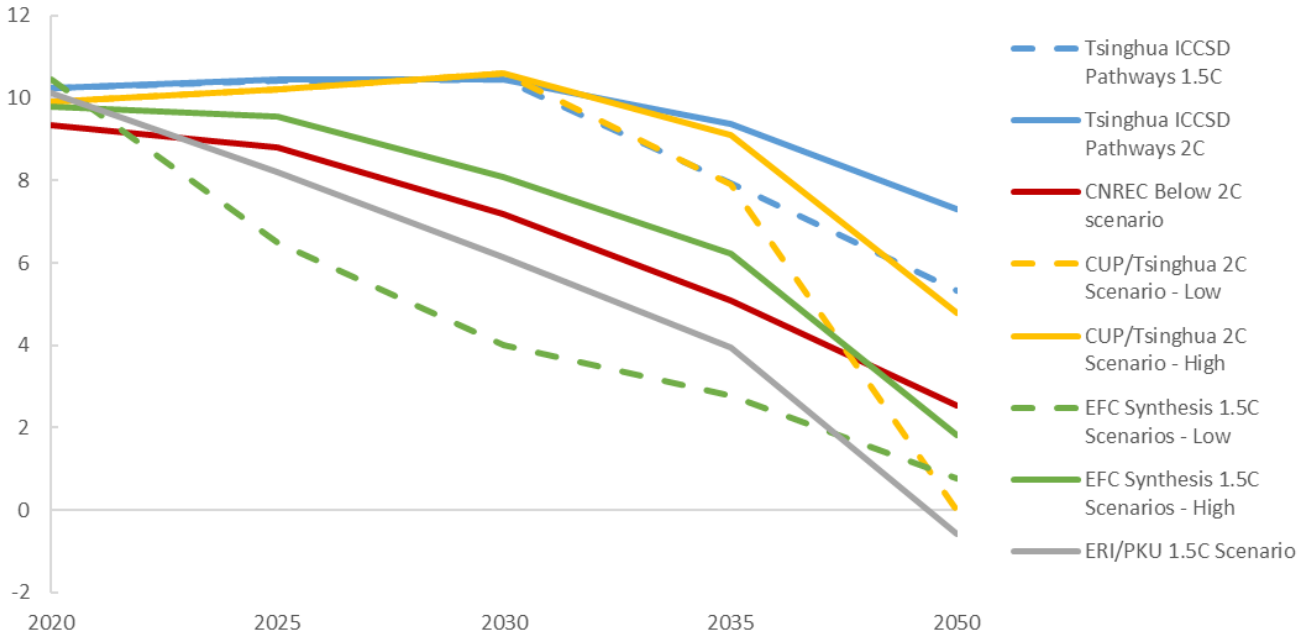
The literature on sociotechnical regimes would suggest that China's energy transition faces huge challenges, given the importance of fossil-fuel sociotechnical regimes and institutional barriers (discussed in greater detail below) to an economically efficient society-wide transformation. Yet China's top leadership has decided to pursue a path to carbon neutrality. It is important to note in this context that China's leaders and planners use phrases other than 'low-carbon energy transition' to describe the country's policies and plans in the field of energy and climate – namely, 'carbon peaking', 'carbon neutrality', 'low-carbon', 'new energy', 'ecological civilization', and 'a revolution in energy production and consumption'.

This paper employs the phrase 'low-carbon energy transition' to refer to both China's prior scaling-up of renewable energy together with its efforts to reduce carbon intensity and the cleaning up of fossil fuel production, as well as to current and future efforts to reach China's 2030 and 2060 carbon peaking and carbon neutrality goals. While the term 'energy transition' is more common outside China, for decades China has discussed and implemented various policies around greening the economy, promoting 'green' manufacturing, enhancing domestic energy efficiency, introducing low-carbon initiatives, and developing technologies to promote more sustainable production and consumption. Moreover, tackling climate change has been recognized as a government priority, gaining in importance in the 2000s, albeit lower on the list of priorities compared to improving local air quality. Prior to the September 2020 pledge, climate change and related low-carbon or clean energy policies had never reached the top of China's policy agenda.

While we employ the phrase 'low-carbon energy transition' in this paper, we acknowledge that there exist many definitions of energy transition,[42] and the concept contains disparate elements that may complement or contradict one another. By design, the phrasing of some Chinese policy concepts allows for flexibility and interpretation: for example, the phrase *carbon neutrality* could refer to all greenhouse gas emissions, or only to some. That said, in July 2021, Xie Zhenhua, China's special envoy for climate change, noted that carbon neutrality includes all greenhouse gases (GHG) such as methane and hydrofluorocarbons (HFCs), not just CO_2, although the 2030 peak referred to CO_2.

Even though the Chinese government has committed to an early carbon peak and to carbon neutrality by 2060, it retains ample flexibility within these goals to pursue a variety of energy transition outcomes. For illustration, a high peak of carbon emissions in 2030 followed by a long plateau and steep cliff could result in double the cumulative carbon emissions of a different scenario with an emissions peak in 2025 and a linear decline to zero. To guide provincial and industry officials away from such an outcome, President Xi announced in April 2021 that China would pursue a flattening of coal consumption before 2025 and start phasing out coal after 2026,[43] which would likely result in a flatter carbon emissions peak.

Figure 4: Comparison of China's CO2 emissions projections



Note: The scenarios include Tsinghua University Institute for Climate Change and Sustainable Development (ICCSD) (lead)'s China's Long-term Low Carbon Development Strategy and Transition Pathways, 1.5°C and 2°C Scenario; Energy Foundation China (EFC, lead)'s Synthesis Report on China's Carbon Neutrality; Jiang Kejun, He Chenmin, et al. (Energy Research Institute, Peking University) Carbon Management paper; China National Renewable Energy Centre of Energy Research Institute (CNREC)'s China Renewable Energy Outlook Report; Pan Xunzhang, Chen Wenying, et al. (China University of Petroleum, Tsinghua University, etc.) Energy Policy paper
Source: CCCI, LBNL[44]

When taken in the context of the current energy system described above, the task at hand is tremendous and the outcome nothing short of transformational.[45] While these changes will create new areas of growth, they also require a radical transformation – if not destruction – of the economically and politically powerful hydrocarbon industry. To assess China's institutional capacity to engage in this change, it is critical to understand the motivations behind the 2060 pledge.

Support for China's clean energy transition comes from the highest ranks of China's political leadership: The overall task of the central government is to manage the political and economic stability and development of the country, and that has typically entailed a heavy focus on managing economic growth. The energy sector has played a starring role in China's economic rise, both in powering other sectors and in absorbing huge capital investment flows. As such, energy has become a critical sector, both economically and politically. In terms of policy, efforts have first and foremost focused on meeting surging demand, while also attempting to diversify energy sources and improve energy efficiency.[46] In the recent two decades, clean energy and climate change have gradually entered the discussion, and reached centre stage following President Xi Jinping's September 2020 announcement that China would target carbon neutrality by 2060.

Although, as mentioned above, it is difficult to pinpoint the starting point of a 'low-carbon energy transition' (as defined above) in China, the government has sought to introduce changes to its supply and demand patterns for reasons related to economic development, ecological protection, and social stability. The primary motivations have changed over time, shifting from economic efficiency and self-sufficiency in the 1990s and early 2000s, to air quality and other domestic environmental concerns in the 2010s, and more recently towards low-carbon policies. Despite the temptation to consider these as

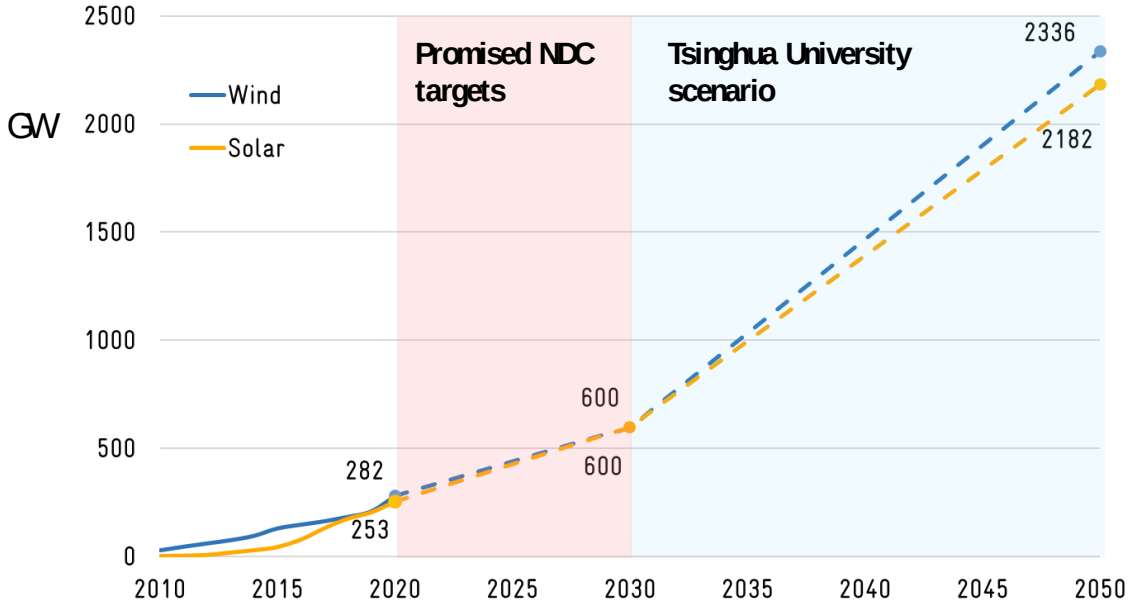
discrete phases, multiple overlapping drivers and motivations have been at work. The following factors currently motivated China's clean energy policies:

2.1 Industrial development

Adoption of advanced energy technology, both for export and domestic consumption, has been a part of China's economic development strategy for decades, including the early development of nuclear power as well as that of wind, solar, and energy storage. From the 1980s and 1990s, China exempted imported wind and solar equipment from some tariff duties to encourage industrial development. In the 2000s, energy technologies were included in various lists of encouraged technology, such as the Catalogue of Currently Encouraged Industries, Products and Technologies in 2000,[47] the Guiding List of Industries for Foreign Investments in 2002,[48] the 10th Five-Year Plan (2001–2005),[49] the Preferred Industries for Foreign Investments in Central and Western Regions in 2004,[50] and the sustainable-development strategies of more than 20 provinces.

The country's 10th Five-Year Plan set targets for wind, solar PV, solar water heating, and biomass capacity additions, as well as for employment in these sectors, stating explicitly that the country should have 10–15 internationally competitive companies in the solar water heating field by 2005.[51] From 2007 to 2012, China's renewable energy sector got a boost from the Clean Development Mechanism under the Kyoto Protocol. In the peak years of CDM, China was responsible for the majority of CDM projects registered, and most of these were in the renewable energy sector. China's law on participation in CDM specified, among other things, that projects must be undertaken by Chinese enterprises, and that they should promote the transfer of technology to China.[52] China's 2005 Renewable Energy Law, modelled in part on Germany's Renewable Energy Law, targeted wind and solar for development – requiring that grid companies purchase energy from these sources – and established a subsidy fund. Also in 2005, China set a 70 per cent domestic content requirement for all new wind plants, to encourage development of a domestic industry.[53] Though the domestic content requirement was rescinded a few years later, in the interval domestic producers largely replaced imports for key components.

Figure 5: China's long term targets and scenarios for installed renewable capacity



Source: State Council of China, 20 December 2020 and National Energy Administration, Jan 2021, Institute of Climate Change and Sustainable Development at Tsinghua University, April 2021

In early 2006, the National Program Outline for Medium and Long-Term Development of Science and Technology (2006–2020) included indigenous innovation and sustainable development as pillars for technology progress in industry.[54] In 2007, China's Renewable Energy Development Plan foresaw that clean energy technologies would develop rapidly, holding the potential to supplant fossil energy sources, and set explicit targets for wind, solar, biomass, and for non-hydro renewable shares of energy

and electric power for 2010 and 2020.[55] Renewable energy and new energy vehicles were listed among the Strategic Emerging Industries in 2011.[56] Wind and solar energy capacity targets featured prominently in the country's five-year plans, starting with the 11th Five-Year Plan.[57] The China 2030 Report summarized the strategy of policies to encourage clean energy industries explicitly in economic terms:

> 'The intention is to encourage new investments in a range of low-pollution, energy- and resource-efficient industries that would lead to greener development, spur investments in related upstream and downstream manufacturing and services, and build international competitive advantage in a global sunrise industry'.[58]

Wind and solar played a key role in China's economic expansion after the 2008 world financial crisis, including the expansion of solar PV manufacturing for export. Following the introduction of anti-dumping tariffs against solar imports from China by various countries in the early 2010s, China boosted domestic installations of PV plants using higher capacity targets and attractive feed-in tariffs, illustrating the importance of preventing an all-out collapse of the new industry.[59] During this period, management of the solar sector shifted from the Ministry of Science and Technology (MOST) and the Ministry of Industry and Information Technology (MIIT) to the newly created National Energy Administration (NEA), a department of the National Development and Reform Commission (NDRC), showing that it had achieved scale as an energy source,[60] as it had effectively transitioned from being a matter for technological and industrial development, to being an energy resource regulated by the central planning authorities.

In a similar vein, China's nuclear energy programme dates to the 1970s and has received sustained financial and policy backing from the state domestically.[61] The country now hosts the world's largest ongoing programme for constructing nuclear power plants. At the same time, it has developed substantial indigenous expertise, as well as capacity, for research, design, and construction. The initial rationale for developing nuclear energy was to provide an additional source of electricity supply to support industrialization. As concerns relating to greenhouse gases and air pollution have grown, the emphasis has shifted towards the environmental benefits of nuclear power. The other policy objective is to allow China's nuclear power companies to play a leading role in the international market. Two of the country's main nuclear power companies, CNNC and CGN, have built on French designs to develop an indigenous Generation III reactor, Hualong One. The first of these, Fuqing 5 in Fujian Province, went into operation in January 2021. Eight others are under construction. The Hualong One design is also intended for export. Chinese companies have been pressing ahead with a variety of new technologies that they hope to export as well. These include high temperature gas-cooled, molten salt and fast neutron reactors, as well as floating plants.[62]

The country's five-year planning process and other documents have repeatedly emphasized technology and, over time, have moved to consider distributed clean energy as a trend. With economic activity gradually slowing in the 13th Five Year Plan – and, with it, energy demand growth – the focus has shifted from adding the 'hardware' of new energy supplies, to developing the 'software' to manage more effective and intelligent energy development and uses. The 13th Five-Year Plan for Energy Development contains a section on '"Internet +" intelligent energy development' and promotes various smart technologies for monitoring and managing energy use and generation, as well as for enabling markets. The 13th Five-Year Plan states:

> 'With the support of smart grids, energy microgrids, electric vehicles and energy storage technology, we can develop a distributed energy network'.[63]

In late 2020, the 19th Central Committee meeting of the Chinese Communist Party called for the development of the 14th Five-Year Plan to reflect a shift from rapid economic growth to 'high quality economic growth'; it also emphasized self-sufficiency in technology, and listed 'clean, low-carbon, safe and efficient use of energy' as one field of the energy and environmental sector to further promote.[64] In 2020, China's macroeconomic policy priorities in the wake of the Covid pandemic were summarized in a New Infrastructure Policy, which included EV charging and high-voltage transmission (seen as key to integration of more utility-scale renewable energy) as priorities for investment.[65] In its 2020 economic work plan, the National Development and Reform Commission emphasized new energy vehicles and

energy storage as targets for development of 'high quality industries', and included renewable energy and high-voltage grid investments under the heading of 'energy security'.[66]

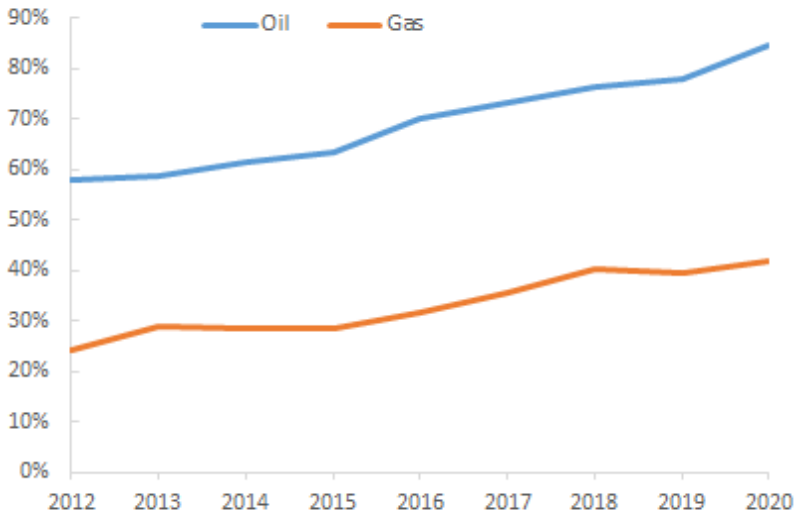
To summarize, sustainable development and renewable energy began to be included as national economic and industrial development priorities in the 1990s, and this trend accelerated after wind and solar began to achieve scale between 2005 and 2010. China's wind industry development preceded the CDM, but CDM projects played a role in scaling up the industry and reducing costs, and Chinese energy analysts began to forecast that wind could become economically competitive with coal. A similar process took place with solar, where an industry developed initially around exports, then transitioned to become a domestic energy source over time. Battery energy storage, new energy vehicles, high-voltage transmission, and hydrogen have all been developed for a combination of economic and industrial development reasons, with low-carbon being just one of several attributes that make these technologies appealing to central government officials.

2.2 Energy security and geopolitics

Reducing exposure to potential oil import disruptions and oil price volatility played a central role in kicking off alternative energy development in the West in the 1970s, and it has certainly contributed to China's efforts to reduce its reliance on imported crude oil. More recently, a low-carbon energy transition is widely acknowledged to have major implications for geopolitics in several fields, not limited to oil and gas imports. Over the past decade, several scholars have suggested that a transition to clean energy would benefit China's economic and national security, by reducing reliance on imported oil and gas, enhancing domestic energy production of non-fossil sources, diversifying energy sources, and boosting Chinese manufacturing and resource production.[67]

Though China only became a net importer of oil in 1996, today the country imports over 70 per cent of its consumption (see Figure 6), with a worrying trend of rising consumption and flattening domestic production. China is now the world's largest oil importer, placing a large financial burden on Chinese state coffers and posing a strategic threat, with large volumes of imports passing through vulnerable sea lanes that the US navy could potentially use to choke off supplies.[68] As a result, China has been engaged in an 'energy scramble' that some have attributed to its efforts to obtain access to upstream and midstream oil assets and to protect sea lanes militarily.[69] Natural gas use is following a similar trend (see Figure 6), with consumption rising to meet targets for clean air and flexible power production, but domestic supplies failing to keep up with demand. As a result, even though most of China's primary energy derives from domestic sources, various indices of energy security have shown China's situation has worsened over the past two decades.[70] China's clean energy transition initially began with renewable energy, which substitutes for coal rather than for oil, but increasing adoption of electric vehicles has already dented oil consumption and is altering the outlook for future demand growth.[71]

Figure 6: China's oil and gas import dependency (%)



Source: China customs, NBS, OIES

Further, aside from reducing imports, an energy transition based on renewable energy and energy storage has multiple potential effects. By becoming a supplier of wind, solar, and energy storage, China positions itself within an emerging energy industry. Some geopolitical analysts have explicitly posited that countries with greater clean energy R&D and innovation potential will be the biggest winners in a global energy transition – and create new vulnerability and dependency for countries that fall behind.[72]

By dominating the production of key minerals, such as rare earths, China in turn could even become a new global chokepoint for the development and deployment of wind, solar, and batteries – though given the scale of demand, durability, alternative supply sources, and recycling, the relative importance of such minerals to energy security could be far lower than dependence on, or exposure to, consumable fossil fuels such as oil.[73] Lastly, by becoming the leading developer of high-voltage power grids to integrate renewable energy regionally – or even globally – China has the potential to exercise control over key energy infrastructure, and thereby avoid allowing its neighbours or allies to become dependent on others in this regard. At the same time, reduced global demand for consumable oil and gas over the coming decade, when China's own consumption is still expected to rise, makes it a coveted buyer for all producers. But at the same time, falling consumption of oil and gas could lead to instability among producing countries, potentially disrupting China's physical supplies even as prices decline, and creating instability along China's borders.[74] Nonetheless, to the extent that developing non-fossil fuels in China can help mitigate the vulnerabilities associated with imports, they are an important policy goal for the government. With rising geopolitical tensions between the US and China, and given the history of US sanctions on Iran and Venezuela – which impacted global shipping and financial flows – the urgency for China to insulate its energy supply chains is increasing.

2.3 Environmental quality

Concern for environmental quality has risen steadily, becoming a top national priority in recent years. In the 1980s and 1990s, economic development policy, especially at the local level, often took little account of environmental impacts. Economic development policies consciously sacrificed environmental quality, as exemplified by the phrase 'first pollute, then clean up'.[75] However, in the 1990s, sustainable development policies started to grow in importance. In 1994, the publication of China's Agenda 21 White Paper emphasized the need for sustainable development strategies and policies.[76] A research group established by the NDRC published three national reports on sustainable development in 1997, 2002, and 2012, reporting on China's progress on sustainable development issues, summarizing China's policies on human and economic development, and presenting China's position on global climate issues.[77]

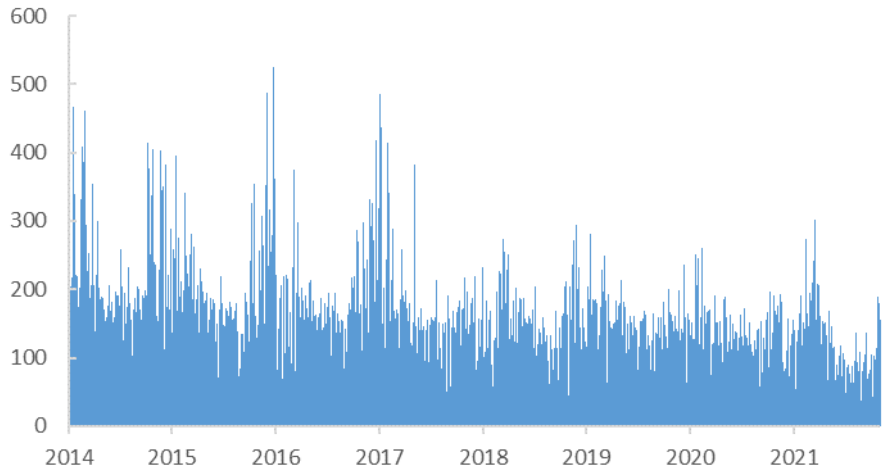
A 2004 central government effort to adopt a measure of 'Green GDP' was dropped,[78] but the concept of quality growth oriented towards sustainability continued to develop. The China 2030 Report, published in 2010 by the World Bank and the Development Research Council of China's State Council, highlighted the importance of environmental sustainability to improve the quality of economic growth and reduce negative economic impacts. The report discussed ways to incentivize local officials to place greater emphasis on environmental quality, raise environmental awareness among the public, and place economic value on both negative environmental externalities and positive environmental protection activities.[79]

Central government concern for the environment was motivated by a variety of factors, including social stability, external image, and expectations regarding the need for environmental quality to achieve a vision of a moderately prosperous society – in which the environment becomes an element of prosperity. During the period of 2000–2015, Chinese scholars continued to pursue analysis based on the hypothesis of the Environmental Kuznets Curve, positing that the economy of China – or of specific regions of China – had reached the stage where further economic growth leads to improved environmental quality rather than degradation, as the public places more value on quality of life and living standards than on income.[80] The validity of the hypothesis and its applicability to China remain contested.

The importance of environmental quality as an objective in itself for the central government has become especially apparent since the introduction of the paradigm of the Ecological Civilization, which was promoted by President Hu Jintao at the 17th National Congress of the Chinese Communist Party in 2007.[81] Between 2007 and 2012, the concept of Ecological Civilization appeared in over 4,000 Chinese

academic articles and over 130,000 media reports.[82] In 2013 a Small Leading Group (SLG) on Ecological Civilization was created inside the bigger central SLG on the Deepening of Socio-Political Reforms, initiated by Xi Jinping. The concept was written into the Chinese constitution in 2018.[83] The definition of Ecological Civilization is extremely broad, embracing water, air, and soil quality; clean energy and climate change; food security and health; and ecosystem health. It is not limited to environmental aspects related specifically to economic development or quality of life.[84]

Figure 7: Beijing PM2.5 levels



Source: Beijing Environmental Protection Monitoring Center

Notwithstanding the Ecological Civilization paradigm, it is widely recognized that China's environmental and clean energy policies have mainly targeted local environmental concerns, such as air quality, with climate change or clean energy as only a secondary consideration, particularly in the period of the War on Air Pollution in the mid-2010s.[85] (See Figure 7.) Alleviating public concerns and social instability related to air quality has been a major driver of energy policy.[86] Aside from public concerns, air quality poses major health costs and other economic damage, particularly in major urban areas.[87] As a result, Chinese leaders have launched both systematic, long-term national policies to reduce emissions from the power sector and other energy-intensive industries, and a range of targeted short-term campaigns and regional approaches. In several cases, the policies bear names or introductory language (Action Plan on Air Quality Control and Prevention, War on Air Pollution, Blue Sky Battle Plan) that speak to both the urgency demanded by the centre as well as the need to involve all actors within the bureaucracy and economy.

While energy transition is not the explicit purpose of such plans, they have necessarily targeted the major sources of urban air pollutants – namely coal consumption in industry, heating, and power and transportation exhaust. Energy policies relating to air quality, such as the coal-to-gas fuel switching policies, or regional and provincial targets for renewable energy, often reference air quality as a goal. Cities with strict air quality control policies have been among the leaders in incentivizing private EV adoption or requiring bus and taxi fleet vehicle electrification.

2.4 Climate change

Though some aspects of the energy transition relate mainly to energy security or economic development, climate change has played an increasingly central role over time. Before China had officially agreed to undertake actions under international climate change agreements, the national government had recognized the potential benefits of climate action via energy policy. In early 1999, the State Development Planning Commission (SDPC), the predecessor of the NDRC, published a study stating that China

> 'views climate policy as a very serious means for reaching goals for the energy supply sector in 2050'.[88]

China's White Paper on Climate Change Science, published in 2008, recognized the country's unique vulnerability to climate change, noting that temperature increases in China have exceeded the global average, and citing China's immense demand for food production on relatively limited agricultural land, and regional imbalances in water availability.[89] In 2020 and 2021, extreme weather events highlighted the risks of climate change and their impact on China's food security. In the 14th Five Year Plan, food and energy security are discussed in a joint paragraph, highlighting these linkages.

Systematically addressing climate change via an energy transition became more compelling as a national priority just as research began to show co-benefits for the climate of actions taken to address air pollution. Although many actions taken to improve air quality have few direct climate benefits – such as the case for shifting emissions-intensive industry to less populated areas – Chinese and international atmospheric scientists have shown that many of China's air quality policies have benefits for reducing greenhouse gas emissions as well. However, end-of-pipe controls (such as sulphur scrubbers for coal plants, or emissions control equipment on trucks and cars) have been found to be insufficient to meet the country's air quality goals: Only combining such controls with changes to the overall energy supply structure would suffice.[90] A combined approach to air quality and climate results in lower overall cost and fewer investments that might be stranded or otherwise rendered obsolete by future policies on greenhouse gas emissions.[91] Indeed, because of China's reliance on carbon-intensive coal, large capital investments to boost efficiency, or to reduce emissions at existing or future coal-burning facilities, have a carbon lock-in effect that would increase the costs of subsequent carbon-related policies.

China's first carbon intensity target was announced by President Hu Jintao in a speech at the UN in September 2009.[92] Domestic policy evolved quickly, with carbon intensity goals introduced in the five-year planning process, and gradual moves towards adopting carbon markets in the power and heating sectors. In 2011, China developed plans for provincial carbon market pilots, and these were officially launched in 2013.[93] Each pilot had its own design, established by local authorities. By 2019, China's eight pilot regional carbon markets saw trading volume of 696 million tons CO_2-equivalent and a cumulative transaction volume of RMB1.56 billion,[94] out of overall national emissions of around 10 billion tons annually. In 2020, by comparison, the European Union ETS saw trading volume of over 9 billion tons.[95] Thus far, several studies have shown that China's emissions pilots have not resulted in a decrease of emissions,[96] and may have been designed more to test and strengthen market institutions such as monitoring, reporting, and verification.

Plans for a national carbon market were included in China's 2015 draft Intended Nationally Determined Contribution (INDC) to the United Nations climate change framework, and an initial design for a national market was published in 2017.[97] In mid-2019 China announced that power markets would trade carbon credits on an emissions intensity basis, avoiding binding emissions caps.[98] China's subsequent 2020 commitment to pursue a carbon emissions peak before 2030 and carbon neutrality by 2060 suggested that China's climate-related policies – including carbon markets – might become more ambitious over the next few years. Indeed, in July 2021, China officially launched its national carbon market.

Figure 8: China climate targets

	2016 NDC	2021 NDC
	1. To achieve peak CO2 emissions **around 2030** and making best efforts to peak early; 2. To reduce CO2 emissions per unit of GDP **by 60-65% from the 2005 level** 3. To increase the share of non-fossil fuels in primary energy consumption **to around 20%** 4. To increase the forest stock volume by around **4.5 billion cubic meters** on the 2005 level	1. To achieve peak CO2 emissions **before 2030** and making best efforts to peak early 2. To reduce CO2 emissions per unit of GDP **by over 65% from 2005 level** 3. To increase the share of non-fossil fuels in primary energy consumption **to around 25%** 4. To increase the forest stock volume by around **6 billion cubic meters** on the 2005 level 5. To bring total installed capacity of wind and solar power to over 1.2 billion kilowatts by 2030
Absolute emissions level*	13,744-15,194 MtCO2e	13,205-14.045MtCO2e
Emissions compared to 1990 and 2010*	1990: 321-365% increase 2010: 26-39% increase	1990: 263-287% increase 2010: 20-28% increase
Net zero target	No	Yes, by 2060

*Excluding land use, land use change and forestry

Source: Climate action tracker

2.5 Environmental diplomacy

China has a long history of participation in international negotiations on environmental issues, and the central government has consistently treated the topic as an important aspect of international relations. As early as 1989, the phrase *environmental diplomacy* entered the Chinese lexicon in an important speech by Song Jian, director of the environmental protection committee of China's State Council, stating,

> 'If we [large developing countries] can adopt a common stance, it will help strengthen China's status and let us speak for the peoples in Third World'.[99]

In the decade that followed, China established a position that recognized the need to address climate change, while stating that China would not take action until reaching middle-income status, and that industrialized countries bore primary responsibility for most historic emissions and should therefore shoulder most of the burden of addressing climate change. By adopting a position in favour of 'common but differentiated responsibilities' for developing countries, China sought common cause with countries of developing Asia, Africa, and Latin America. China also saw this position as an inducement to encouraging technology transfer to China.[100]

After 2007, when China became the world's largest annual emitter of CO_2, its position in climate talks began to attract more controversy. During and after the 2009 Copenhagen climate conferences, several climate negotiators portrayed China as the main obstacle to an international agreement.[101] Over time, China's position evolved, as the country's negotiators sought to simultaneously maintain flexibility, resist a binding cap on emissions, and obtain recognition of the need for funding from wealthier nations, while also avoiding negative publicity. The country's changed development status as a middle-income nation implied a new approach to international climate negotiations. In 2014, President Xi leveraged the climate issue to reach a bilateral climate accord with US President Barack Obama, which laid the

groundwork for the Paris Climate Agreement the following year. China's Nationally Determined Commitment (NDC) to address climate change included provisions that matched previously announced long-term targets in non-fossil energy, and set targets for carbon intensity and carbon peaking that many analysts viewed as reflecting trends and policies already underway.[102] The country declined to adopt any cap on carbon emissions.

In the years that followed, China's position evolved rapidly, especially after the election of Donald Trump in the US and his withdrawal from the Paris Agreement; this left an opening for China to use climate to improve its image as a responsible player. Speaking to world leaders at the World Economic Forum in 2017, President Xi also urged the US to remain in the Paris Climate Agreement. China now seeks to be seen as leading on the issue of climate change.[103] Xi Jinping, at the 19th National People's Congress in 2017, stated that China would take a 'driving seat in international cooperation to respond to climate change' and become a 'torchbearer' in creating an ecological civilization.[104] In September 2020, President Xi announced China's new target of carbon neutrality by 2060 and carbon peaking before 2030, declining to make the surprising announcement in a bilateral statement with the European Union – apparently to emphasize China's leadership role on climate.

Beyond climate talks, domestic clean energy and low-carbon policies have the potential to create national soft power, as has been cited in the case of Germany.[105] Indeed, environmental soft power was discussed at the same 2007 Party Congress where Ecological Civilization was adopted as a key goal.[106] Beijing smog during the period 2008–2014 appeared to many observers as a national embarrassment, highlighting the flaws in China's economic and social model. Since then, progress in environmental quality – and in air quality in particular – has partly reversed this, and China's efforts on air quality can be seen as a model for scientific approaches to improving environmental quality. Journalists have cited China's clean energy leadership as an example of soft power,[107] and European and American policy makers have even sought to position their own clean energy policies as a strategy to counter or compete with China in this aspect of soft power.[108]

Climate and environmental issues can also serve as a trade bargaining position – and indeed, that is already happening. China has been critical of plans to establish a carbon border tax in the EU,[109] and climate change was a central point of negotiations in the talks leading up to the 2020 EU–China investment agreement.[110] Some Western journalists have portrayed China as using climate change as a 'bargaining chip' for talks with the US.[111] After the advent of the Biden Administration, China rejected the concept of a separate track on climate change cooperation with the US, linking progress to US non-interference in Hong Kong, Tibet, and Xinjiang, as well as harmonious relations on other issues, likely including trade.[112]

These five drivers of China's low-carbon energy transition – industrial development, energy security, environmental quality, climate change, and environmental diplomacy – now converge more than previously. Several factors could explain this convergence: The cost-effectiveness and global competitiveness of China-made wind and solar, the near-term potential to develop an electric car industry for both domestic consumption and export, the greater experience that China's national, local, and economic leaders have with clean energy technology and policy, and the risk that China could fall behind technologically if it can't follow other leading economies in decarbonizing its economy and society.

The commitments to peaking emissions by 2030 and achieving carbon neutrality by 2060 are driven by a number of converging interests and come from the highest echelons of the Chinese Communist Party. Will China's strong central government be more effective than more liberal governments around the world in delivering the energy transition?

3. China's institutional setting both helps and hinders the energy transition

- *While the Chinese leadership is clearly committed to its 30–60 targets, especially given that there is now a greater convergence of interests to pursue them, challenges remain. Ministries and local government have, at times, incentives to either go slow on low-carbon policy or to promote high-carbon or energy-intensive industry as a development strategy.*

- *Policy implementation is also **fragmented**. In the context of a strong central government that sets policies, implementation is left to ministries, state-owned enterprises, and industries that compete for resources and for input into the policy-making process. Provincial officials and state-owned enterprises sometimes engage in protectionism to pursue their own interests, or are caught between competing policy priorities.*
- *Central government regulators have **limited capacity**, which hinders their ability to manage complex processes. Furthermore, they are constrained by the power of provinces and large energy SOEs. What is more, limited central government capacity means that corporate actors and industry associations support policy making and provide technical inputs. This, in turn, influences the ability to design and implement energy transition-related policies and overcome resistance.*
- *Provincial governments often support local companies – typically prioritizing state-owned entities over private companies – which can favour businesses with low productivity, thereby hindering innovation and efficiency. Local protectionism can also lead to siloed technology adoption.*
- *But provincial power structures also enable experimentation, as the central government often initiates pilots at local levels, and competition among provinces can support pilots of new technologies and diverse business models.*

Whereas in the previous section we showed that central government has several strong motivations to pursue a long-term, low-carbon energy transition, in this section we look in detail at China's government institutions at various levels, showing several institutional aspects that either help or hinder this transition. At the broadest level, it is widely understood that China's central government drives the country's low-carbon energy transition, while elements within the bureaucracy and local government at times have incentives to either go slow on low-carbon policy, or may even promote high-carbon or energy-intensive industry as a development strategy. Limited capacity at key institutions, fragmentation of authority, and structural economic incentives work against the energy transition in the short- and medium-term.

China's centralized political and economic systems are often cited as important aspects of its ability to engage in the energy transition. China's primary government authority rests in the Communist Party of China (CPC) and in the National People's Congress (NPC). The importance of the CPC and its control over policymaking has been strengthened by President Xi Jinping since he took office as Party Chairman in 2012. Three bodies stand at the apex of the CPC: the Central Committee with about 200 members; the Politburo with 25 members drawn from party and government organizations, the military, and provincial-level bodies; and the Politburo Standing Committee.[113]

China has historically featured a strong and hierarchical government, and a political culture that largely accepts a strong, central government structure with the ability to exercise direct or indirect control over wide aspects of government policy, public welfare, and individual behaviour. Within the energy and environment field, the central government's inclination towards adopting stricter policies favouring lower emissions and low-carbon energy has been described as having the features of authoritarian environmentalism – that is, top–down policies driven by central government environmental and energy goals, with relatively low contribution of public inputs or societal dialogue.[114] Indeed, some authors have represented China's state development approach to the low-carbon energy transition as a fundamentally different model that challenges earlier Western literature on the energy transition as a participatory and bottom-up change.[115] While these characteristics point to a capacity to drive change from above there are, nevertheless, many aspects of the organization and capabilities of the central government which temper this understanding of China as a highly centralized state power, particularly including aspects within the energy sector.

But just as the central government has multiple motivations for pursuing a low-carbon energy transition – which at times coincide and support a more concerted and coordinated approach toward implementing the energy transition – it also has competing objectives which could complicate China's ability to pursue decarbonization.[116]

3.1 The limits of China's centralized power:

Fragmentation

Delegation of both policy decisions and implementation to powerful bureaucratic actors, including state ministries, state-owned enterprises, and industries, leads to a situation that has been long described as 'fragmented authoritarianism'.[117] There exists a high degree of competition among Chinese government bureaucracies responsible for aspects of the energy transition, as well as resistance from provincial officials and SOEs engaged in local protectionism.[118] The day-to-day management of energy policy – which includes setting and monitoring targets, approving projects, setting development priorities, regulating prices, and establishing markets for energy and emissions – rests with various ministries, provincial bureaucracies, and industry officials. Energy and energy-related environmental policies are subject to an extensive bargaining process, largely behind closed doors, in which relevant bureaucratic groups and industries define policy and constrain its implementation.[119]

Fragmentation results from several factors, including overlapping or separated responsibilities for interrelated fields, as well as from limited capacity. Responsibilities for managing aspects of the energy transition policy are split across various ministries and agencies responsible for energy prices, competition, regulation, land use, project approval, and reforms.[120] For example, the relatively newly-created Ministry of Ecology and Environment has overall control over the development of a market for carbon and for evaluating provincial carbon market pilots, whereas the National Energy Administration (NEA) has primary authority for overseeing and implementing electricity market reforms. Yet energy prices – which inherently relate to both carbon markets and electricity markets – are the responsibility of the National Development and Reform Commission, of which the NEA is only a part.

Limited capacity

After Reform and Opening, management of the energy sector underwent significant decentralization. While central planning is still important, the limited capacity of central regulators hinders their ability to manage a complex energy transition that sometimes conflicts with powerful local and SOE interests. Although in 2018 there was some speculation that China's relatively small National Energy Administration would be upgraded to a full ministry, this has yet to happen.[121] Various corruption investigations have also weakened the authority of the NEA over the last decade.[122] The regulatory function of the NEA is also constrained by the power of provinces and large energy SOEs to mainly regulate themselves, particularly in the field of power system design and operation.[123] The limited size and authority of the NEA results in local governments exercising significant control over project approval. This is particularly the case in the power sector, after the NEA delegated coal plant approvals to provincial officials in 2014 to streamline procedures.[124] Though provincial officials and SOEs are supposed to follow overall central government guidance, especially when policies are ambiguous, energy companies – including oil and gas companies, electricity generators, and transmission grid companies – can circumvent or slow-walk central policies and objectives.[125]

Limited central government capacity also influences its ability to design and implement energy transition-related policies and to overcome resistance. For example, the NEA had only 240 administrative staff as of 2019.[126] (By comparison, the US Department of Energy has a budget of over US$34 billion and nearly 20,000 civilian staff – though given the DOE's different structure and the inclusion of various national labs and nuclear facilities, the two are not directly comparable.) Chinese central government departments are relatively small compared to their US counterparts: the budget for the NDRC is RMB1.2 billion, for the NEA it is RMB1.3 billion, and for the MEE, RMB14 billion. These figures include some regional functions but exclude the provincial divisions of NEA, MEE, and DRCs. (The Guangdong provincial NEA budget is RMB39 million, for example, while the Jiangsu provincial MEE has a budget of over RMB1 billion.) These figures can help explain the limitations of authoritarian environmentalism in China, given that in some fields, national or local authorities lack staff to design and implement policies, or to gather statistics and data to monitor implementation.[127]

3.2 Provincial governments as a source of regime resistance

In the energy and environmental fields, provinces have major authority to guide development, investment, targets, and regulation. This system has been dubbed the 'M-power structure' or 'M-form structure', in the sense that governance has multiple layers and multiple regional loci.[128] Within many

industrial fields, provincial policies have emphasized self-sufficiency at the provincial level. From an early stage, the strong role of provinces has had negative effects on development; this is particularly due to provincial protectionism, development of industries at suboptimal scale, and excessive intervention in markets by local officials.

The provincial power structure has resulted from an ad hoc process largely driven by provincial governments and provincial officials themselves, who had the incentive to build local power bases to ensure performance against economic evaluation indicators. The central government largely acquiesced in this system because it solved the twin problems of employment and revenue.[129] From the early days of the Reform and Opening period, provinces had incentives to encourage the start of new companies, including both spinoffs of government institutions and purely private companies, which would often receive subsidized land, tax incentives, or other preferential treatment. The result is known as 'local state corporatism'.[130]

Local state corporatism is not only responsible for the rapid build-out of new companies in sectors targeted for development, but also for duplication and segmentation along provincial and regional lines. As early as the 1970s, economists noted the lack of differentiation among provincial development plans and the pursuit of resource and technology self-sufficiency by provincial officials, leading to the development of what has been called the 'cellular economy'.[131] Within the energy sector, the combination of protectionism for in-province energy companies and competitively promoting investment in local energy infrastructure is sometimes known as *difang boyi*, or the *provincial game*.

At various times, including in recent years, provinces have pursued policies that resulted in excess production capacity and over-investment in coal, steel, and renewable energy production. There is a clear connection between state planning and overcapacity, which is especially strong in provinces with a lower proportion of private enterprise.[132] Overcapacity has been attributed to anticipation of growth by local officials and enterprises, as well as to provincial responses to central government signals on emerging industries. Often, central government priorities – such as in wind, solar, electric vehicles, or hydrogen – have resulted in provincial copycat promotion of new companies. Cities sometimes dedicate whole districts to targeted technologies, which may or may not pan out.[133] Provincial grants of land, tax incentives, and other interventions to favoured industries can result in industrial overcapacity.[134] Since local governments often allocate resources to failing firms, and grant non-monetary incentives to businesses with low productivity, local policy can work against innovation and efficiency.[135] Powerful SOEs at the local level have close links to local officials: Local SOE managers are often promoted to local government positions.[136] Local SOEs are responsible for implementing local development plans, as well as for contributing to social stability through employment and provision of social benefits.[137] Given the mutual dependence of local SOEs and provincial and local officials, SOE managers face a soft budget constraint, and this can result in overinvestment in incumbent or monopoly industries and less attention being paid to emerging technologies in more competitive fields.[138]

As with bureaucratic fragmentation, the central government has undertaken a variety of actions to redress provincial and regional policies that work against central government policy. Strengthened environmental targets and performance evaluations for firms, provinces, and officials; temporary campaigns such as the Action Plan on Air Pollution Control and Prevention, or the coal-to-gas switching campaign; restrictions on industry capacity in fields deemed to suffer from overcapacity; and specific planning restrictions such as capacity quotas for subsidies, or the traffic-light system (known as the Early Warning Indicators) adopted by the NEA to clamp down on wind, solar, and coal plant construction in certain provinces.

Other institutional factors limit the ability and motivation of local officials to pursue wide-ranging and integrated plans for low-carbon energy transitions. Local government functions centre on providing public services such as energy, water, and transportation at low cost, and enabling rapid economic development. To deliver these services, local governments have limited sources of revenues, and often rely on selling real estate to developers as a major source of funding – this can represent anywhere from a third to a half of local revenues in some years.[139] Low-carbon development often entails integrating across functional areas, and may involve new design practices, new materials or technologies, and in some case extra expenses and maintenance over the life-cycle of long-lived buildings, transport, and other infrastructure. Local officials in some cases have tended to focus on the

simplest, single-function activities that can be accomplished quickly, are easy to quantify, and require minimal coordination across municipal functional boundaries. Technologies that receive subsidies or promotion from the central government have priority. Actual operations and maintenance may be an afterthought. For example, in the prominent eco-city of Baoding, officials focused on installation of LED streetlights, addition of PV panels to power traffic lights at major intersections, and planting of gingko trees along major roads. Officials noted that targets or concepts such as 'low-carbon' would only be implemented if attached to measurable activities. Only a few years after the completion of the eco-city project, due to lack of funds for maintenance, many of the LED streetlights had been replaced by conventional sodium lights and PV panels had been removed.[140]

Within the buildings sector as well, local officials often desire to promote sustainability and low-carbon projects to attract attention and development, sometimes partnering with international architectural firms and equipment suppliers. However, real estate developers and construction firms are focused on short-term performance, and particularly on rapid construction and sale of real estate projects. While real estate and construction firms do have some motivations that coincide with low-carbon development, such as increasing the value of state-owned assets and enhancing their reputation, their focus is on maximizing the return on investments.[141]

Of course, there are also institutional incentives at the local level that directly counteract efforts to promote a low-carbon energy transition. For example, efforts to promote building energy efficiency and clean heating have run into opposition at the local level, where local governments derive revenue from district heating plants that charge customers on a floor area basis.[142] Local officials have also promoted combined-heat-and-power, giving local coal plants must-run status in the winter, and resulting in curtailment of electricity produced from wind plants.[143]

This example also points to regional and local differences among local institutions as they relate to energy transition processes. In the case of electric mobility, Shanghai has historically instituted subsidies to new energy vehicles that included plug-in hybrid electric vehicles, even when evidence emerged that many customers purchased vehicles without the ability to charge them, just to take advantage of subsidies. Shenzhen and several other cities, in contrast, promoted subsidies limited to pure battery electric vehicles. The difference arguably reflects the presence in Shanghai of a major SOE automaker, SAIC, whereas Shenzhen has long served as the heart of China's information technology and electronics industries.[144] Local and regional protectionism has also led to siloed technology adoption, with mandates or subsidies for taxis, buses, and government fleets targeted at locally-made EVs, and with EV manufacturers sourcing parts and batteries from local firms.[145]

Punctuated equilibria, campaign governance, and inspections

Limited bureaucratic capacity and divided attention among multiple interrelated priorities, combined with resistance from provincial and industry officials, leads to periodic efforts by top leadership to regain control, overcome resistance, and reset priorities. As a result, China shows some of the features of punctuated equilibria, both over the short term, through campaigns lasting a few months or years, or over longer periods, when new policy priorities are established by the centre via slogans and targets.

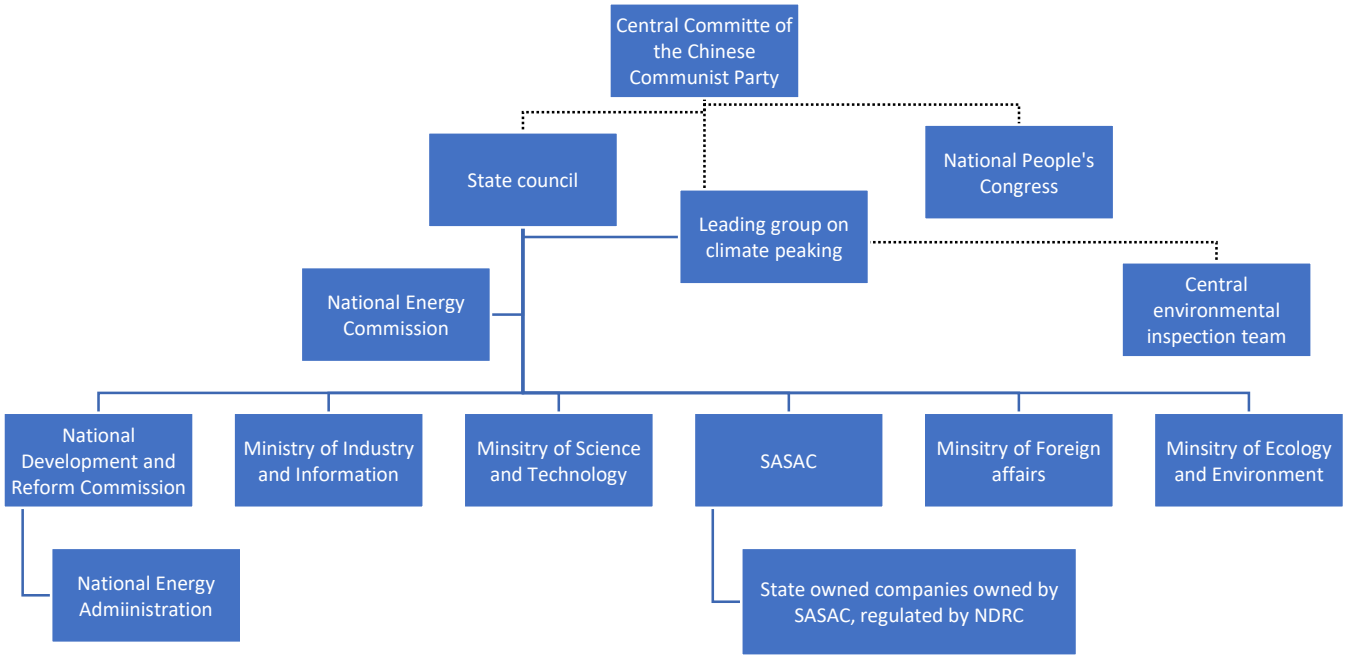
While the theory of punctuated equilibria originates from political systems featuring a degree of pluralism and potential for public participation, the theory described by Baumgartner and Jones rests, to a large extent, on changes in equilibria driven by shifting relationships among bureaucratic actors and politico-economic subsystems, such as within an industrial field and related professions.[146] China's central government institutions also show features of punctuated equilibria: One recent study has shown that, within the environmental field, the organization of Central Leading Groups can illustrate relatively rapid shifts in priorities and bureaucratic management.[147] Evidence from China also indicates that the country's relatively limited public feedback mechanisms can lead to sharper changes in policy when government officials finally recognize the need for change.[148] This process may have been at work in the case of air pollution, where a high degree of negative publicity in turn led to a major government response. Notably, China in 2021 also established a new Central Leading Group on Climate Change.[149]

So, while fragmentation and limited capacity can hinder effective policy implementation, punctuated equilibria can support rapid and sharp changes in policy: Short-term policy campaigns are one method by which central officials can exercise control and overcome resistance to policy priorities. Campaigns are communicated within party structures, via public slogans and posters, and through speeches by top

leaders, but without establishing long-term institutions and market incentives to match. Such campaigns can last a season or multiple years, and have often been employed in the energy and environmental sectors, as exemplified by the War on Air Pollution (2013–2016), and the Jing-Jin-Ji coal-to-gas switching campaign that led to heating shortages in 2017–2018. While, over the past decade, numerous studies have pointed to the drawbacks of relying on temporary campaigns to address long-term policy issues, campaigns remain a feature of governance, both in short-term crises like the Covid-19 pandemic, and when dealing with structural issues such as industrial overcapacity or air pollution.[150] Arguably, since Xi Jinping's 2030 and 2060 pledges in September 2020, the 'dual carbon goals' have also become the subject of a political campaign, though in mid-2021 central officials called on local officials to avoid campaign-style climate and energy measures.[151] Campaigns are most prominent in policy areas where long-term structural tensions between central and local interests hinder consistent enforcement of central government policies, such as in environmental protection.[152]

Inspections from senior party officials are another way for the central government to exercise control and overcome resistance, and inspections can clearly signal to the bureaucracy and other stakeholders that certain policy priorities must be considered as pre-eminent, or responsible officials may face punishment. This mechanism has been used most vividly in 2020–2021 to signal to energy regulators that central officials were dissatisfied with the implementation of energy policies by the NEA. The Central Environmental Inspection Team (CEIT) was created by President Xi Jinping and reports directly to the Central Committee of the CPC. The CEIT can pursue investigations more like investigative journalists, with avenues for public input and complaints. The CEIT is directed by Han Zheng, the senior Politburo member for environmental matters.[153]

Figure 9: The Central Environmental Inspection Team in the context of China's Party–State



Source: Authors' analysis

The result of the CEIT's inspection of the NEA, which was simultaneously published on the websites of NEA and MEE in January 2021, indicated that the CEIT found discrepancies in the excessive approval of coal plants, planning of high-voltage power lines with low proportion of renewable energy, and an overall lack of seriousness in supervising provincial projects.

> ‘After [NEA-delegated] approval of coal-fired power generation projects, supervision was not put into place, and [as a result] some key regions are violating the relevant requirements for new coal-fired power projects’.

This results in ‘what should be built is not built, and what should not be built is built’.[154] Though the inspection document mentions only air quality and omits climate change, it is significant for the management of the energy transition because it could force the NEA to strengthen policies towards coal and renewables just prior to the 14th Five-Year Plan draft and just after the central government’s carbon neutrality announcement. In its formal reply to the inspection, the NEA focused on strengthening its monitoring of provincial energy caps and intensity targets, while promoting efficient coal plants and retiring smaller, older plants – concepts that suggest more continuity than change.[155]

Central inspections have also been a key tool in keeping provinces in line with national enforcement, complying with the campaign style mentioned above.[156] There are indications that the central government intends to use inspections as a way to fundamentally address the issue of fragmented environmental and economic governance, boosting the priority that local officials attach to environmental policies over the long term, and thereby reducing the sense that environmental governance is managed through campaigns or shifts in central government agendas. However, some analysts have noted that inspections mainly constitute a ‘stick’ for officials or local governments they deem to have performed poorly, and provide no systematic positive incentive for long-term good performance or innovation. Further, officials sometimes lack the specialized policy training to apply complex reforms to incentivize low-carbon investment or performance, and may apply simplistic or short-term measures.[157]

Local governments as drivers of innovation

The provincial power structure has also had benefits for development, by enabling experimentation and competition among provinces, resulting in a race to the top in terms of economic growth, innovation, and tax revenue. China’s system of provincial pilots represents an institution that helps support both policy and technology innovation. The central government often initiates pilots at provincial or local level and encourages experiments with different designs for new market institutions – such as in the case of carbon, green finance, electricity demand response, and electric power spot markets.

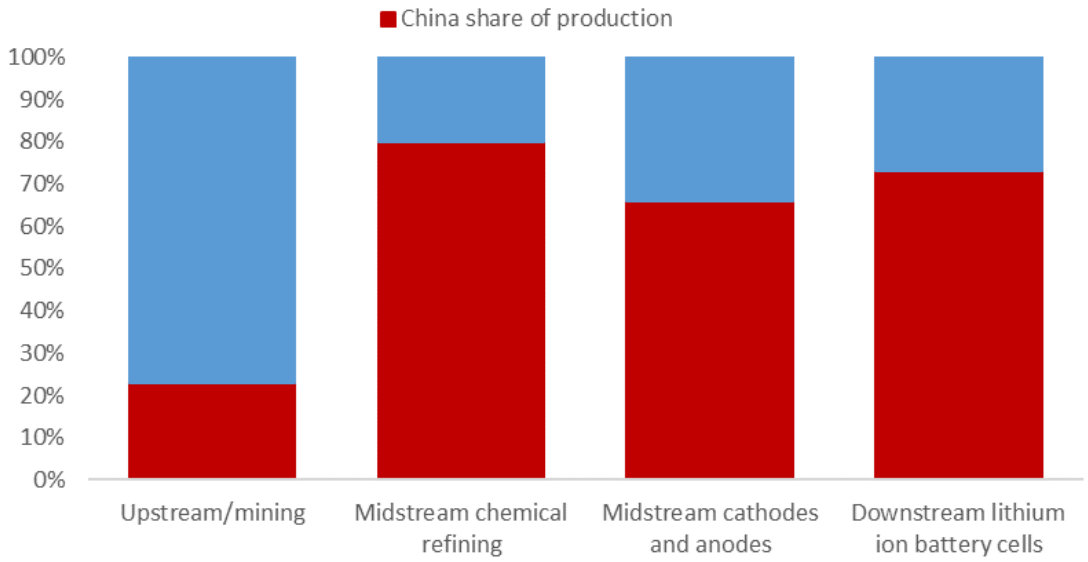
Provinces also pilot new technologies, such as wind, solar, and electric vehicles. In these cases, provincial policy makers not only promote new industries through subsidies and supportive policies, but also interact with, and co-create, institutional paradigms and policy frameworks that determine the development path of new industries – often subject to the heavy influence of incumbent industry players. For example, Yang et al. show how both Inner Mongolia and Jiangsu province pursued policies to support solar PV, but with very different paradigms and results:[158] The nascent solar manufacturing industry in Jiangsu and large industrial customers worked together to develop and support a paradigm of decentralized energy production and consumption – including both residential and industrial models. In Inner Mongolia the solar industry, grid companies, and coal companies worked together to privilege a model of large-scale, central solar production paired with long-distance transmission for export, and incumbent players successfully demonized renewable energy as unreliable for local grid integration and consumption. A similar model of provincial policy innovation has taken place in the field of EVs – as we will discuss below.[159]

While piloting does enable experimentation and diversity, at the same time China’s provincial and local pilots are hardly a free-for-all. A 2016 study of China’s innovation policy by Chen and Naughton found that most pilot policies emerge from above, and provinces adopt such frameworks with only minimal adaptation or specialization.[160] A 2016 study of solar promotion at the provincial level found that provincial officials in Jiangsu and Zhejiang province either adopted central policies with little or no changes, seeing provinces as restricted to an ‘assistant’s role’.[161]

While much of the energy transition literature, including this article, focuses on national and provincial aspects and on the large-scale production and consumption of energy, it is widely recognized that cities and other local areas, with their myriad of local and national institutions, serve important energy policy functions: determining how energy is consumed, the design and use of energy and transportation infrastructure, and the shaping of the overall low-carbon paradigm across all levels of society. According

to the vision in which distributed renewable energy production, storage, and utilization combines with energy efficient and low-carbon buildings, cities would obviously play a major part.

Figure 10: China's share of lithium-ion battery production and supply chains (%), 2019



Note: Includes lithium, Cobalt, Nickel, Graphite, Manganese, Cathode, Anode
Source: Benchmark Minerals

In China, low-carbon cities and eco-cities have been a major theme of development for over a decade. These initiatives differ sharply from those in Europe or the Americas: Chinese low-carbon and eco-cities are often geared towards developing visually attractive, high-end properties to attract property buyers and foreign companies – sometimes leading to conflicts with architects and advisors seeking to implement more ecologically transformative changes involving clean energy, density, or walkability.[162] Many eco-city initiatives have been driven primarily by government officials aiming to raise local economic performance, diversify regional development by attracting new investment, obtain approval for new infrastructure projects, and showcase new technology.[163] When highly motivated, local officials have wide-ranging abilities to integrate policies across land use planning, energy, water, building design, and transportation. Local government can also convene key stakeholders and mobilize expert advisors and consultants – in some cases, bringing academic experts into short-term consulting roles to manage across functions and ensure targets are met.[164]

Other local stakeholders can also play a positive role in local energy transitions. In some instances, SOEs have helped design and manage projects that integrate across multiple aspects of city management. For example, in the case of the Hongqiao district of Shanghai, a local heating SOE helped design and build a combined-heat-and-power plant to raise the energy efficiency of a new business district. However, this case also illustrated the limits of both local officials and SOEs: the city was unsuccessful in efforts to reduce electricity costs for the district, because of State Grid regulations mandating a minimum electricity consumption quota for the development. In the end, the CHP facility designed for both heating and cooling could only be used for heating, and cooling was provided by electricity.[165]

4. China's central government can mandate changes to the hardware of energy supplies …

- *Strong central government mandates will be critical drivers of change. Given the governance and institutional settings in China, this tends to favour state-owned companies which use state-owned financing to develop new infrastructure. But this could hinder larger structural changes or stakeholder participation in a wider low-carbon energy transition.*

- *State-owned companies play a key role in planning, investment, and expenditure on technology. While they are guided by government signals, they are also sources of expertise and technical knowhow, and are therefore central to policy planning. As guarantors of energy security and economic stability, they may be slow to embrace revolutionary structural or technological change, especially if policy change could reduce the value of their assets.*
- *Emerging industries have, in some cases, succeeded in aligning local strategies with the government's policies in support of technology development and diversification of energy sources. The solar energy industry, for instance, played a key role in China's 2012–2014 solar policy shift from export-oriented to domestic installations.*
- *While the private sector has been critical in China's economic growth and technological development in the past four decades, including in energy technology such as solar and batteries, the role of the private sector in China's future energy transition is more ambiguous.*
- *Meanwhile, China's financial sector has played a major role in accelerating the scale-up of China's new energy industries, although efforts to green the financial system have only been underway for a short period and it will likely take time for policies in support of the 30–60 targets to be rolled out.*
- *Moreover, transparency remains weak, investor interest is unclear, and most efforts have been led from the top down. Banks prefer to lend to large firms that are connected to large infrastructure investments and enjoy government sponsorship. So, funding for new entrants, small businesses, and innovation focused on smaller, more modular technologies, equipment, or software with clean energy or efficiency benefits may be challenging.*

Just as with China's formal government institutions, the country's unique economic institutions are a mixed bag, in the extent to which they tend to help or hinder a low-carbon energy transition. On one hand, the state is a central player in the energy sector, which is dominated by state-owned companies expected to respond actively to policy requirements. On the other hand, by the active role they play in setting policy, and given their conservative instincts as guarantors of energy security and economic stability, state-owned companies may be slow to embrace revolutionary structural or technological change. And while the private sector has been key to China's economic growth and technological development in the past four decades, including in energy technology such as solar and batteries, the role of the private sector in China's future energy transition is more ambiguous. In this section, we also discuss the role of China's financial system, which presently favours large-scale infrastructure investment and is oriented mainly towards the state sector rather than to private or smaller-scale players. Overall, we find that China's economic institutions tend to help the state play a coordinating role in planning, investment, and technology development, but could hinder larger structural changes or stakeholder participation in a wider low-carbon energy transition.

Much like regional governments, incumbent industries have immense power within this system as centres of employment, drivers of regional economic development projects and investment, and holders of expertise and specialized knowledge. While overt resistance to central government priorities is generally impossible, slow implementation and adoption of potentially contradictory policies can result from the bargaining process among actors. But when the government signals a new policy direction, incumbent industries, alongside industry associations, can also mobilize resources to support change. Indeed, the tight relationship between industries and the central government in implementing technology development policy is at the centre of the Chinese energy model.[166]

Incumbent industries, particularly those in the energy sector with large asset bases and network monopolies, tend to pursue strategies that seek to extend the utilization of such assets, and even construct more such assets, in the face of policy changes that may reduce their value. In the past decade – and as in other countries – Chinese industrial officials have promoted ultra-supercritical coal-fired power plants as a form of low-carbon energy, even though their efficiency represents only a modest improvement over the existing coal fleet, and no carbon capture is involved. Since the announcement that China would pursue an early carbon peak and 2060 carbon neutrality, various energy SOEs have

produced their own plans, generally emphasizing a combination of existing fossil fuel investments and new energy. For example, CNOOC's plan calls for continued growth in gas production, and cutting oil use only by half to 2050 – which would obviously fall short of carbon neutrality.

Aside from setting their own plans, large companies and especially SOEs directly participate in the setting of long-term plans through the five-year planning process and other procedures. While some five-year plans are broken down by policy topic – such as energy or the environment – many are organized around areas of production and supply, such as coal, hydro, or steel. Plans are elaborated by central government officials in concert with industry associations as well as government-owned think tanks, which are often organized on a sectoral basis and may derive revenue from serving companies in those sectors.[167] Industrial associations (see Figure 11) also play a role in the policy-making and planning process. Many industrial associations were originally carved out from state ministries in 2003, were initially staffed by former government officials from ministries, and exercise functions equivalent or similar to government agencies.[168] Government agencies also organize similar associations for newly emerging industries. For example, the Electric Vehicle Charging Infrastructure Promotion Alliance not only maintains data on charging infrastructure and quality, but organizes and contributes to setting industry standards for EV charging, evaluating provincial EV charging policies, and setting national targets for EV charging.

Though incumbent industries have a major influence on setting the overall direction of national policy – such as targets for energy production, electricity production, or steel output – new and emerging industries have been able to establish market and policy niches. In some cases, these industries have also succeeded in linking up to local and national policy makers to establish enduring policy subsystems to support continued expansion and development, particularly when doing so would align with the government's overall direction in support of the technology development and diversification of energy sources. For example, the solar energy industry played a key role in China's 2012–2014 solar policy shift from export-oriented to domestic installations.[169] The existence of powerful wind and solar subsystems, aligned with national priorities, has enabled these industries to continue to develop, even as the national policy priority shifted towards elimination of feed-in tariff subsidies for wind and solar in 2017–2018.

Figure 11: Industry associations in wind, solar, and electric vehicles

Name of Association	Year established	Number of membership institutions or companies	Main tasks
China Photovoltaic Industry Association[170]	2014	444 (as of December 2020)	- implement policy - research on industry and market - promote product standardization - promote cooperation between the solar industry and other industries - protect legal rights of member companies - hold academic exchange events - facilitate international communication - workforce training - publications - carry out public service beneficial to solar PV development
Chinese Wind Energy Association[171]	1981	Equipment manufacturers – 111 Wind investors – 27 Wind farm companies – 8 Wind power consultancy – 10 Scientific research institutions – 5 Others - 27	- organize academic exchange workshops and technology achievement exhibition - invite international experts to give training - monitor and analyse international wind technology development - publish magazine *Wind Energy* and industry statistics

China Electric Vehicle Association (CEVA)[172]	2004	107	- industry investigation and data collection and analysis - promote national policies - provide technical, economic, and market information for member companies - talent training - connect with international organizations
China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA)[173]	2015	173	- promote interconnectivity of charging infrastructures - implement standards of charging infrastructure, interaction between EV and smart grid - promote diversified development of charging service business mode - promote research on charging technologies

Source: association websites, 2021

Of course, the interests of industry groups and related subsystems – including in emerging clean energy fields – can also clash with those of other industries, and at times result in contradictions with national policy. One study has illustrated this phenomenon in the field of electric vehicles, where central government policy has focused on electric vehicles as a substitute for the conventional internal combustion car, in part aiming to create a set of new national champions; however, given the presence of differently-organized industry subsystems, along with emerging use cases, the result has been thriving models of electric bike, low-speed electric vehicle, and electric car-sharing/bike-sharing usage.[174]

4.1 Incumbents need strong policy signals, but will that be enough?

China sees state-owned energy companies as playing a central role in the country's economic and technological development. China's energy SOEs are among the world's largest energy companies: State Grid is likely the world's largest electricity grid owner and operator. China's Big Five state-owned power generation companies (China Huaneng Group; China Datang Corporation; China Guodian Corporation; China Huadian Corporation; and China Power Investment Corporation) produced approximately 44 per cent of China's electricity in 2019, a percentage roughly unchanged from previous years.[175] The country's three state-owned oil majors – Sinopec, China National Petroleum Corporation (CNPC), and China National Oversees Oil Corporation (CNOOC) – dominate the country's oil and gas sector. A new pipeline SOE, PipeChina, will oversee the country's domestic oil and gas midstream infrastructure, including the inter-provincial transmission pipeline system, as well as LNG import terminals.

Since the inception of the Reform and Opening period, China has oriented reform of the state-owned energy sector to maintain a high degree of state control while raising the overall economic efficiency of SOEs. Building on policies in the 1990s to 'grasp the large, release the small', SOEs have become much more efficient, though there remains a performance gap with the private sector.[176] SOEs remain tasked with achieving policy goals related to employment, investment, and social stability. SOEs still employ a huge fraction of the urban workforce,[177] and are especially dominant in regions that rely on older manufacturing or extraction industries.[178] Further, SOE reform has tended to strengthen existing SOEs through forced mergers, aiming to create national champions that dominate certain sectors rather than encouraging competition.[179]

China's leadership has emphasized that the country's SOEs should focus on consolidation, with the aim of continuing to develop energy companies as national champions, especially in energy, infrastructure, and IT. Within the energy field, the decision to empower SOEs and provide high-level state backing, rather than relying on private Chinese oil players, may have been partly a response to state intervention by Western countries to exclude Chinese oil companies from various projects and mergers.[180] Within China, both the creation of PipeChina in 2019 and the 2015 guiding document on deepening power market reform have focused on retaining SOEs in fields with natural monopolies,

while to some extent liberalizing upstream and downstream activities, albeit with participation of SOEs. Document 9 on Deepening Reform in the Electric Power Sector specifically refers to this as 'releasing both ends while retaining the centre'.[181] Such market access reforms could provide greater access to new entrants or new technologies in the fields of renewable energy, energy storage, demand response, and EV charging.

SOEs have taken a substantial stake in China's clean energy infrastructure to date. This is illustrated clearly in the case of renewable energy capacity. By the end of 2019, the installed renewable energy capacity of the Big Five state-owned generation companies accounted for almost 30 per cent of China's total renewable installed capacity – with the highest shares of wind and hydro.[182] Many solar plants are owned by SOEs other than the Big Five.[183]

Figure 12: Installed renewable capacity by big-five generation group by the end of 2019 (GW)

	Wind	Solar	Hydro	Total
SPIC	19.33	19.29	23.95	62.57
China Energy	41.16	1.34	18.63	61.13
Datang	18.37	1.44	26.99	46.8
Huaneng	19.96	4.0	26.97	50.93
Huadian	14.2	3.2	27.3	44.7
Total	113.02	29.27	123.84	266.13
Share of national total	54.1%	14.3%	34.6%	30%

Source: Beijixing, 2020; Downie, 2021

In addition to asset ownership, SOE generation companies have a lead role in *planning* renewable energy targets. Whereas both outside observers and officials may portray government targets as based on objective technical conditions, in practice there is a large element of industry bargaining inherent in such targets. For example, several renewable energy targets have been set based on existing plans already set out by the large SOE generation companies.[184] Though China has often exceeded installation targets, the targets themselves often act as an upward bound for what the government will expect grid companies to integrate, leaving the rest of the power sector revenue pie for incumbent generators. This obviously has the dual effect of placing SOE generation companies in the driver's seat for both building new renewable capacity as well as potentially blocking entry by private players.

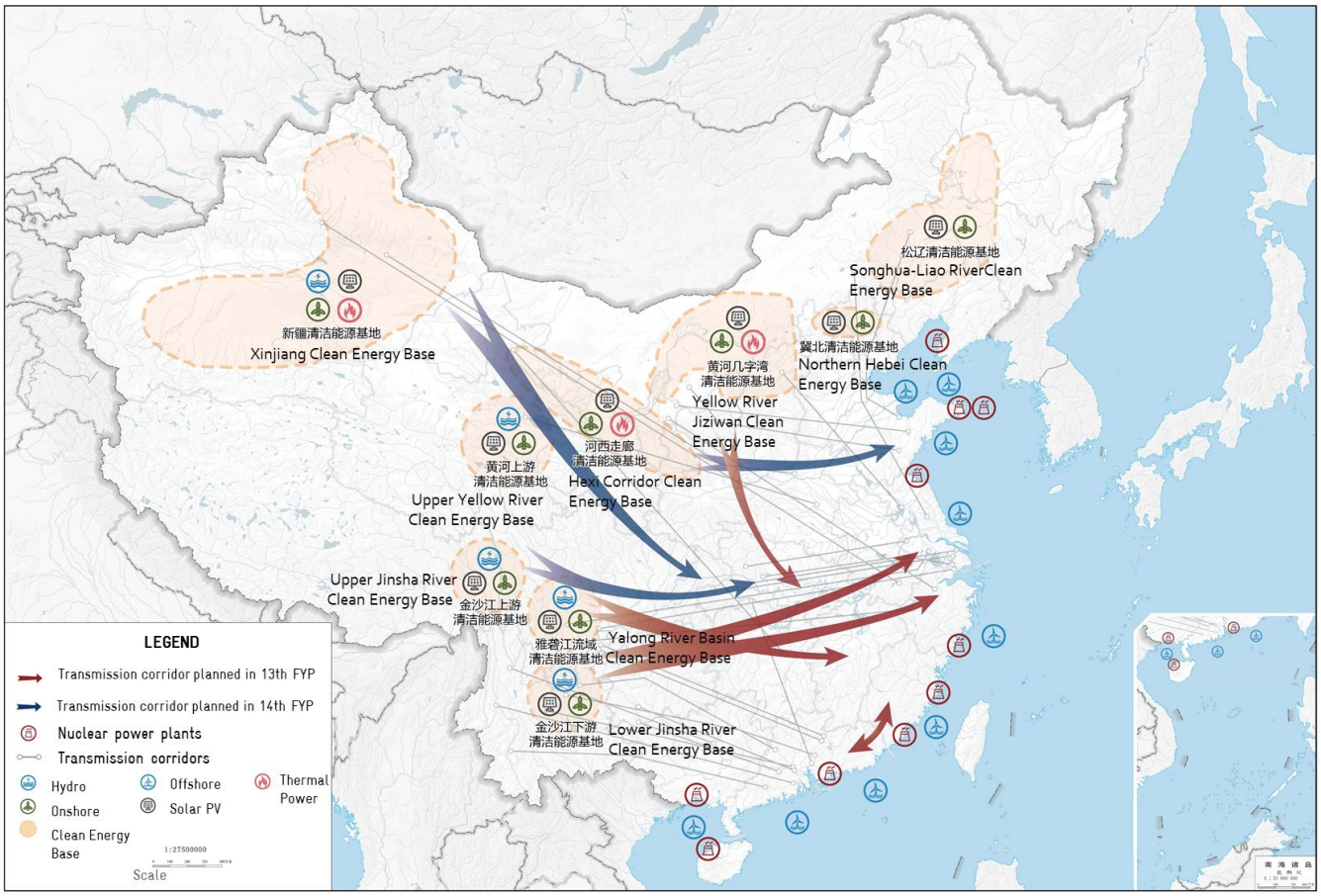
To date, the role of China's grid companies in the energy transition has been mixed: In the early 2010s, grid companies posed a significant barrier to distributed solar installations due to a slow and complex application and approval process, meter installation, difficulty receiving documentation needed for subsidy payments, and subsidy payment delays.[185] Supported by various national policies, the adoption of mobile phone-based applications has simplified these procedures,[186] though other obstacles to distributed solar (builder–owner–occupant dilemmas, low power prices, difficulty financing, and lack of awareness) continue to pose problems.[187] Safety and other regulations have also hindered distributed energy storage in cities.[188]

Various aspects of grid company planning and dispatch have also hindered utility-scale wind and solar development, leading to high rates of curtailment of wind and solar electricity output. Historically, conventional power plants were dispatched based on fixed operating hour contracts, in which the grid company allocated operational hours (and, therefore, revenue) to plant owners on the principle of equality.[189] Though renewable energy in theory had priority for dispatch, grid dispatch tended to prioritize satisfying demand with plants from within a single dispatch level, in a narrow geographical area, before bringing in power from a higher level of dispatch.[190] Provincial officials also sought to maximize utilization of within-province coal plants.[191] A succession of policies, including renewable energy obligations, generation rights trading between provinces, and mandates for compensation for curtailed renewable energy, have apparently helped resolve the renewable curtailment issue.

In addition, planning of power lines is conducted by the grid companies based on supply and demand forecasts, and generally seeks to ensure that newly-built lines are justified by a high utilization factor. This in turn tends to favour the construction of large new energy bases that include coal plants to ensure

high transmission line utilization. In recent years, the NEA has sought to resolve this problem by setting minimum targets for renewable energy on major transmission corridors.

Figure 13: Energy base strategic layout from 2021 Five-Year Plan Outline



Source: State Council, March 2021

Grid companies and SOE oil and gas companies have sought a role in EV charging. For a time, in the early 2010s, State Grid favoured the development of grid-owned battery swap stations in suburban locations, to minimize grid investment cost and reduce peak loads, rather than developing fast-charging near consumers, since this would entail upgrading distribution lines in urban areas.[192] Auto firms opposed this, citing the requirement to meet consumer needs for convenience and attractive variety of vehicle sizes and performance, avoid the necessity to standardize all battery sizes and formats when the EV products were still developing, and harness the energy of the private sector to accelerate growth.

Subsequently, private EV charging players have built out a substantial network, with Tgood and Star Charge ranked first and second in terms of numbers of public charging posts. State Grid accounts for roughly a fifth of public or fleet-dedicated charging posts as of year-end 2020, while Southern Grid has relatively few public or fleet charging posts.[193] State Grid has a near monopoly on highway charging, which will give it a substantial or central role in providing services related to long-distance travel and fast-charging.[194]

Oil companies with fuel stations in urban areas cited grid company opposition to upgrading distribution grids as a major barrier to expanding urban charging at existing fuel stations.[195] In 2011, China Southern Grid partnered with Project BetterPlace, an Israeli startup that subsequently went bankrupt, to develop a network of battery swap stations.[196] In the same year, China oil major China National Overseas Oil Corporation (CNOOC) became a shareholder of private-sector charging provider Potevio.[197] In 2016, Sinopec partnered with BJ EV, a division of Beijing-based SOE car maker BAIC, to develop its own network of battery swap stations.[198] China's oil majors continue to explore involvement in EVs and EV charging, in part by taking advantage of valuable land in urban centres.[199]

And while the state-owned companies have recognized the importance of decarbonizing China's energy system (see Figure 14), they were arguably more focused on adapting their strategies to other political priorities such as price reform, at least until late 2020. In the oil and gas sector, for instance, the majors have had to contend with new private actors as well as PipeChina, the new central SOE that was created in late 2019 to manage pipelines and thereby address anti-competitive behaviour by SOEs that had stalled construction of national infrastructure. In recent years, China's oil majors had tended to use control over liquefied natural gas (LNG) terminals, pipelines, and other oil and gas assets to hinder competition, and were reluctant to grant third-party access to pipelines or terminals, or to construct pipeline interconnections.[200] The central government's creation of PipeChina to manage and expand pipeline assets and encourage third-party access, was an attempt to resolve these issues.[201] This was in line with a 2019 announcement by Premier Li Keqiang that network monopolies should be separated from other businesses,[202] and follows from plans laid out by the State Council to initiate reforms in the oil and gas sector to encourage greater competition, in part through separation of transmission, distribution, and retail for both oil and gas.[203]

Since China's dual carbon pledge, however, the SOEs have been issuing their own carbon peaking plans and looking to align with the latest priority from the central government. One recent review has found that SOE plans released so far lack specifics and suggests that many firms are waiting for more direct, industry-specific signals from central leaders.[204] Several power generation SOEs have announced dates for peaking emissions and plan to increase investment in renewable energy. State Grid's 2021 Carbon Peaking Plan mentions a new target of reaching 50 per cent renewable energy on new transmission lines.[205] Meanwhile, China's oil companies have made initial plans for carbon neutrality, although they have not aggressively sought to transform their businesses.

- Sinopec has focused on the development of hydrogen, aiming to become China's largest hydrogen producer, and plans to further develop carbon capture, utilization, and storage (CCUS).[206] The company is cooperating with solar manufacturers GCL Group, Trina Solar, Longji Group, and Zhonghuan electronics to develop utility-scale solar PV facilities linked to hydrogen production and use, and to develop hybrid wind–solar–hydrogen demonstration projects.[207] In 2020, Sinopec developed its own distributed solar and wind plants near its facilities,[208] and also in 2020 invested in two early-stage companies developing thin-film-related solar glass and other components.[209]
- CNPC has taken a small step into various fields connected to clean energy. In 2021 the company announced a partnership with a Chinese automaker and a charging provider to develop charging at a conventional CNPC fuel station.[210] The company has also signed agreements with CPIC to invest in renewable energy plants,[211] and with a district in Guangzhou to develop distribution grids.[212] Most concretely, CNPC in 2019 participated in the development of the 600 MW Ruidong offshore wind plant.[213] As for efforts on carbon neutrality, the company has promoted the milestone of producing more gas than oil for the first time in 2020,[214] and tree planting in Maanshan to net out emissions from the Daqing oil field.[215]
- CNOOC has focused its energy transition efforts on the fields of electrification of offshore oil platforms and port facilities, as well as offshore wind. The company has undertaken major shore power electrification at Qinhuangdao and Caofeidian,[216] two of China's largest energy ports, and is planning to electrify most of its offshore platforms. In addition, CNOOC in 2020 connected its first 300 MW offshore wind plant to the grid and in 2021 signed an agreement to develop a 1,000 MW offshore wind facility.[217] CNOOC plans to raise the proportion of clean energy investment in its capital budget from the current 3–5 per cent to over 5 per cent.[218]

Oil companies have tended to see hydrogen as an attractive industry, since it involves large-scale investment in conventional pipelines and refineries, which could build upon existing infrastructure monopolies or oligopolies where the oil companies have a presence. All three of China's oil majors have focused on hydrogen. CNOOC in 2020 launched a tender to develop offshore hydrogen electrolysis and offshore hydrogen transportation systems.[219] CNOOC has signed a memorandum of understanding to cooperate on developing hydrogen infrastructure in China with the European industrial

gas company Linde.[220] CNPC has established general plans to include hydrogen in its new energy investment portfolio.[221]

Figure 14: Greenhouse gas emissions of China's national oil companies

		2016	2017	2018	2019	2020
CNOOC Ltd	Scope 1	6.7	7.7	7.3	8.6	9.1
	Scope 2	0.4	0.1	0.1	0.2	0.2
	Scope 1+2	**7.1**	**7.8**	**7.5**	**8.8**	**9.3**
PetroChina	Scope 1				132.2	127.6
	Scope 2				41.9	39.9
	Scope 1+2				**174.1**	**167.4**
Sinopec Corp	Scope 1		123.1	128.6	125.7	128.6
	Scope 2		39.6	43.0	45.0	42.4
	Scope 1+2		**162.7**	**171.5**	**170.7**	**170.9**

Source: Erica Downs, 'Green Giants? China's National Oil Companies Prepare for the Energy Transition', 29 September 2021, Columbia, Center on Global Energy Policy

Corporate identity is one potential indicator of the commitment of large energy companies to the energy transition that is different in China when compared with the West. Chinese energy SOEs have highly specific names that allude to their corporate past as government ministries and drivers of regional industrial development. There have been only a handful of major SOE mergers and renamings that appear oriented towards broadening their business strategies. Shenhua (the world's largest coal mining company and owner of a substantial coal power fleet, whose name alludes to the greatness of China) and Guodian (one of China's Big Five power groups, and also a large owner of wind assets) merged to create China Energy Investment Group in 2017.[222] State Power Investment in March 2015 merged with Sino Nuclear Power Technology Corp, but retained its name as State Power Investment Corporation (SPIC).[223] China's oil majors have not sought to change names or identities, nor has China Coal sought to diversify its business or change its identity.

Many incentives at China's SOEs favour a go-slow approach and risk-aversion including, in particular, personnel and management incentives. Management personnel at Chinese SOEs differ markedly from those at large firms outside China. For large industrial firms, virtually all upper managers have been Party members from a young age, were recruited into their industry from engineering or science majors, and have held just a few positions before reaching management rank. Career tracks of upper management typically remain within a single industry, often within a single business group, sometimes with a period working in an industry-related supervisory agency.[224] Manager advancement depends on achieving multiple key performance indicators, many of which are short term in nature, and subject to political bargaining, giving managers with closer political relationships greater operational flexibility.[225] These factors contribute to information asymmetry, leading to principal–agent dilemmas for government management of the state sector.[226]

Though Chinese policy has worked to professionalize the management ranks of SOEs and to open SOE management to managers with international experience or even to foreign executives, in practice only a tiny fraction of SOE managers have international work experience or degrees.[227] SOE management policies, as well as cross-cutting pressure from local officials, favour delivering services and preserving social stability and discourage risk-taking. Risk aversion is enhanced by the centrality to career advancement of maintaining good relationships with superiors.[228]

Still, the incentive structure at SOEs is more fluid than this description fully captures. As key actors within powerful organs of state policy, SOE managers operate within a networked hierarchy of SOEs which have pervasive linkages to other state institutions. This creates a form of institutional bridging that connects information and incentives to managers. Information, ideas, and perceptions flow in multiple directions, not just top–down, but also bottom-up from SOEs to government policy makers and ministries.[229] Promotion is not entirely a matter of rigid performance indicators, but also requires

organizational and group adherence to Party directives and central government guidance. Further, the privileged position of SOEs within the economic structure, especially in the energy field, enables such firms to make investments in new fields with the assurance that such plans, when aligned with central government objectives, will not result in losses. Indeed, within the renewable energy sector, SOEs have been willing to accept low returns and delayed subsidy payment in exchange for market share and access to favourable land and renewable feed-in tariff quotas.[230]

Going forward, the role of China's SOEs in the energy transition will depend on central government policy and whether they receive clear policy guidance and strictly enforced mandates. In the absence of strong policy signals – including personnel policies and incentives structures – the SOEs will likely tend towards risk-averse decisions, protecting existing business activities and hindering innovation. The future direction of SOE reform will also need to be well defined: if SOEs are encouraged to become more economically competitive, they could resist clean energy policies that hurt short-term profits but conversely, could also be discouraged from investment in assets that could become stranded. Or, SOEs could be guided, by economic or administrative signals to invest massively in fields where such investment will likely be needed.

4.2 Is there a role for the private economy?

The creation of a thriving private sector has been a central feature of China's economic growth over the past four decades. Though much of the country's energy infrastructure remains in the hands of SOEs, and will likely remain so, the private sector is also involved: private wind, solar, energy storage, and electric vehicle manufacturing firms have grown rapidly. A range of energy transition literature or innovation literature suggests that new entrants – likely private – are more likely to pursue disruptive technologies. As noted above, China's SOEs are risk averse and, though they adhere to government directives and policies, pursue incremental business and technology strategies.

However, it is important to recognize that the distinction between public and private firm behaviour in China is relatively blurred. Studies have found that SOEs and private-owned enterprises, particularly large ones, are difficult to differentiate.[231] The largest private companies in many fields owe their prosperity to tight government connections, monopoly rents, and protection from competition. In many cases local governments or local state-owned companies own shares in the private companies. Provincial and local officials encourage the development of local champions in key fields, and use project approval, land-use rights, and subsidies to direct revenues and profits to favoured firms. Private companies with political connections have favourable access to SOE bank loans[232] and to stock listings.[233]

Although market entry is allowed for private or foreign firms in many fields, licensing, capital requirements, and access to physical infrastructure networks pose major challenges, raising overall barriers to entry and favouring those with greater policy connections.[234] Government officials can force private companies to consolidate to meet industrial policy goals, sometimes forcing mergers with SOEs, often done at provincial level – for example in periods when policy makers were concerned with excess competition or overcapacity. For the largest firms that can reach national scale, state control is even larger than outside observers expect (whereas central government control of SOEs may be less than expected).[235] Party committees within large companies are involved in the management and monitoring of company business activities and strategies, and this has been shown to influence management behaviour.[236] Some have suggested that increased government influence over corporate governance could increase risk aversion and reduce innovation.[237]

These factors are all at work within China's new energy field. For example, to deal with the perception of overcapacity in the solar PV sector, in 2012 the NEA issued policy guidance setting targets for solar PV efficiency and manufacturing scale, promoting merger or acquisition for firms that couldn't meet the targets.[238] MIIT issued detailed technology targets around the same time.[239] In 2014, MIIT issued further guidance calling for mergers in the solar sector.[240] Over a dozen such mergers and acquisitions took place, including the takeover of the troubled firm Suntech, and the acquisition of several thin-film technology firms by Hanergy.[241]

Controlling shareholders, often state-owned, typically dominate corporate governance for large listed firms. Institutional investors are not permitted to own over 10 per cent of a listed firm's shares. In one

study of listed firms over the period 2003–2018, the average total ownership of all institutional investors in a listed firm was only 6 per cent, while the average percentage of shares held by the controlling shareholder was 36 per cent. Therefore, in China, institutional investors may lack incentive or power to influence governance or behaviour of management.[242] Indeed, perhaps owing to low ownership stakes, institutional shareholding doesn't correlate with personnel changes.[243]

The influence of state-owned entities is on clear display even in the most innovative startups of the new energy sector. For example, the prominent EV startup NIO was initially founded as a joint venture with GAC, the state-owned Guangdong Auto Company.[244] After NIO ran into financial difficulties, a rescue was organized by JAC, an SOE based in Hefei, Anhui, where NIO's vehicles are manufactured on the same lines as vehicles from JAC.[245] NIO hence gives these two major state-owned automakers exposure to both the EV market and NIO's proprietary battery-swap network, while providing NIO with flexible manufacturing capability that can ramp up quickly in response to policy changes that promote EV adoption.

Considering these differences, Chinese corporate governance is neither shareholder-oriented nor stakeholder-oriented, and from this perspective, as Lin and Milhaupt have noted, China is neither a liberal market economy (LME) nor a coordinated market economy (CME) per the 'varieties of capitalism' literature.[246]

Aside from the differences between management of the private sector, it is also worth noting that China's energy sector is dominated by larger firms and SOEs, and often hinges on government connections. If innovation in new energy technologies and related businesses/services mainly derives from smaller firms and the sharing of ideas among entrepreneurs, a smaller space for such entities in the Chinese energy sector might become a barrier to the energy transition. This may become more important in emerging low-carbon energy transition fields that have a more distributed structure or that are focused on demand-side measures, such as distributed solar, storage, electric vehicle charging, smart grid, smart building, or building energy efficiency.[247]

In summary, SOEs are likely to remain dominant actors in the energy sector for years to come, and their private peers rely heavily on government connections and mandates, and in many respects resemble SOEs. The prevalence of a strong state sector would imply risk aversion and therefore tend to hinder adoption of new 'software' for the energy transition. Yet China's private companies are likely to be only part of the solution, with the SOEs still playing a large role, as long as central government signals continue to point in the direction of the energy transition. One area in which the central government toolkit seems to be evolving in favour of the transition is in finance. While state-owned lending favours incumbents and policy-oriented lending, should central government signals start pointing consistently toward the energy transition, finance flows could begin to impact investment choices.

4.3 Could finance become an enabler of the energy transition in China?

China's unique and powerful financial sector has played a major role in accelerating the scale-up of China's new energy industries. For over a decade, the central government has led a push towards introducing green finance measures throughout the country's financial system. Within the financial sector, loans from SOE banks still dominate, accounting for around half of annual financing. The bond market is still in second place behind the SOE banks, although it has grown quickly and is now larger than the US bond market in terms of issuance outstanding. The stock market is far smaller, but similarly remains one of the world's largest in terms of trading.

Bank lending:

Bank lending is the largest component of China's financial sector, accounting for well over half of financial flows. Over half of loans are held by the largest five SOE banks.[248] The SOE banking sector also plays a leading role in implementing government policy, and is strongly supported by the central government. The government encourages policy-oriented lending both through development banks and through national/regional SOE banks. Top bank officials are usually Party members and may move in and out of the banking sector and policy positions.[249] SOE banks are central to short-term fiscal and monetary management. Officials enacted the economic stimulus of 2009–2010 primarily through credit expansion by SOE banks to SOE firms,[250] whereas private firms were at a disadvantage in obtaining

new credit.[251] The loosening of lending restrictions for local projects has been a major element of the fiscal response to the Covid economic crisis in 2020.

Policy makers have a major role in coordinating lending decisions. Regional banks are often forced to lend to local SOEs, leading to large problems with non-performing loans.[252] Since local governments have a near monopoly on the land supply, and land sales account for a large portion of local government budgets, land and land sales are used to secure loans for government-supported projects, such as highways, railroads, electric power infrastructure, and other projects.[253] Although the central government is cracking down on local government land transfers,[254] land is still the main source of local government finance. Governments tend to favour projects that are both capital- and labour-intensive.

Banks also prefer to lend to SOEs or state-backed companies. Loans to SOEs have been shown to benefit from an implicit government guarantee: local SOEs and local government funding vehicles enjoy lending rates almost one percentage point below those of private firms. Central SOEs enjoy an even greater discount.[255] As a result of government favouring infrastructure and heavy manufacturing investment, the supply of long-term unsecured loans to these sectors, both to SOEs and non-state owned projects, is almost unlimited, whereas the light sector relies mainly on short-term loans backed by collateral.[256]

Stock and bond markets

China has the world's second-largest bond market. Government entities, SOEs, and private companies are all active issuers. Liquidity in secondary trading of bonds has increased steadily in recent years. The country has taken gradual steps since the mid-2010s to open up its domestic bond markets to foreign investors, but yields remain higher than comparable industrialized economies and correlations with international bond markets remain low, indicating country-specific risks.[257] However, the relative lack of defaults has led many investors to characterize the Chinese bond market as lacking adequate credit risk pricing of mature bond markets, though this could change as more defaults have been allowed in recent years.[258]

China's stock market is the third-largest source of financing in China, but lags far behind bank lending and bond markets.[259] Access to private capital through the stock market also shows marked differences with the situation in the US and Europe, which could limit access for more innovative technologies, and potentially discourage companies from modifying corporate strategy to meet shareholder demands. Although China's stock markets are no longer regarded as completely disconnected from corporate performance, they still feature high volatility and are segmented from other world markets.[260] Chinese stock trading is dominated by individual investors who generally trade more on short-term news reports, market rumours, and purported insider information, and less on company valuation – exhibiting a high degree of herd behaviour.[261] Poor corporate transparency, the overarching importance of government policy, and availability of insider information may lead to greater herd behaviour.[262] This may explain why Chinese publicly listed firms have less published research than firms in other major markets.[263]

Highly concentrated stock ownership, and government control, are associated with stock movements that are more correlated with industry and market moves (synchronicity) than with individual firm news or expectations.[264] Government frequently intervenes in stock markets, using the so-called national team of traders with state-owned investment institutions. As a result, investors spend relatively more time evaluating or anticipating government intentions rather than expectations for firm or industry performance.[265]

China has a relatively low ratio of institutional investors, accounting for under 20 per cent of shareholdings in 2019, according to UBS.[266] (However, regulators are pushing more institutional investors, such as mutual funds and pension funds, into stock markets.[267]) Institutional investors are believed to be more rational, invest more on the basis of long-term value, serve to suppress market volatility, and may encourage good corporate governance.[268] But in China, institutional investors often adopt a contrarian strategy, selling against the buying trends and buying against falling trends – patterns distinct from other markets, and possibly reflecting access to inside information.[269] Institutional investors are often state-owned investor vehicles, which may have different behaviour and motivations than private companies.[270]

One result of these structural distortions is over-investment in capital infrastructure.[271] While this problem has been noted for years, and both policy makers and economists have called for an economic rebalancing towards services and consumption, infrastructure remains a major policy lever at both the central level for macroeconomic control, and at the local level for jobs and growth. This has been shown most recently in the surge in steel and cement production in the wake of Covid in 2020 and 2021, which also coincided with a burst in power plant approvals.

Although government support for the clean energy sector has been fairly consistent for the past decade, policies have undergone various revisions, and at times policy makers have sought to reduce dependence on subsidies and other forms of government support. There have been periodic booms and busts in renewable energy installations and EV production, and this has gone along with changes in the financing environment for the energy transition, including among the SOEs that participate. Perhaps it is unsurprising that the first major SOE bankruptcy was in the solar sector in 2015.[272]

In general, the financial system favours investments in long-lasting physical infrastructure. Such investments are mostly SOE-owned, and represent projects approved on a regular cycle by provincial DRCs, based on various quotas and planning priorities set out by the central government. These projects have predictable cash flows, and benefit from preferential treatment in the form of cheap land or tax breaks. Beyond SOEs, banks prefer to lend to large firms, particularly those connected to large infrastructure investments that enjoy government sponsorship.

Regarding the energy transition, the result of these biases in the financial system is mixed. On one hand, it likely reduces the funding available for new entrants, small businesses, and innovation focused on smaller, more modular technologies, equipment, or software with clean energy or efficiency benefits. In many cases, the private sector may be starved for funds for riskier or more innovative projects. Excessive investment in infrastructure, whether for fossil fuel infrastructure, transport infrastructure, or for clean energy, could lead to lock-in of certain suboptimal technologies and asset stranding.

However, excessive investment in infrastructure also avoids the paradox experienced by other economies, where high capital costs of clean energy technology relative to incumbent technologies pose a fundamental barrier to their development. The relative availability of low-cost capital for large projects favoured by policy makers and supported by local governments has undoubtedly helped build out China's wind, solar, and EV industries, as well as its growing network of high-voltage transmission lines. China is also likely to surpass the US in nuclear capacity over the next decade. Low capital costs for large companies will likely favour development of carbon capture and hydrogen infrastructure, potentially making China the largest market for these technologies and encouraging further technology transfer from countries where such projects are still prohibitively expensive.

Green finance

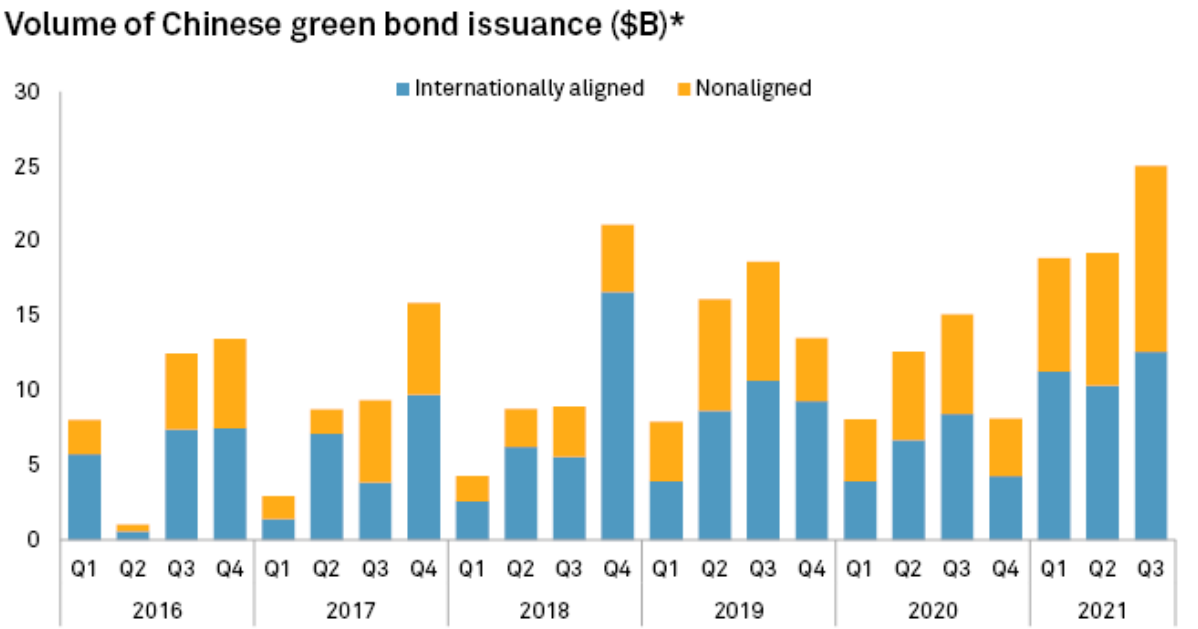
Since the mid-2000s, the central government has led a push towards introducing green finance measures throughout the country's financial system, culminating in the People's Bank of China's 2016 Guidelines for Establishing the Green Financial System.[273]

In 2007, the then State Environmental Protection Administration (SEPA), the People's Bank of China, and the China Banking Regulatory Commission (CBRC) jointly issued the Opinions on Implementing Environmental Protection Policies and Rules and Preventing Credit Risks, calling on banks to make compliance with environmental laws and regulations a necessary condition for loan approval, to actively offer credit support for 'encouraged' industries, and disallow credit for projects in 'restricted' and 'to-be-eliminated' industries. In 2012, the CBRC issued the Green Credit Guidelines, stating that banks should increase support to green, low-carbon, circular economy sectors and adopt stronger environmental and social risk management for loans to companies or industries in the 'restricted' category.[274]

In 2015, the PBOC issued the Notice on Green Financial Bonds, and this was followed in 2016 by a new set of Guidelines for Establishing a Green Financial System, along with supporting regulations from the stock exchanges in Shanghai and Shenzhen. The China Securities Regulatory Commission issued a further catalogue for evaluating green bonds in 2017.[275] China's green finance policies have resulted in the country becoming the world's second-largest issuer of green bonds (see Figure 15), with over RMB800 billion outstanding, though this is still less than 1 per cent of the country's total bonds outstanding.[276]

Given that the central government has a long-term policy to boost the construction of newer, more efficient coal power plants, China's green finance taxonomies have typically included coal, leading to international criticism as well as concerns that the taxonomies are incompatible with international investor expectations. As of 2019, China was the world's second-largest issuer of green bonds, after the US, but around half of its bond issuances complied only with Chinese standards and not international standards.[277] In 2020, a newly published green bond taxonomy excluded coal from the list of green investments.[278] However, Chinese green bond standards still differ from international standards in important respects, such as allowing for half of proceeds to go towards repaying loans or general working capital.[279]

Figure 15: China green bond issuance



Data compiled Oct. 12, 2021.
* Volume includes bonds aligned with international standards and bonds aligned with only local standards.
Internationally aligned green bonds are limited to those where at least 95% of proceeds are designated for green projects aligned with the Climate Bonds Taxonomy.
Source: Climate Bonds Initiative

Many issuers are large SOEs and local governments, and transportation projects such as subways and high-speed rail – which presumably would have been funded via regular bonds or loans – have accounted for a large fraction of issuance. One third of green bonds issued by property developers went for green building projects. In 2021, carbon neutral bonds made their debut as an asset category: activities listed in the government-approved green bond catalogue qualify for the designation.[280] However, it is unclear whether green bonds are making a difference in opening up funding to cleaner projects or reducing investment in dirty infrastructure. Differences between China's standards for classifying bonds as green (or carbon neutral) as well as lack of investor appetite mean that green bonds offer little price difference with other bonds from comparable issuers, at least for now.[281] Most green bonds are held by SOE banks or government entities and few institutional investors have shown interest in them.[282] Green bonds have been almost exclusively issued by state-owned banks, other state-owned enterprises, local governments, and policy banks – entities with strong credit ratings that face little default risk. Only 28 per cent of proceeds went to clearly identifiable new projects, and issuers failed to identify a clear use of proceeds in the case of 51 per cent of green bond issuances.[283]

Regional and local governments are also involved in the effort to promote green finance. Over 500 local and provincial green finance regulations had been issued up to the end of 2019, and China has also designated seven provincial green finance pilots. Guangzhou plans to establish itself as a green financial centre.[284]

In 2008, SEPA and the China Securities Regulatory Commission issued the Guiding Opinions on Strengthening Supervision and Management of Environmental Protection by Listed Companies, requiring environmental protection audits and environmental disclosures, and leading to the development of new standards. However, environmental disclosures among listed firms often focus on positive marketing of green products or investments undertaken, not actual disclosures.[285]

One of the challenges of analysing the influence of China's green finance policies is the fragmentation of responsibilities for managing green finance, which is directed by the PBOC, CBRC, CSRC, and the China Banking and Insurance Regulatory Commission, and coordinated with the State Council, NDRC, and MEE. As discussed above, the NDRC, MEE, and NEA are the lead bodies in charge of managing environmental and energy policies, which are themselves fragmented, and subject to contestation with local development and lending priorities that dominate China's financial system. As a result, ministries must work together to resolve bottlenecks in funding for clean energy. A recent example was issued in early 2021 by the NDRC, Ministry of Finance, PBOC, CBRC, and NEA on increasing financial support for wind, PV, and other industries: the new policy grants companies the flexibility to switch payment terms between feed-in tariffs versus grid parity projects (the former may face payment delays, making the latter more attractive for companies facing financial pressure) and encourages renegotiation of loans to companies receiving feed-in tariffs.[286]

Efforts to green the financial system have only been underway for a short period, and analysts generally agree that it will take time for various policies in the financial system to catch up with policy measures underway to peak carbon emissions and achieve carbon neutrality. While there have been steady efforts to promote green financial instruments and environmental disclosures, transparency remains weak, investor interest is unclear, and most efforts have been led from the top down.

5. … but mandating changes to the software are harder

- *China's governance structure has been successful at driving change and has historically been better at creating the 'hardware' of new supply-side investments. But issues such as market reform have been slower to develop and could remain constrained by the prominence of state-owned actors in their design.*
- *While China remains committed to allowing markets to play a 'decisive role' in the economy, and therefore in the allocation of energy and environmental resources, market mechanisms are only likely to play a limited role, alongside the guiding arm of the State.*
- *The central government is pursuing, and even accelerating, power market reforms and has introduced carbon emissions markets which will support renewable sources of energy at the margins, but administrative planning and targets remain more powerful guides for investment and production than market signals.*
- *Administrative planning may even assume a greater role as China phases out coal use, in light of the large-scale changes in employment and industrial structure. Meanwhile, market transparency is constrained and information sharing remains limited at times. But as the energy transition unfolds, greater transparency on pricing, as well as supply and demand, will be required as new energy consumers, and new technologies will become active participants in matching up supply and demand.*
- *China's legal system tends to place private firms and public interest litigation at a disadvantage versus state-owned enterprises or government bodies. Such weaknesses are likely to undermine the development of markets for electric power and carbon allowances – and would tend to hinder private sector participation at a level of equality with well-connected state-owned entities.*
- *Finally, academic advisors and civil society also play a limited role in bringing about broader change. University departments and top academic experts play a central role in developing five-year plans and other long-term plans. But often, NGOs and civil society can operate within a narrowly restricted political space. In general, the Chinese government sees NGOs*

as a means of transmitting and achieving government policy objectives rather than as autonomous entities.

While strong mandates to provincial governments and energy companies can lead to change, mainly in the hardware of new supply-side investments, the institutional framework guiding the 'software' seems harder to change. Despite calls by the government to deepen market reforms, these have been progressing slowly and China's energy transition seems unlikely to be able to rely solely on market signals. The slow development of market reforms, and the relative dominance of state-owned actors in the design and orientation of those market reforms underway, tends to hinder more thoroughgoing changes to the structure of the low-carbon energy transition.

China continues to be a centrally planned state, particularly within the energy sector. In the 1990s, reforms resulted in the splitting up of vertical energy ministries and a spinning-off of energy majors to become separate SOEs, and various aspects of energy pricing were liberalized, though state control remained paramount and administrative planning quotas continued to guide investment throughout the sector. While in many non-industry sectors – such as banking, telecommunications, and airlines – SOEs retained dominance or even monopoly status under strong regulators, energy was an exception. NDRC retained pricing power, a separate regulator for the electric power sector was abolished after a short period,[287] and sectoral targets have remained highly guided and specific, at both the central and provincial levels.

That said, China officially remains committed to introducing markets into the energy and environmental sectors. According to the communique issued after the Third Plenary Session of the 18th CPC Central Committee in November 2013, markets should play a 'decisive role' in the allocation of energy and environmental resources.[288] In the electric power sector, a new phase of market-oriented reform began in 2015, with the publication of a new reform framework and agenda that is still underway today.

5.1 The long and winding road of power market reform

Power sector reform has proceeded slowly and cautiously. The first step was a transition from fixed-operating-hours contracts at regulated prices towards mid-to-long-term bilateral electricity contracts, where a market was established in 2016.[289] Such contracts are typically for periods of a month or a year, and are negotiated between generation companies and large industrial customers. The mid-to-long-term market transaction volume covered 77 per cent of total electricity consumption in 2019, according to the China Electricity Council.[290]

Three other aspects of electricity markets have also undergone reforms: transmission and distribution (T&D), ancillary services (short-term power supplies for periods of milliseconds to a few minutes), and spot power markets (short-term energy trading over periods of an hour). T&D pricing reform has been carried out nationwide, standardizing payment to grid companies for transmission and distribution services as well as cross-provincial transmission investments.[291] Under T&D reforms, a new regulated price for such investment is negotiated between the government and grid companies based on actual costs, and grid companies no longer earn revenue from the difference between wholesale and retail prices.

After the introduction of bilateral mid-to-long-term electricity trading, China also established seven spot market pilot provinces. These provinces established trading centres and began developing models for spot markets based on various practices in other countries. Some provinces opted for zonal pricing and others for nodal pricing, and provinces also adopted varying practices for which entities may participate and how bidding is performed.[292]

China has also sought to emulate market mechanisms in its approach to phasing out subsidies to renewable energy; however, those mechanisms it has adapted from abroad, such as renewable obligations and green certificates, have been modified for the Chinese context to more closely resemble administrative quotas. For example, in the case of green certificates, which represent the purchase of electricity from wind or solar energy projects, in July 2017 the NEA launched a voluntary green certificate market, but designed the certificates to reduce the government's subsidy payment obligation.[293] Purchase of a certificate transfers the subsidy obligation for existing projects rather than

creating a market for projects that would provide additional renewable energy beyond that already existing. For this reason, China's voluntary green certificate market never took off.[294]

China's renewable obligation (RO) sets targets for the provinces and grid companies to meet minimum proportions of electricity supply from non-hydro renewable energy sources. The initial policy covered just three years, and was subject to several adjustments – for example, the provincial obligation for 2020 was adjusted in June 2020 to reflect output more closely. This means that the obligation resembles an administrative planning quota and does little to promote market-based investments in clean energy over the long term.[295] Perhaps to address this, in early 2021, the NEA released a new draft policy that set specific provincial targets for renewable energy out to 2030.[296] In April 2021, the NDRC set renewable feed-in tariffs at levels below on-grid coal prices and established operating hours limits for receiving these fixed FITs, pushing the remaining operating hours into market transactions.[297]

5.2 Carbon emissions trading markets – a long term tool

China is working to establish markets for carbon emissions allowance trading, yet for several reasons, these markets are likely to have less of an influence on the energy transition than other policy factors. The first relates to their design, which includes free allocation at levels unlikely to lead to high prices, and allocation based on emissions benchmarks. The second relates to the political economy of the institutions that are subject to the carbon markets themselves – mainly state-owned entities in industries where state planning and administrative targets remain paramount, and where no independent market regulatory framework yet exists. Indeed, as a 2017 paper by Goron and Cassia noted, China's carbon market pilots have resulted in reinforced state domination rather than an emergence of regulatory institutions or a transfer of some responsibility to markets. Local governments are not committed to market independence or transparency, and they intervene frequently to guide short-term market prices and engage in other short-term industry operational management.[298]

As early as 2009, China signalled its intention to develop a carbon market as a means to eventually address greenhouse gas emissions, and in 2014 China committed as part of the US–China Climate Accord to adopt a carbon trading market covering the electric power sector. Seven national carbon market pilots were established (eventually expanded to eight markets) and were designed by provincial officials and think tanks. The pilot markets adopted either grandfathering or benchmarking methodologies, included differing sets of industries covered, and featured relatively low trading volumes and low prices for allowances.[299] Various studies have found the emissions trading pilots had either mixed or insignificant effects on reducing emissions,[300] though arguably the main purpose of the provincial pilots was to develop administrative capacity and to experiment with different market designs.

In 2017, a national carbon market was launched, but this proved to be mainly an initial design of a carbon market for the electric power sector, which was further refined in 2019.[301] Final trading rules were published in January 2021, establishing the level of benchmarks for coal power and coal-heating plants.[302] A total of over 2,200 plants are covered. A 2020 analysis by the IEA estimated that China's benchmarks would be set at a fairly generous level that would enable power companies to meet their obligations simply by exchanging surplus allowances allocated to supercritical coal plants with subcritical plants.[303] (Newly-built ultra-supercritical coal plants emit roughly 15 per cent lower carbon emissions than China's national average for all coal power plants as of 2018.[304]) In July 2021, live trading on China's national carbon ETS began, but trading volume has remained low – just 10 tonnes changed hands on one day in mid-August 2021. For the first few months, trading was limited to a small number of SOEs, and often trades were completed between divisions of the same SOE. Prices traded within a narrow band of RMB40–55/tonne.

Benchmark-based carbon markets are oriented mainly towards optimizing the operation of existing assets. Though offsets are included in the carbon market design, low-carbon entities will not generally participate in the market, and there will likely be no economic transfers to renewable energy sources other than via offsets, which are capped at 5 per cent of compliance.[305] There have been calls from some officials and state think tanks, such as the director of the Shanghai Environment and Energy Exchange[306] and the China Council for International Cooperation on Environment and Development (CCICED),[307] for China to adopt absolute carbon emissions limits in its five-year plans in order to provide a clearer market signal. In March 2021, a draft proposal for future ETS regulation from the

Ministry of Ecology and Environment raised expectations that China's carbon market would transition towards allowance auctions and a hard-total cap on emissions.[308]

A 2020 China carbon pricing survey indicates that market participants expect China's carbon prices to remain low, rising to only RMB193/tonne by 2030 and RMB167/tonne in 2050.[309] Further, survey respondents continue to view policy signals as more important indicators of future pricing rather than the market signals themselves. This is potentially far below the present-day cost of abatement for hard-to-abate sectors. After the 2021 announcement, analysts expected the market to be oversupplied with allowances initially.[310] Notably, the initial carbon market design calls for a maximum fine of just RMB30,000 for failing to even submit any allowances to comply – an insignificant amount for a large SOE. Subsequently, a draft regulation would increase penalties for companies that falsely report or refuse to fulfil their obligations to RMB500,000.[311] This amount may be irrelevant in practice, however, as informal punishment for officials and entities that fail to treat the market seriously could serve as a more meaningful incentive.

There is presently no concrete timeline for integrating China's carbon markets with wholesale electricity prices, which several analysts consider important to ensuring that power prices accurately reflect the price of carbon and incentivize low-carbon electricity for both the power sector and power consumers.[312] The National Energy Administration issued a 2020 draft policy on developing a Long-Term Clean Energy Consumption Mechanism which included a general suggestion to integrate power markets, green certificates, and renewable obligations, but omitted mention of carbon markets.[313]

These tentative steps towards market reforms in the electricity and carbon emissions spaces may never reach the stage where markets play the leading role in signalling long-term investment pathways. Rather, the government may plan to retain that authority and rely primarily on administrative planning and long-term planning guidance documents, allowing for substantial short-term market interventions and keeping price fluctuations to a minimum.

The official government rhetoric that markets should play a 'decisive role' in the allocation of resources coincides with an ongoing, four-decades-long trend favouring liberalization of electricity markets and utilization of markets to achieve economic efficiency in power sector investment and emissions pricing. The benefits of such reforms are still hotly debated, and there exists nothing approaching a consensus model for power markets or carbon markets. Further, the record of power markets and emissions prices in countries that have pursued these policies most consistently suggests: (1) that these market designs have played only a small role in the energy transition to date, (2) that the publicly stated economic efficiency objectives for these markets, particularly for power markets, have evolved far from their original goals, (3) that political economic considerations – many of which relate specifically to what energy transition scholars would consider as institutional barriers or regime resistance – suggest that efficient market incentives for the low-carbon energy transition are by no means just around the corner. The lack of an advanced or consensus market model for the low-carbon energy transition means that China will likely proceed with its own unique and ad hoc effort to balance market reforms with administrative measures for guiding industry and energy sector development.

Based on international experience to date, there are several reasons to temper expectations for by how much market reforms in China could drive a low-carbon energy transition – even assuming thorough and rapid implementation. Outside China, studies have suggested that carbon pricing, to date, has had a limited effect on the energy transition, with demand-pull policies playing a dominant role.[314] According to a 2016 review, carbon ETS prices have also not resulted in measurable changes in innovation and patenting.[315] To be sure, now that carbon prices have risen in Europe and elsewhere, they are certain to feature more in business decisions, investment, and innovation, albeit they may still remain too low to promote long-term investments in high-priced abatement technologies in hard-to-abate sectors.[316]

For power markets, the record similarly shows that electricity sector restructuring, and the adoption of spot power markets and other designs, has resulted in the retirement of older assets and some upgrading of emissions controls, not in new investments.[317] However, state planning and regulatory regimes play a central role in transmission and distribution, a major bottleneck for renewable energy integration.[318] Market incentives to promote distributed renewable energy, storage, aggregation, and electric vehicle charging are at an early stage even in areas where the government has promoted these as a paradigm shift.[319] Electricity grids remain a natural monopoly, and in most regions grid companies,

generation companies, and local officials continue to exercise various political and institutional methods to block new entrants and limit access to renewable energy.[320] While transparency and regulation are potential solutions to monopolistic practices and regime resistance, even in the most transparent markets incumbent players are able to exercise market power without disclosure.[321] In many regions energy companies remain among the most powerful political lobbyists, able to distort markets to their own advantage.[322] These aspects of regime resistance are likely to have analogies in China's energy sector, dominated as it is by state-owned companies.

Many international and Chinese observers of China's halting steps towards power markets and carbon markets may lament their slow progress, seeing lack of markets as a major, or even the primary, barrier to the clean energy transition. Given international experience, perhaps the dominant role for short- and long-term administrative planning in allocating resources and selecting technologies for adoption, and failure to adopt a high carbon tax as the main instrument of climate policy, may have only a minor effect on the speed of the energy transition in China. It may be time to recognize that China's go-slow approach is likely to continue to keep the role of markets in a small box, and that this does not necessarily reflect a lack of sophistication or a type of institutional or market barrier to the energy transition.

5.3 Market transparency remains constrained

Transparency is an important element of market function; market transparency differs from country to country and from product to product. In China, there exist several political, social, and institutional barriers to market transparency that could affect the degree to which markets are able to facilitate an energy transition with a large number of diverse stakeholders.

In many respects, China's environmental disclosure has increased since the adoption, in 2008, of the Open Government Information Regulations and Environmental Information Disclosure Measures.[323] While the government exercises strict censorship and control over the Internet, it has also encouraged Internet data monitoring on environmental matters as a means to prevent companies or regional governments from distorting reports on environmental improvement. Public information platforms track and report on issues with air quality, emissions, and water quality. China has also established numerous other information platforms, often managed by industry associations, covering topics such as EV sales, EV charging, renewable energy, and carbon trading.

However, there exist many restrictions on what information can be shared, including in fields such as weather, building energy use, or mapping. While many companies are required to make disclosures related to environmental, social, and governance matters, and environmental impact assessments are required for many projects, the quality of such procedures and disclosures varies, and often public participation is limited.

China's government statistics remain the most trusted source of information in China, potentially partially due to lack of alternatives. However, the transparency of official statistics is lower than in many countries.[324] Notably, in the energy sector, participation of new entrants, energy consumers, and new technologies to match supply with demand could require greater transparency on pricing, supply, and demand. China's power sector presently does not have a public information platform that could offer information on the real-time electricity supply, load curve, or generation mix, either at the national or provincial levels. Such information may be considered a national security concern or proprietary information. Indeed, China in 2021 is poised to adopt sweeping new laws on data security that could freeze efforts to free up data related to energy markets or consumption.[325]

Similarly, China's grid companies and provinces have undertaken smart grid pilots which feature advanced control technologies, such as smart transformers, to improve grid operation. However, these do not necessarily include public information platforms that could enable greater user participation in balancing supply and demand. Such platforms, if they existed, could result in the innovation of new services related to distributed energy production or consumption, or the integration of demand-side technologies. Open information platforms, rather than centralized and closed platforms, enable new products and services by new entrants, but the value of such openness may not be recognized by SOEs such as grid companies, that seek to retain control of such information.

5.4 The legal system will always protect the Party-State

China's legal system has several unique features that distinguish it from those in other countries,[326] and these could affect the low-carbon energy transition, such as by putting private firms and public interest litigation at a disadvantage versus state-owned enterprises or government bodies. The Chinese approach to law arose from an amalgamation of ideas from several schools of thought, among which the Legalist and Confucian schools were prominent as in the political sphere.[327] The result was a system of law-making, laws, regulations, and courts that was directed at promoting and protecting the interests of the state. Neither philosophy was consistent with the rule of law as espoused by Western nations.[328]

Since the introduction of economic reforms in the late 1970s, the government has taken great strides to draft new laws and regulations, to create a new cadre of professional lawyers and judges, and to spread understanding of the importance of the law. In pushing forward these reforms, China has drawn extensively on international examples, especially in the realm of economic law.[329] Law making through the National People's Congress has become more transparent and involves seeking suggestions from the public by placing drafts on the internet. Further, the government has passed a number of administrative laws that seek to enhance the accountability, transparency, and effectiveness of government itself, though the results vary greatly across the country.[330]

Constraints to the pace and development of legal reform include the close relationship between the courts and both the Communist Party and local governments. Courts have traditionally been directly responsible to the local government, party, and people's congresses at the level at which they operate, and their budgets come from the local government.[331] Since coming to power, President Xi has emphasized the need to reform the legal system and enhance the role of the courts.332 Key measures have been to reduce the influence of local governments over local courts by centralizing authority at provincial levels and to build on earlier efforts to professionalize the judiciary.[333] However, the overall approach to the law continues to show a high degree of continuity with past practices. The law is still seen as an instrument of government and of the Party, to be deployed to retain power, maintain social order, and promote economic development.[334]

In terms of the role of law in economic activity, two important features deserve emphasis. First, the law in China is notorious for failing to provide formally secure property rights, and government agencies at all levels of government exercise their right to transfer rights with little due process. Within this context, many enterprises have been very successful at enhancing the degree of protection of their property rights, through building interpersonal networks and by the use of personal connections involving both public and private sectors.[335] Second, citizens, companies, and public agencies continue to prefer to settle civil disputes through private negotiation rather than by going through the court system, though the use of the courts is increasing.[336] Such weaknesses are likely to undermine the development of markets for electric power and carbon allowances – and would tend to hinder private sector participation at a level of equality with well-connected state-owned entities.

The leadership's determination to address the country's pressing environmental challenges led to a revision of the Environmental Protection Law that came into effect in January 2015. For the first time, officially registered environmental NGOs were permitted to file public interest claims in the People's Courts.[337] However, NGOs face many obstacles to doing so. In addition to the requirement to be officially registered with the government, most Chinese environmental NGOs lack funds and expertise, face difficulties in obtaining the necessary evidence, and encounter overly restrictive rules of standing in the context of environmental cases. Moreover, they have no right to bring cases against public authorities – only the procuratorates can do so. This is important because most violations have their roots in the failure of local governments to fulfil their obligations.[338] Furthermore, Chinese law is ambiguous about whether private parties launch public interest cases to prevent other private parties causing damage before the damaging action takes place.[339]

In 2016, the prominent environmental NGO, the Friends of Nature, filed cases against the grid companies of Gansu and Ningxia on the grounds that they had failed to purchase all the available wind and solar energy in their respective areas of jurisdiction. The claims were based on the environmental damage caused by the companies' actions. Progress in the courts has been very slow[340] and, as of September 2021, neither case seems to have been resolved. Likewise, as of 2018, no cases had been

brought by either the NEA or renewable energy companies against the grid companies for failures to purchase renewable energy. Hence, the present legal structure does not strongly support private actors or companies intervening in a meaningful way to influence the implementation of policy and regulatory requirements by SOEs. This can affect the low-carbon energy transition when the interests of new entrants, new technologies, or smaller clean energy players come into conflict with those of larger, state-owned entities.

5.5 Think tanks and civil society have an important but restricted role

Much as the legal system is only able to challenge Party–State institutions at the margins, academic advisors and civil society also play a limited role in bringing about broader change. University departments and top academic experts from institutions such as Tsinghua University, Peking University, the China Academy of Social Sciences, the China Academy of Sciences, and others also play a central role in developing five-year plans and other long-term plans. This system of expert advice from academic insiders has been termed a form of pragmatic pluralism, a concept which challenges notions of purely top–down policy making or, conversely, fragmented authoritarianism.[341] A recent example of the complex interaction between top leadership, line ministries, and academia is the publication of 'China's Long-term Low-Carbon Development Strategy and Pathway' by Tsinghua University Institute for Climate Change and Sustainable Development (ICCSD) and 18 other Chinese research institutes.[342] The study provided the basis for the decision by the top leadership to announce the carbon neutrality target for 2060.

China has a reputation as a strongly centralized state – albeit with elements of fragmentation – and minimal channels for societal participation. Yet at times the public and civil society organizations have played a role in energy and environmental policy. NGOs and international actors support and guide central government policy by coordinating the input of experts with sector-specific professional knowledge.

Environmental NGOs, including both Chinese and international NGOs, have long advocated policies to reduce pollution and increase the proportion of low-carbon energy to address climate change and air quality. In the 1990s and 2000s, NGOs contributed to raising awareness of environmental issues, building capacity, and developing legal and institutional reforms – often with the support of government officials.[343] Since 2015, NGO involvement in China's policy making process has been subject to many new constraints, particularly for foreign-based NGOs or Chinese NGOs that operate with foreign funding. For example, NGOs must submit annual work plans to their government supervisory entity for prior approval, and all activities must conform to these plans. Instances of public controversy may result in discussion with security authorities. One aim of these measures is to limit and pre-empt any public campaigns by NGOs, even in areas that support existing government policies or programmes.[344] However, even prior to these measures, the ability of NGOs to register officially, organize activities, and interact with officials or the public was constrained.

Nevertheless, NGOs and individuals do have a limited role in China's present energy and environmental policies.[345] NGOs can cooperate with government partnerships within a narrowly restricted political space, they can engage in training and awareness-raising for companies and organizations with inadequate professional capacity, and to some extent they can engage in public advocacy.[346] In general, the Chinese government sees NGOs as a means of transmitting and achieving government policy objectives rather than as autonomous entities.[347]

Outside China, NGOs often have their biggest impact in mobilizing stakeholders at the local level, often but not always in partnership with local government leaders or official bodies. In China, however, evidence from literature related to the establishment of eco-cities or low-carbon communities suggests limited, or almost no, role for NGOs in these processes. Local officials, SOEs, businesses, industry associations, professional consultants, and academic experts are involved, but NGOs are rarely granted access to official planning or policy-related processes.[348]

Government at various levels does provide other avenues of public participation, such as complaint hotlines, requests for information, and NGO monitoring of environmental performance. A 2018 review of such policies suggests that these avenues for public or NGO inputs to policy remain in place.[349] Indeed, there is some evidence that government agencies are pursuing public comment rounds as a

central feature of 'modern governance' which the government has made a top priority. Based on our own review of policies posted on the websites of five government agencies connected to the energy transition, in 2020 the NEA, NDRC, and MEE each issued over 30 such requests for public comment on major policy drafts.

Public comment and discussion of environmental and energy issues can influence public policy, even in the absence of direct channels of influence, and even when these concerns are subject to active censorship. The documentary film 'Under the Dome' is widely credited with raising awareness of the health impacts of urban air pollution, even though it was censored and removed from the Internet days after its release.[350] But even prior to the film, concerns about rising awareness of air pollution appear to have catalysed policy to address urban air quality, with the War on Air Pollution announced just following a period of intense international media attention to high air pollution levels in Beijing in 2013.[351]

Although media tend to focus on the influence of the public on environmental policy, central government officials have often launched awareness campaigns seeking to inform the public of the importance of addressing environmental issues, including air quality, climate change, and biodiversity. During the War on Air Pollution, for example, vivid posters portrayed a teddy bear wearing a gas mask and holding a string of exploding firecrackers under the headline, 'Do you really need to set off another string?' China has celebrated its participation in international climate agreements and promoted achievement of carbon intensity targets and the establishment of low-carbon cities. Further, China has publicly equated pursuit of energy transition policies with economic development, incorporating the theme of Ecological Civilization into the China Dream, as well as goals to achieve a moderately prosperous society.

Perhaps as a result of such campaigns, public opinion surveys have shown that public perception of climate change and the clean energy transition is high, with over 90 per cent of the public aware of climate change in 2017 (66 per cent viewing it as primarily caused by human activity), and 83 per cent knowing about the low-carbon transition.[352] In various surveys, Chinese respondents strongly supported government action to address climate change – which included adopting renewable energy, establishing carbon markets, promoting energy efficiency, or other actions – and many expressed support for taking individual action.[353] Awareness of climate change in China has risen over time, and coincided with public awareness campaigns such as the National Low-Carbon Day, launched in 2010. The Chinese public holds relatively favourable views towards a variety of low-carbon energy sources to enable the energy transition, including both renewables and nuclear.[354]

As we have discussed in the preceding sections, China's institutional settings will both help and hinder the energy transition. While much depends on the consistency of the messaging from the Party–State over time, China's institutional framework is capable, as we have discussed, of some adaptation. Since the Party–State can mobilize resources and galvanize the state-owned banking and industrial sector, the incumbents can become part of the change, benefitting from and investing in the energy transition. But equally, there are limits to the state-dominated system's capacity for change. With the role of the market, transparent flows of information, the legal system, and civil society being constrained, China's energy transition is unlikely to be a system- and society-wide transformation, and it is unlikely to unfold in an economically efficient manner even though the energy mix is likely to evolve considerably.

Assessing progress in the elements described above will help gauge the speed and depth of the transition and, based on the initial framework laid out here, we do not expect it to be a smooth or linear path. At the outset, China will likely make greater progress in areas related to the hardware of the energy transition, as these are usually able to satisfy a larger number of political and economic interests. But changes to the software of market reforms – demand-side management and disruptive technological innovation – will likely prove more challenging.

6. The institutions of innovation

- *As discussed in previous sections, China's institutional settings will both help and hinder the energy transition. With consistent messaging from the Party–State over time, China's institutional framework is capable of some adaptation, and incumbents can become part of the change. But equally, there are limits to the state-dominated system's capacity for change. With the role of the market, transparent flows of information, the legal system, and*

civil society being constrained, China's energy transition is unlikely to be a system- and society-wide transformation, and it is unlikely to unfold in an economically efficient manner even though the energy mix is likely to evolve considerably.

- *At the outset, China will likely make greater progress in areas related to the hardware of the energy transition, as these are usually able to satisfy a larger number of political and economic interests. But changes to the software of market reforms – demand-side management and disruptive technological innovation – will likely prove more challenging.*
- *China's energy innovation system has already helped to develop and scale-up certain modular and manufacturing-intensive technologies. The state has mobilized immense resources for R&D investment, so China's proclivity for capital-intensive infrastructure investment, coordination by powerful state-owned industries, and a system of provincial pilots has given it an advantage.*
- *Carbon capture, utilization, and storage (CCUS) and nuclear differ vastly from wind, solar, and storage, both in scale and design complexity, and may have less potential for rapid, solar-type learning curves based on scale-up. While China's proclivity towards capital-intensive infrastructure investment, coordination by powerful state-owned industries, and system of provincial pilots could give it an advantage in the fields of CCUS, nuclear, and also hydrogen electrolysis, these cases display a substantial difference with wind, solar, and energy storage – fields where policies on manufacturing and technology catch-up played the leading role in enabling learning and cost reduction.*
- *To implement central government policies and thereby capture more resources, SOEs tend to favour large, long-term capital projects aligned with those policies rather than pursuing small, disruptive innovation. New technologies that require greater consumer interaction or greater coordination between sectors or between supply and demand are likely to prove more challenging.*

For over a half-century, innovation has been a core topic of efforts to bring about an energy transition, and this remains the case today. However, several low-carbon technologies have reached full commercial scale and appear poised to deliver a large part of the technical solution to climate change without a great deal of further innovation. For example, the International Energy Agency's annual technology assessment rates solar PV, wind, battery electric vehicles, and heat pumps as fully commercialized, whereas other advanced technologies in the buildings and heavy industrial sectors are at an earlier stage.[355] Nevertheless, even within fields where commercialization has already taken place, innovation will bring ongoing improvements that will influence the speed and direction of the clean energy transition.

China's success in achieving carbon neutrality will depend on, and influence, global developments in technology innovation, and its own technology pathway will be shaped by systems of innovation – global, national, sectoral, and technology-specific. We find that China's energy innovation system has already helped to develop and scale-up certain modular and manufacturing-intensive technologies, but these successes may not translate to all industrial fields – particularly for future energy systems that require greater consumer interaction or greater coordination between sectors or between supply and demand.

6.1 China's innovation systems

China's innovation capacity remains a subject of debate, both among policy makers and academics. Within the energy transition literature, scholars have noted that innovation takes place within a technology innovation system. A technology innovation system relates to a specific technology or group of technologies. Technology innovation also takes place in the context of national innovation systems, and sector innovation systems. Such systems also have international aspects that have been characterized as belonging to a global innovation system.[356] In this section, we will briefly touch on each.

Technology innovation systems differ by sector and by individual technology, and the energy sector includes a variety of technologies, both mature and emerging. Coal, oil, and more recently gas – and electricity derived from these sources – dominate China's existing energy sector, but wind, solar, nuclear, and electric vehicles constitute emerging fields. To understand China's innovation in the various technologies needed to achieve carbon neutrality, the evaluation systems developed by Hekkert et al.,[357] and Bergek et al.[358] can capture some of the characteristics of these technology innovation systems. Such an evaluation should consider:

- ▪Entrepreneurial activities, including the existence of new entrants, innovation among existing players, number of experiments with new fields, and diversification of economic activities.
- Knowledge development, including learning-by-searching (R&D) and learning-by-doing (scale-up). R&D projects, R&D spending, patents.
- Knowledge networks, including maps of key actors, workshops, conferences on technologies, as well as formal R&D agendas among major energy-related institutions.
- Guidance of search by government, industries, and the market – sometimes through explicit targets, strategies, or roadmaps, and sometimes based on success stories, paradigms, or leader rhetoric.
- Market formation through protective policy or commercial niches.
- Resource mobilization, such as spending on knowledge production or technology scale-up.
- Creation of legitimacy for new fields and efforts to counteract resistance to change.

Within a given country, a technology innovation system is embedded within a national innovation system.[359] Countries display marked differences in innovation patterns, reflecting historical specialization in different technologies, trade relations, industry structure, institutions, and patterns of learning. Industrial organization differs across countries and appears to represent a major factor leading to differences in innovation across countries.[360] Such systems coevolve with institutions governing innovation within the country.

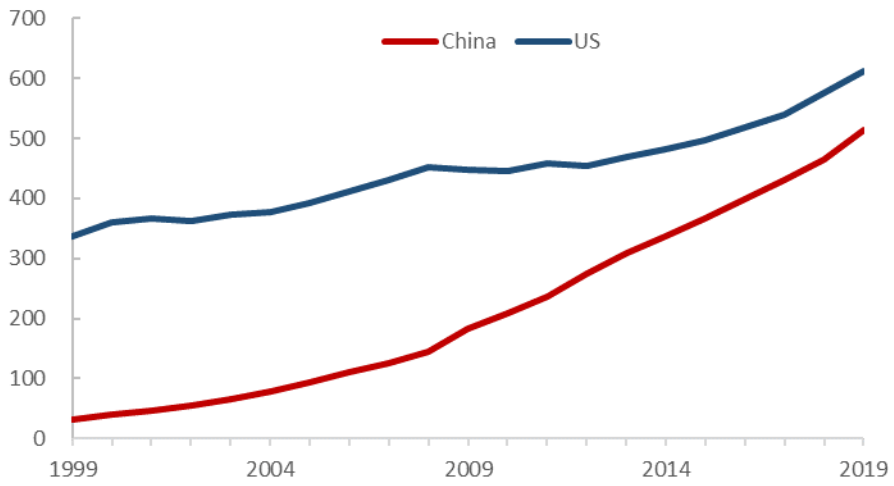
In addition to technology innovation systems and national innovation systems, there also exist sectoral differences – and hence, sectoral innovation systems. Sectoral innovation systems consist of firms active in developing and making a sector's products and technologies, and relates to both technologies and to firm interactions through technology development and market competition.[361] Sectors tend to differ in innovation based on factors such as appropriability of technology (whether firms can protect technologies from imitation), cumulativeness of innovation (whether technologies build upon earlier innovations in the same field, giving an advantage to early movers or those with scale), size and variety of technology opportunities, and knowledge production patterns. Around the world, the fossil energy and electric power sectors have historically featured network effects that resulted in high cumulativeness and appropriability leading to large companies and monopolistic practices and slower innovation. Further, the Chinese government has targeted the energy sector for greater consolidation under large, powerful SOEs, which will likely affect both innovation within the top incumbent companies as well as the degree to which new entrants – such as technology providers, retail energy aggregators, energy service companies, or generation owners – could gain access to the market.

Considered from the perspective of a national innovation system, which emphasizes industrial organization, China's economy has a mixture of SOEs and private enterprises, and an innovation system directed by government policy, implemented by various ministries, national key laboratories, SOEs, and private players, as discussed in detail above.[362] In recent decades, the central government has made reform of innovation policy a national priority, and in 2016 the State Council set a goal for China to become an innovative nation by 2020, an international innovation leader by 2030, and world innovation powerhouse by 2050.[363] As part of reforms to national innovation policy, China established a central leading group on science and technology innovation, implemented reforms to personnel evaluation and programme budgeting, and consolidated programmes to reduce duplication. However, these reforms are, in some respects, still incomplete.[364]

China's national innovation system has become more centralized and institutionalized. As Chen and Naughton have shown, in the past decade China's policies on innovation have not evolved towards a 'light touch', but have rather adopted a specific pattern of administrative institutionalization.[365] In this pattern, national leaders determine basic long-term goals, and give broad guidance and indirect signals of their intent. Government ministries and think tanks then draft policy priorities in somewhat greater detail, bringing together experts from throughout the bureaucracy and industry to provide inputs to policy. Ministries and bureaucrats then shape and implement these policies in ways that aim both to achieve goals set by top leaders, while also maintaining resources and control of key ministries. From this process, certain sectors are targeted for promotion, investment by both SOEs and financial institutions, and R&D spending by universities and large enterprises.

China's spending on energy R&D has risen and accounts for a large amount of the world's share of government R&D spending. China accounted for around 24 per cent of government energy R&D spending in 2019, according to the IEA, whereas in 2006 China accounted for just 6 per cent of global R&D spending.[366] Government R&D spending in a given field or industry, especially when sustained over long periods, has been shown to correlate with future innovation in related fields.[367] Furthermore, corporate and venture capital investment into energy has been increasing, in China and worldwide, and has tended to shift from fossil fuel sectors to more clean energy sectors.[368] In the past, China has benefited from knowledge spillovers from private sector energy R&D resulting from foreign direct investment in manufacturing, as well as through efforts to attract returning scientists and business entrepreneurs.[369] More recently, Chinese overseas investment in clean energy field has had the potential to lead to both technology transfer and reverse innovation in China.[370]

Figure 16: China, US gross domestic R&D expenditures (constant US$ PPP, billion)



Source: OECD

While the state and market have mobilized immense resources for R&D investment, there remain considerable questions about the efficiency of R&D in China. A 2020 analysis of patenting shows that many applicants for Chinese patents also seek international patents, China has a large and ongoing international deficit in licensing royalty payments, and Chinese private firms exhibit low R&D spending versus SOEs. China's high R&D spending results in low efficiency and innovations that rarely reach the market.[371] Other authors have cited R&D policies that allocate most resources to large, central SOEs, despite a poor record of bringing new products to market.[372] This is perhaps most acute in the energy sector, where central SOEs are responsible for managing and maintaining a large, interconnected asset base linked to fossil fuel extraction and production, whereas most renewable technology innovation derives from new entrants. To implement central government policies and thereby capture more resources, SOEs tend to favour large, long-term capital projects aligned with those policies rather than pursuing small, disruptive innovation.[373] Indeed, the tendency of SOE managers to deploy resources in support of empire-building, and to focus on maintaining existing assets, would tend to push SOEs

towards incremental innovation within existing fields.[374] Given the sensitivity of energy infrastructure, it is difficult for energy SOE managers to support disruptive innovation in fields unrelated to present SOE activity, to engage with and learn from non-state stakeholders such as individual consumers or international companies, or to make energy data available via public information platforms that could enable third-party innovation.

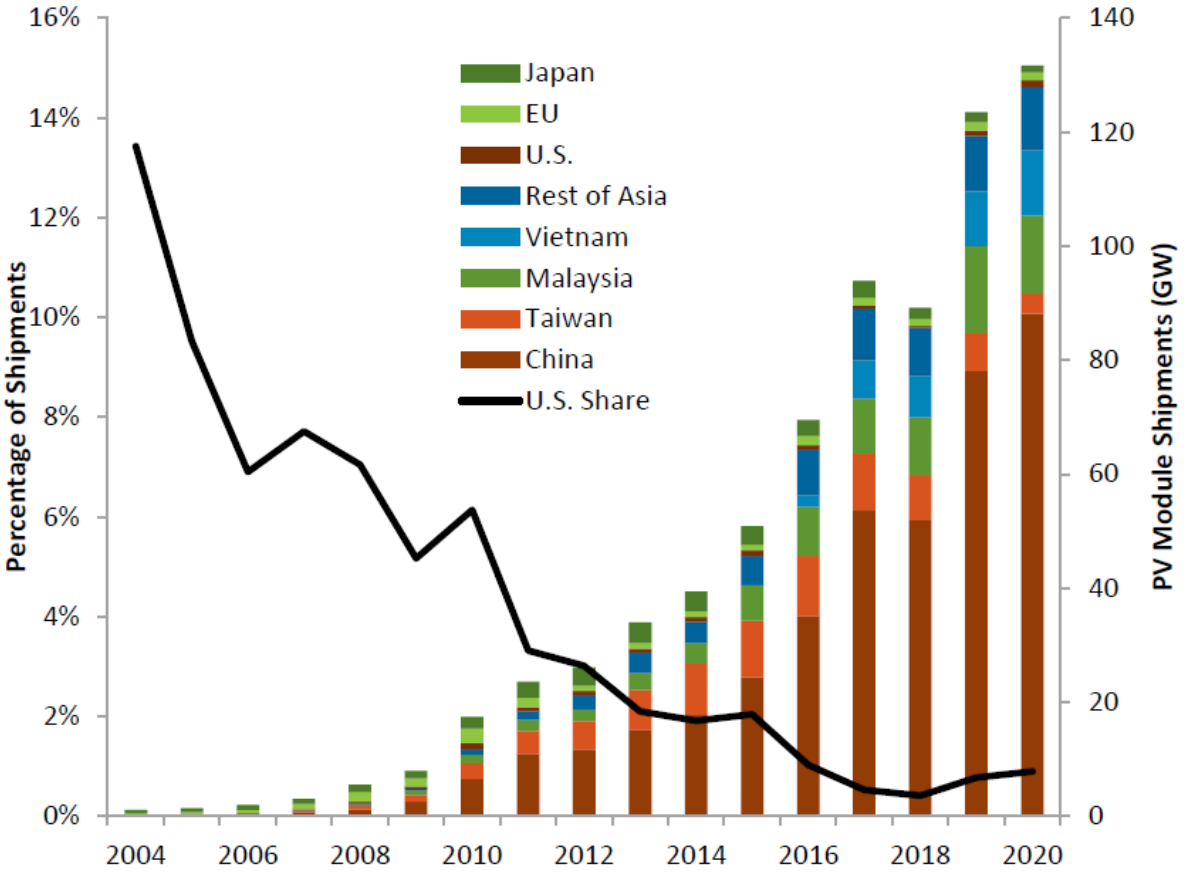
In terms of consistent policy support for new energy technology, China has adopted a dizzying array of innovation targets at all levels and over multiple time periods. China's 13th Five-Year Plan for solar development listed various solar technology targets, aiming to increase advanced crystalline silicon PV cell industrialization conversion efficiency to 23 per cent, and develop thin-film technology.[375] The National Development and Reform Commission in 2016 also set strategic development targets for wind power. The government highlighted four areas for innovation: large-scale wind equipment, offshore system construction, wind farm cluster operation based on big data and cloud computation, and recycling of waste equipment.[376] The National Energy Administration established targets for energy storage, emphasizing development of storage with renewable energy, microgrids, reduction in cost of storage, and improvement in safety and security of energy storage.[377] In October 2020, the State Council outlined several new energy vehicle technologies as key areas for innovation in the next 15 years. These include battery technology, smart network technology, and charging infrastructure improvement.[378] Equivalent examples exist for technologies in the fields of hydrogen, building technology, smart grids, and industrial energy efficiency.

In terms of market formation through supportive policy and establishment of market niches, China has been instrumental in scaling up wind, solar, energy storage, and electric vehicles. In all of these cases, China was a technology follower that scaled up manufacturing first, before shifting to production for domestic markets as the technology reached the potential for commercialization. As noted above, China has used a combination of R&D push (funding, technology roadmaps, performance targets, technology priority catalogues) and demand pull (targets, quotas, subsidies) to enable technologies to progress from initial market entry to scale. Local and provincial governments, in concert with central government guidance, have undertaken pilots and competed to support new industrial development, not always successfully. Commercial enterprises have also supported original niches in fields not targeted by government policy, resulting in new business models and commercialization pathways, such as those for electric bikes, electric shared mobility, and mobile electric vehicle charging.[379]

Lastly, as noted above, the central government has increasingly promoted the overall legitimacy of new technology fields, placing them within an overall societal vision of Ecological Civilization, and placing the power of the Party firmly behind adoption of the low-carbon and energy revolution concepts. While the prior regime continues to exist, and the central government continues to support an 'all-of-the-above' strategy – emphasizing clean and efficient use of coal in the 14th Five-Year Plan, for example – there is ample guidance and space for the energy transition to develop.

Further, the legitimacy of the overall low-carbon energy transition in China, as well as certain new energy technologies such as wind, solar, and electric vehicles, have been helped by the examples available from other countries. As with technology catch-up, in which a follower country can sometimes leapfrog technology stages based on the existence of successful examples and products from other countries, the same process has been shown in terms of energy transition niches and regime changes.[380] For China, the highly-varied energy transition examples from Germany, the UK, Denmark, Norway, Japan, Korea, and US states such as California can help raise the legitimacy of specific policies, practices, and technologies. Further, the Technological Innovation Systems framework acknowledges the importance of face-to-face or interpersonal networks in the innovation process, and such networks increasingly cross international boundaries, such that innovation can no longer be situated clearly at a national or firm level.[381] Global innovation networks have played a part in the development of solar, wind, and battery technology development in recent decades and are likely to continue to do so, even as trade barriers or intellectual property conflicts continue to increase.

Figure 17: Global annual PV shipments by region



Note: Excludes inventory sales and outsourcing
Source: David Feldman et al, H1 2021 Solar Industry Updated, NREL, p. 40, https://www.nrel.gov/docs/fy21osti/80427.pdf

From the foregoing discussion in this section, we can see that consistent policy – both on R&D and on demand-pull policies – has guided innovation and manufacturing scale-up in wind, solar, energy storage, electric vehicles, and other new industries. National policies such as feed-in tariffs, purchase subsidies, quotas, and administrative support to resolve market barriers have also led to the creation of large market niches for these same technologies. Central and provincial governments have mobilized resources for renewable energy and electric vehicles, both for R&D and manufacturing scale-up. Government officials, and worldwide energy trends have contributed to the legitimacy of these new fields.

6.2 China's position within the global clean energy innovation system

While China was long portrayed as primarily engaged in technology catch-up, and lacking in technology absorptive capacity, this approach appears not to have captured changes over the past decade that have resulted from R&D, stricter environmental targets, and policies that provide long-term support for clean energy. Academic studies have found that China's innovative capacity in clean energy has now, at least partially, shifted from technology catch-up, to the fully developed stage. Particularly in the solar and energy storage sectors, China appears to have moved towards the centre of the world energy technology innovation system.[382] Whereas a decade ago, Chinese companies filed few solar patents and these were rarely cited outside the industry, in recent years Chinese solar patents have been among the most cited within and outside the industry. A similar change has taken place in energy storage. By contrast, in the field of wind power, where China also leads in annual installations, China's innovation and patent activity appear focused on more peripheral innovation, and the country remains relatively dependent upon foreign technology.[383] Domestic turbines cost less but offer lower performance than those in the US.[384]

Why does China lead in some clean energy technologies but not in all, and what does this portend for the future of clean energy in China? Several factors are at work: in terms of the number of patented components, solar and battery technologies appear somewhat simpler, and patent analysis suggests innovation in these fields depends on materials and electronics-related R&D, in comparison with wind power and other technologies that are dependent upon both materials and mechanical engineering innovation.[385] The wind power market is dominated by a few major players manufacturing large equipment for multi-MW devices, whereas solar and storage feature commoditized manufacturing and high-priced competition among producers of relatively smaller cells, packs, and modules. China's policies in the wind sector encouraged domestic content requirements and localization of manufacturing under a FIT regime that ensured steady revenues, compared to solar where the globally competitive export market and a multiplicity of players forced innovation to keep up with price declines.[386]

6.3 China's institutions and the nature of clean energy technology

Clean energy journalists and proponents have cited Moore's Law and Ray Kurzweil's Law of Accelerating Returns to support the idea that clean energy worldwide could scale up far more rapidly than is implied by most conventional energy forecasts.[387] For example, a 2014 article in Greentech Media cited Kurzweil in projecting that solar could dominate electricity production in less than 20 years, and a similar 2013 article from an EV proponent suggested that battery electric vehicles could dominate vehicle markets worldwide by 2030.[388] Wind and solar are already at or near price parity on a levelized cost basis, but will price declines continue, and does this depend on China's innovative capacity?

The economic literature on learning rates and their application to clean energy can provide various answers to this question. Looking at worldwide cumulative production of wind and solar, there exist a range of estimates of the learning rate – the decline in cost for each doubling of capacity for a given technology – showing that wind's learning rate is roughly 5–10 per cent, solar 20–30 per cent, and battery energy storage 20 per cent.[389] Based on these learning rates, hybrid renewable facilities combining wind, solar, and energy storage would become economical before the mid-2020s.[390]

These numbers mask the many different factors that underlie the cost declines. For example, a 2018 MIT study showed that in the 1990s and 2000s, solar PV cost declines were driven by R&D and technology diffusion, whereas in the late 2000s and early 2010s manufacturing scale-up and related knowhow were more important.[391] As noted by Schmidt and Huenteler, solar PV, wind power, batteries, and electric vehicles can be characterized as technologies with varying complexity in terms of design and manufacturing. Solar PV and batteries represent examples of modular, manufacturing-intensive technologies suitable for rapid technology catch-up, commoditization, and industry relocation to manufacturing centres, whereas wind represents a highly cumulative, design-intensive technology requiring close integration with, and learning from, early customers, leading to a pattern in which early leaders retain strong global market share.[392] Today, wind and solar PV have reached the full commercialization stage, while battery energy storage is beginning the phase of rapid global scale-up.

To date, much of the literature on clean energy innovation has focused on renewable energy. Carbon capture, utilization, and storage (CCUS) and nuclear differ vastly from wind, solar, and storage, both in scale and design complexity, and may have less potential for rapid, solar-type learning curves based on scale-up. While hydrogen electrolysis has potential for rapid learning rates,[393] electrolysis is only one component of a complex hydrogen economy comprising production, transportation, storage, and use. CCUS, nuclear, and hydrogen may be better described as complex product systems, which operate at large scale and entail high capital costs and extensive periods of piloting and experimentation.[394] While China's proclivity towards capital-intensive infrastructure investment, coordination by powerful state-owned industries, and system of provincial pilots could give it an advantage in such fields, these cases display a substantial difference with wind, solar, and energy storage – fields where policies on manufacturing and technology catch-up played the leading role in enabling learning and cost reduction.

Furthermore, in the areas of energy efficiency and ensuring that energy demand (such as for EV charging or industry) can respond to variable renewable energy output, a broader suite of innovation in networks and IT will be needed. These fields require interaction and the open-ended engagement of many stakeholders.[395] In addition, energy efficiency and demand-side energy technology innovation face large institutional barriers (such as the builder–owner–occupant dilemma, in which building construction firms, owners, and occupants are different entities and hence each lacks the incentive to

build or operate for energy efficiency or sustainability), lack of consumer awareness, and historical reliance on cheap energy that likely cannot be overcome by market reforms such as spot power markets or carbon prices.

Historically, China's innovation policy has favoured supply-side innovation,[396] rather than moderating the energy demand. For these reasons, while China's technology innovation system has developed highly sophisticated functions in some fields – especially manufacturing-oriented technologies such as solar and batteries – innovation in fields either dominated by large, conservative, state-owned entities or requiring stakeholder interaction at multiple levels, may be inherently more difficult. This is especially true if China's relations with the US and other Western economies continue to sour and there are fewer international inputs into the innovation process. As such, China's involvement in the international energy and climate system can help, and could also hinder, the energy transition.

7. International energy and climate governance as enablers of the energy transition

- *China's governance system and domestic interests will be central to its energy transition. But international energy and climate governance also play a role, with the close relationship between China's institutional setting and international institutional development supporting the adoption of domestic climate policies, including the 2060 carbon neutrality commitment.*
- *Formal international institutions such as the UNFCCC, the IEA, and IRENA, despite their fragmentation, are increasingly focused on the energy transition, pointing to greater international coordination on climate change. They have also undertaken specific bilateral cooperation projects with the Chinese government and non-governmental partners on China's power sector reform, carbon markets, and the development of green finance, among other questions. Similarly, major international climate summits are action-forcing events for many countries, with China also timing major climate-related policy announcements to coincide with international events and conferences.*
- *Multilateral development banks (MDBs) increasingly play a role in global climate governance, helping to develop standards related to environmental, social, and governance issues. MDBs are involved in financing climate change mitigation and adaptation projects in China, together with related capacity-building efforts, and such efforts directly engage Chinese policy makers, researchers, and private companies.*
- *Bilateral and multilateral government cooperation projects also help shape agendas, while international NGOs support climate governance by advising policy makers, publishing reports, funding and conducting research, and providing technical assistance to both public and private organizations.*
- *The global media and international private firms play a mixed role, however. With the international media often portraying China's posture on climate and energy negatively – emphasizing issues related to urban air pollution, coal plant construction, and rapidly rising emissions, and with access to international media in China being increasingly limited – it is unclear whether media coverage – positive or negative – hinders or helps accelerate policies toward the low-carbon energy transition. Similarly, large international companies and investment firms have taken the lead in promoting low-carbon business strategies. At the same time, energy companies, manufacturing firms, and consumer goods companies with large supply chains in China may seek only to comply with existing regulations at the lowest cost, or even to relocate production or investment elsewhere if conditions change.*

Literature on the energy transition-related institutions of individual countries often pays little attention to international institutions, which have played an increasing role in international energy and climate governance in the past few decades. The global energy industry and technology innovation systems are highly internationalized. China's domestic institutions are, in many cases, highly integrated into global energy governance and technology innovation systems, with some exceptions. Broadly, the close relationship between China's institutional setting and international institutional development has

supported China's adoption of domestic climate policies, including the 2060 carbon neutrality commitment.

7.1 Formal international institutions

The most visible international institutions related to energy and climate governance are formal institutions such as the United Nations (including the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC)), the International Energy Agency (IEA), and the International Renewable Energy Agency (IRENA). These, and other formal organizations, form the heart of an international climate change regime,[397] and also constitute a global energy governance regime.[398] However, these energy and climate regimes are highly fragmented, and their constituent organizations and elements differ in terms of goals, activities, focuses, and technology emphasis.[399] A 2020 review found at least 128 international organizations dedicated to global energy governance, covering fields such as standards, operations, policy analysis and planning, information sharing, finance, and networking.[400] Many international energy governance organizations have regional character, or represent subnational actors, such as the Clean Energy Ministerial, which constitutes 'a voluntary, bottom-up, government-owned forum for exchanging knowledge and insights, building networks and partnership, and facilitating coordinated actions on clean energy', or the Global Covenant of Mayors on Climate & Energy, which describes itself as a global alliance of over 1,000 cities from 140 countries. Energy governance is highly fragmented and decentralized, often created from the bottom up by individual groups or blocks of countries.[401]

Formal institutions associated with the international climate and energy regime have a variety of focus topics, such as energy security (IEA), price coordination (OPEC), energy access in the developing world, energy innovation, or policy coordination. Nevertheless, climate change has steadily grown as a topic for international coordination. The United Nations has referred to climate change as 'the defining challenge of our times' and the UN Secretary General has urged countries to raise their ambitions on climate and declare a 'climate emergency'.[402] The IEA – which was established following the global energy crises of the 1970s and initially focused mainly on oil, but now publishes scenarios related to Paris Climate Agreement targets – has recently published a scenario of how the world might reach net zero carbon emissions by 2050, and has projected that solar will become the 'king' of energy sources in the coming decades.[403] The changing attitudes of these international organizations, and the participation of Chinese experts as staff, secondees, or leaders in international organizations working on low-carbon energy, can be considered an element of China's energy institutional context.

In addition, international organizations such as the UN Environmental Programme, UN Development Programme, and the IEA have undertaken specific bilateral cooperation projects together with the Chinese government and non-governmental partners. These include research and modelling efforts, hosting workshops, and providing expert technical feedback to Chinese policy makers in the process of developing carbon and energy markets. For example, in 2019 the IEA published an extensive report on China's power sector reform,[404] and in 2020 the IEA published a report on China's carbon market.[405] The UNEP and UNDP have cooperated with Chinese think tanks on developing green finance policies for the Belt and Road. Such cooperation enables international organizations to directly provide policy suggestions and feedback to the Chinese government within the Chinese context.

7.2 Climate and other international diplomacy

Major climate summits and negotiations are a central aspect of climate governance, at which national leaders, top diplomats, or energy and climate officials can negotiate new commitments (binding or otherwise), declare new domestic climate actions, and respond to international criticisms. The degree of attention that leaders pay to the climate issue obviously varies over time and depends on the leader or government official. However, climate change and renewable energy have risen as a priority among the 2,500 top world energy leaders from over 100 countries surveyed by the World Energy Council.[406]

Climate scientists, business leaders, and environmental activists, together with non-governmental organizations, also attend such meetings to exchange views and best practices, apply pressure, advertise their own activities and publications and, most importantly, directly participate in international climate negotiations. Cooperation and participation of non-governmental parties is a foundational aspect of the Paris Climate Agreement of 2015.[407] China has encouraged Chinese NGOs to participate

in climate COPs, and since 2007 China has had an officially recognized NGO for youth action on climate change.[408]

China is an active participant in climate negotiations. In 2009, China and the United States were widely criticized for playing an obstructing role in preventing the adoption of more aggressive climate goals or binding commitments. China's bilateral climate agreement with US President Barack Obama in 2014 set the stage for the Paris Climate Agreement, and the entire structure of the agreement reflects the position of China and other countries that climate negotiations should continue to reflect common but differentiated responsibilities among countries, and that voluntary, nationally-determined contributions should form the basis for international action.

Like many countries, China times its major climate-related policy announcements to coincide with international events and conferences. For example, President Xi Jinping delivered his announcement about China's 2060 carbon neutrality goal at the 2020 UN General Assembly. In April 2021, after a two-day US–China climate summit, and during a meeting with French President Emanuel Macron and German Chancellor Angela Merkel, President Xi announced that China would accept the Kigali amendment to the Montreal Protocol on ozone-depleting substances.[409]

7.3 Multilateral development banks

Multilateral development banks increasingly play a role in global climate governance, as sustainable development is increasingly recognized as essential to the banks' development missions. MDBs have developed various standards related to environmental, social, and governance issues, such as the Equator Principles. Since 2011, MDBs have reported on their climate finance activities, and in 2019 the leading MDBs pledged at least US$65 billion to climate finance by 2025.[410] The Paris Climate Agreement committed MDBs to

> 'making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development',

and subsequently, in 2018, pledged

> 'to shift from financing climate activities in incremental ways, to making climate change … a core consideration and a "lens" through which institutions deploy capital' (Climate Action in Financial Institutions, 2018).

Chinese institutions such as AIIB (an international bank headquartered in Beijing in which China is the largest stakeholder) have adjusted their strategies over time, becoming more responsive to international concerns about climate change. China's activities abroad, including in relation to the Belt and Road, lead to greater dialogue with other countries and international institutions on climate-related issues, including emissions as well as adaptation. In 2019, at the second Belt and Road Initiative forum, the NDRC and MEE held a sub-forum dedicated to building a 'green Belt and Road' to align the BRI with the UN Sustainable Development Goals.[411] Subsequently, the UN and over 20 UN agencies joined with China and others to establish a Belt and Road Initiative International Green Development Coalition (BRIGC) to support green investment in recipient countries, including in relation to climate change.[412] The China Council for International Cooperation on Environment and Development (CCICED) established a special task force composed of top government officials and international experts to develop policies to align the Belt and Road with the SDGs.[413] However, until recently climate has not been considered a major risk in managing SOE investments abroad,[414] and until mid-2021, when China pledged to end public financing for coal projects abroad, the country remained the leading financer of coal projects worldwide, though renewable investments abroad have also picked up pace recently.

MDBs are involved in financing climate change mitigation and adaptation projects in China together with related capacity-building efforts, and such efforts directly engage Chinese policy makers, researchers, and private companies. The World Bank has worked with Chinese counterparts, mainly the NDRC and NEA, to develop renewable energy and reduce carbon emissions. In the early 2000s the Renewable Energy Development Project (US$27 million) and the China Renewable Energy Scale-up Program (CRESP) Phase I (US$40 million), piloted and deployed wind power and solar PV. Since 2013, the World Bank's CRESP Phase II has focused on technology improvement, cost reduction, and

preparing renewables to enter the power markets. The Distributed RE Scale-up Project, and the China Renewable Energy and Battery Storage Promotion Project, both approved in 2019, aim at distributed renewables, battery storage, and green hydrogen production. The Bank also finances activities related to low-carbon mobility, accelerating the energy transition in the power sector towards carbon neutrality, and provincial low-carbon energy transition in Shanxi province.[415] The World Bank in 2016 began to finance a US$500 million project to reduce air pollutants and carbon emissions through increasing energy efficiency and clean energy in the Jing-Jin-Ji region of northern China.[416]

The European Investment Bank and the Asian Development Bank have also financed renewable energy and low-carbon energy transition-related investments in China. In 2006 the EIB launched phase I of its US$500 million China Climate Change Framework Loan to support clean energy and energy efficiency projects in China, and the project was renewed for a further US$500 million in 2010.[417] The ADB implements the Shandong Green Development Fund, which aims at development of climate positive infrastructure and business in Shandong province.[418] The SGDF uses the Green Climate Fund investment criteria and framework, and includes elements related to capacity building, public–private partnerships, and innovation. The ADB has also financed efforts to switch from coal to gas in Hebei province and to support green finance and institutional development in Hubei province.[419]

7.4 Bilateral cooperation

Bilateral and multilateral government cooperation projects also directly engage policy makers, experts, and industry officials in promoting low-carbon energy. Recent cooperation projects include the EU–China Energy Cooperation Platform, implemented by the NDRC Energy Research Institute and ICF, which holds expert workshops and publishes research reports on topics such as power market reform, renewable energy integration, and carbon emissions trading; the Sino-German Energy Partnership, the Sino-German Energy Transition Project, the Sino-German Clean and Low-Carbon Transportation Project, and the Sino-German Climate Partnership, implemented on behalf of various German and Chinese ministries by GIZ a German federal international cooperation and development agency;[420] the China Prosperity Fund, which is administered by the UK Embassy and funds various low-carbon and clean energy projects and capacity building activities; the Boosting RE project, a long-term cooperation between Denmark and China on modelling low-carbon energy transition pathways; and several renewable integration and low-carbon-oriented power market reform activities undertaken as part of bilateral cooperation between Norway and China.

China's government ministries, state-owned enterprises, and subnational governments have cooperated with international organizations, foreign governments, and foreign NGOs, often setting up and managing cooperation through dedicated international cooperation departments. In addition, China has long-established think tanks specifically dedicated to international cooperation. The China Council for International Cooperation on Environment and Development (CCICED) was established in 1992, around the time of the Rio Earth Summit. CCICED has 50 expert members, half Chinese and half international, serving five-year terms. The members have comprised key political leaders, business leaders, representatives from international organizations and NGOs, and the council chairperson is the vice premier of the State Council with responsibility for environmental protection.[421] China's top leaders have met directly with CCICED experts to discuss environmental issues, and CCICED itself issues policy recommendations and reports on topics such as air quality, development of carbon markets, adoption of clean energy technology, and green finance.[422] In addition to CCICED, the China Center for International Economic Exchanges (CCIEE), established in 2009 and also comprising a list of top Chinese academics and current and former officials, conducts studies and makes policy recommendations on environmental and energy matters. CCIEE has cooperated on green finance with the German Konrad Adenauer Foundation, and with the United Nations Development Programme on recommendations for low-carbon development on the Belt and Road.[423]

7.5 International NGOs

International NGOs play several roles in China's low-carbon energy transition, including advising policy makers, publishing reports, funding and conducting research, and providing technical assistance to both public and private organizations. A few examples include:

- *Energy Foundation China, a US-based philanthropic organization, has supported Tsinghua University's Institute for Climate Change and Sustainable Development on developing net zero emissions pathways for China to 2050, working together with two dozen research institutions and think tanks.[424] EFC also supports detailed studies by Chinese researchers and companies on topics related to sustainability – such as electrified bus fleets, energy efficient cooling, the energy–water nexus, and net zero industrial parks.*
- *The US-based Natural Resources Defense Council (NRDC) has worked on various environmental policy topics in China for many years, and in 2013 launched a collaborative research project with various Chinese institutions aimed at capping coal consumption – later expanded to include oil consumption.[425]*
- *For over a decade, the US-based Environmental Defense Fund has advised Chinese researchers and policy makers on establishing a carbon emissions trading system, and in recent years has trained power sector officials on operating emissions trading platforms.[426]*
- *Greenpeace East Asia's activities in China include advocating phasing out coal and working with data centre operators on energy efficiency and renewables.[427]*
- *The US-based World Resources Institute supports national and subnational low-carbon policy roadmaps and early peaking plans for cities, as well as research promoting renewable investment.[428]*
- *Among many wildlife protection and biodiversity-related projects in China, the World Wildlife Fund (registered in China as the Worldwide Fund for Nature) supports research and policy advice on renewable integration, the trading of green certificates for renewable power, and research on low-carbon city policies.[429]*

The activities of foreign NGOs receive support and funding from individuals, international institutions, foreign government agencies, and philanthropic organizations such as the Children's Investment Fund Foundation (CIFF), the MacArthur Foundation, the Hewlett Foundation, the Packard Foundation, the Grantham Foundation, and ClimateWorks.

China's new foreign NGO law, which came into effect in 2017, required foreign NGOs to register with the Ministry of Public Security, file annual reports on finances and activities, and seek prior approval from their official Chinese partner organizations for most significant activities such as workshops, reports, or research.[430] Such requirements have likely served to further constrain the activities of foreign NGOs, not only regarding the activities of China-based staff, but of worldwide activities that might concern China. As a result, foreign NGOs in China may serve in a similar role to domestic NGOs, which primarily advise the government in private, or organize community activities that would correspond with government policy objectives.

Many international cooperation efforts engage with working-level actors in NGOs, think tanks, and academia, as well as with international organizations such as the IEA and UNDP. In many cases, Chinese experts may be involved in multiple collaboration efforts. International organizations and bilateral cooperation projects may sponsor secondments for junior or senior personnel at Chinese government think tanks. Chinese university students and graduates often find internships or short-term employment by participating in such projects, while Chinese academic professors or analysts may serve for periods as consultants or employees of such activities. Through such channels, experts in various countries exchange technical modelling and analytical practices, international knowledge and experience, and policy ideas. Such exchanges contribute to the evolution of global, shared paradigms related to the low-carbon energy transition.

7.6 Global media

Global media mentions of climate change have risen in the past few years, although they remain below their peak.[431] Clean energy transition and renewable energy have grown in terms of coverage and mentions on social media. In recent years, international media have often portrayed China's posture on climate and energy issues in a negative light, emphasizing issues related to urban air pollution, coal

plant construction, and rapidly rising emissions. This may reflect general international media framing of the climate issue as one in which government policy makers have lagged recommendations of scientists for action, and perhaps also negative Western media or audience attitudes and expectations towards China and its climate policies. International media reports of climate conferences often frame stories in terms of whether foreign leaders will seek to place pressure on Chinese leaders to do more on climate, whereas China's domestic media presents Chinese policy as receiving nearly universal international acclaim.[432] Access to international media in China is limited, and it is unclear whether media coverage – positive or negative – hinders or helps accelerate policies or other actions related to the low-carbon energy transition.

7.7 Multinational firms and investors

International private firms and investors likely differ dramatically in the extent to which they promote a low-carbon transition in China through their interactions with Chinese officials or industry peers. On one hand, many large international companies and investment firms have taken the lead in promoting low-carbon business strategies. At the same time, energy companies, manufacturing firms, and consumer goods companies with large supply chains in China may be indifferent or even hostile to addressing climate change, seeking only to comply with existing regulations at the lowest cost, or even to relocate production or investment elsewhere if conditions change.

Large multinational firms have grown more responsive to climate change issues in recent years, for a variety of reasons,[433] and this affects business strategy, investment focus, and the degree of interest in adopting low-carbon practices or energy sources. Outside China, large global consumer brands and other companies have sought to source energy from renewables: for example, FAW–Volkswagen in January 2021 purchased 30,000 green certificates, the largest such transaction to date.[434] International corporate interest has likely had some influence on China's efforts to develop a market for corporate purchases of voluntary green certificates. Some multinational firms with operations in China have sought to encourage suppliers to purchase or install renewable energy or engage in energy-saving practices for both economic and environmental reasons. For example, Apple in 2018 partnered with 10 supplier firms to establish the China Clean Energy Fund to develop over 1GW of renewable energy.[435] International firms work with NGOs, such as the Rocky Mountain Institute, to source clean energy and educate suppliers on their requirements related to green power purchase agreements.[436]

Institutional investors are playing a larger role in encouraging the adoption of environmental, social, and governance measures, particularly in relation to climate change risk.[437] This trend has begun to affect major global fossil energy players, due to both shareholder resolutions and changing valuations for companies with high fossil fuel exposure. Some scholars have used the term *investor governance networks* to refer to such activity.[438] As energy and other companies worldwide shift their strategies and investments in a low-carbon direction, and as carbon-intensive fossil fuel investment valuations begin to respond to investor concerns about climate and policy risks, this could also influence Chinese energy company investment activity and attitudes. For those Chinese company managers with international corporate experience, either inside or outside China, attitudes and expectations could reflect evolving global perspectives on the need for, and feasibility of, investing in low-carbon energy pathways.

Several prominent international energy companies are active in China, bringing their own technologies, expertise, and business practices to the country, and often bringing these perspectives into policy and academic discussions related to the energy transition. While a full list would be impossible, a few larger examples of global energy brands with significant marketing and public engagement include Engie, which invests in Chinese solar PV as well as projects to switch from coal to gas; Total, which in addition to its oil and gas supply and retail activities also operates a solar JV and is a 50–50 partner in a distributed solar company; EDF, which invests in nuclear, coal, and PV projects in China; Siemens and General Electric, both of which supply electrical equipment such as gas turbines and digital control technology, as well as operating R&D centres in China. Many energy companies participate in policy and market discussions via the European Chamber of Commerce or the American Chamber, China, which host energy-related working groups together with Chinese companies or experts, and which draft position papers on key policy issues of interest to companies. In several instances, energy companies actively cooperate in university R&D partnerships or engage in academic cooperation related to energy

policy. BP in 2003 helped found the Tsinghua–BP Clean Energy Research and Education Center, which produces forecasts and policy analysis.

In summary, the overall international institutional context of China's low-carbon energy transition governance appears to help accelerate that transition through technical expertise, sharing of ideas and experience, and reinforcing new paradigms of low-carbon energy systems. Chinese membership in, and cooperation with, international institutions, Chinese leader participation in climate summits, Chinese policy maker or project-level interactions with MDBs on international finance and domestic finance, the activities of foreign NGOs and multinational companies, and academic cooperation all contain elements of mutual exchange, policy analysis, joint innovation, and experience sharing. While each institution is distinct, the flow of ideas and individuals among these organizations, as well as the holding of joint activities or participation in investment projects or business deals, likely has a major positive influence on the diffusion of low-carbon energy business and investment practices, policy ideas, and overall paradigms shaping expectations surrounding the energy transition.

Without question, the overall global energy sector's institutional setting does contain some formal and informal international institutions that could hinder a low-carbon energy transition in China. For example, demand for Chinese loans to support fossil fuel extraction and fossil energy production can support the maintenance of such business lines in China even as the paradigm in China shifts towards long-term targets of carbon neutrality. China's international diplomatic and industrial activities aimed at securing energy resources for import to China likely reinforces and locks-in emissions-intensive infrastructure and business relationships. International trade competition may discourage domestic regulations aimed at reducing emissions or improving the energy mix if such efforts seem to put domestic companies at a price disadvantage. Not all countries, particularly in the developing world, have placed a high priority on addressing climate change; formal and informal exchanges involving these regions may emphasize fossil fuel development and high-emissions development pathways.

Over the past few decades China has progressively deepened its international engagement at all levels, but this could change. The Covid-19 pandemic has obviously disrupted in-person interactions and cooperation activities worldwide, and has likely led to a reduced number of foreign experts who can participate in cooperation or visit China for consultation. Even prior to the pandemic, academic exchange in certain regions had become more challenging due to mutual distrust. Trade conflicts could result in fewer international companies taking an active role in Chinese markets or engaging in technology cooperation with China. Lastly, bilateral cooperation on energy and climate issues has gradually shifted, given that many countries no longer provide overseas development assistance (ODA) to China (the OECD ranks China as an upper middle-income country), a factor which has also affected the intensity of MDB lending in China for energy or environmental activities.

[439] All of these factors could reduce the extent of China's international energy institutional engagement in the future.

Conclusions

China's target of peaking carbon emissions by 2030 and reaching carbon neutrality by 2060 will entail changes throughout the country's economy, particularly in the structure of the country's energy production and consumption. This will require not only a change from one type of energy source to another, but a wider change in the energy sector's sociotechnical regime. China's present energy regime evolved around an energy development pattern supported by, and embedded in, the country's formal and informal institutions related to energy. While China has led the world in scaling up clean energy and other related technologies, different types of institutions in the country will help or hinder the ongoing low-carbon energy transition, depending on their evolving characteristics and features.

China's central government leadership appears committed to achieving carbon neutrality as an element of Ecological Civilization, and has steadily adopted targets, policies, incentives, and regulations to support these goals. The central leadership has several goals: industrial policy, improving environmental quality, reducing energy imports, and bolstering China's diplomatic position. However, fragmented policymaking institutions, and lack of capacity at central government institutions, have occasionally prevented implementation of policies related to clean energy and climate. Administrative

targets and central planning have their limits, especially given the short-term economic goals held by provincial officials and energy SOEs that tend to work against long-term low-carbon energy transition objectives. Further, a serious economic or political crisis could easily lower the priority given to combatting climate change. So, while the short-term commitment to the dual carbon goals has created strong momentum for change, it remains unclear to what extent it can lead to deeper institutional change.

China's energy sector is dominated by the state sector, whether speaking of prices, output, targets and planning, or investment. SOEs sit at the heart of oil and gas production and transportation, the power grid, and electricity production, including renewables. SOEs are also big players in automaking, steel, cement, infrastructure, construction, and other energy-consuming fields. Even in fields with large numbers of private players – such as solar manufacturing or electric vehicle charging networks – quasi-governmental industry associations guide industrial planning, negotiate over regulations, and develop standards. Large private companies often have mixed ownership, and in any case government relationships and regulations play an immense guiding role in determining the economic fate of all companies engaged in energy sector work.

Several factors particularly reinforce the extent to which the present economic structure of China would lead to regime resistance against novel, low-carbon, and potentially distributed energy technologies. China's economic growth pattern has historically relied on large-scale capital investment by state-owned entities, backed by SOE bank lending. As in other countries, asset-owning companies, local officials, and their regulators often seek to preserve and build upon existing, established industries – thereby increasing employment and raising utilization of existing assets. Shifting to wholly new energy sources or patterns of consumption requires not only new investment and potentially the abandonment of older assets, with the employment disruption that could accompany such changes, but it also entails recognition of new low-carbon energy paradigms. As we have seen in the electric power sector, in 2021 Chinese power system planners still see in-province coal power as the primary way to address electricity shortages, while demand response, renewable energy, and interprovincial power trading face resistance.

This said, China today would not have millions of EVs on the road and hundreds of gigawatts of wind and solar installed if the country's economy were incapable of innovation, or if its companies and entrepreneurs were entirely shut out of the state-dominated energy sector. China's private companies and entrepreneurs have responded quickly and nimbly to both clean energy export demand and to supportive policies for domestic clean energy. Local and national officials have supported innovation and growth through consistent policies, subsidies for new industries, R&D spending, and industrial coordination. Within certain fields of clean energy, particularly for manufacturing-intensive goods such as solar PV and batteries, China has a fully-developed technology innovation system in place that can sustain growth, create new products, and reduce costs to enable commercialization.

In other fields, such as hydrogen, demand response, or carbon capture, utilization, and storage (CCUS), these characteristics may be insufficient to promote innovation or enable niches to become truly transformational. Innovation in these technologies necessitates the involvement of larger players and coordination of other, different, stakeholders than was the case for solar or EV batteries, and entails deeper changes to markets, institutional incentives, and dominant paradigms for energy production and use. Since these inherently all require substantial changes at state-dominated energy and industrial companies, reforms will be needed to restructure such firms around low-carbon transformation, and in some cases to substantially shrink companies and industries and redirect their financial and economic resources to new fields. For the energy sector, shifting from an 'all-of-the-above' period of rapid growth in supply and demand to one in which low-carbon energy displaces most or all of the existing fossil fuel industry will likely require major industrial and market reforms, as well as a long-sought rebalancing of the economy away from energy- and resource-intensive sectors.

There is no clear indication that the government would support such structural reforms to energy SOEs or to the overall industrial structure of the energy sector. In the past decade, China's central government has initiated reforms to electricity and energy markets and introduced carbon markets at the provincial and national levels. These reforms have moved gradually, leaving the existing industrial players largely intact, and the timeline remains unclear as to when wholesale energy or electricity prices or carbon

prices would substantially affect investment. Administrative planning and targets currently guide investment and production, and planning may even assume a greater role as coal phases out and large-scale changes in employment and industrial structure come to the fore.

Further, as Green and Stern noted in 2016, China's energy- and resource-intensive economic structure is unsustainable on both economic and environmental terms.

[440] Carbon neutrality entails a broader economic structural shift that cannot be encapsulated in market reforms to specific sectors – and such a transition may not be amenable to the administrative planning typical of existing state-dominated economic institutions in any case. Similarly, China's legal system plays an indeterminate role in encouraging the energy transition, given the strong role of the state in all aspects of both the energy and legal fields.

Lastly, China's energy institutions are embedded within an evolving international institutional regime related to climate and energy. While most large economic actors in the energy field – from oil and gas companies to banks and supplier firms – underpin a continuation of the present energy structure, many formal and informal institutions at the global level have created a network of actors supportive of a low-carbon energy transition. Chinese leaders, experts, entrepreneurs, and scholars draw upon this network for expertise, policy advice, and technical support, and Chinese experts often shuttle between, or share, roles in international organizations or institutions. While China's engagement with international institutions largely supports a low-carbon energy transition, it is difficult to evaluate the relative importance of such engagement given the immense scale and importance of domestic energy sector players.

In sum, there are multiple levels of institutions that both support and hinder China's ongoing low-carbon energy transition. Multiple interactions between China's institutional context and low-carbon technology development exist, implying that success in scaling up one clean energy technology may not imply success in another. Moreover, China's institutions – like those in any country – are evolving and changing. In some cases, such as in power and carbon markets, or policies to support clean energy, these changes may represent deliberate reforms, or strategies of industrial development. In others, changes may represent ad hoc efforts to reinforce the existing regime, or to support local employment, near-term economic growth, or corporate profits. The speed and success of China's low-carbon energy transition will depend not only on technology trends, but also on the willingness of its leaders to adopt major institutional changes within the energy sector to enable clean energy sources, facilitate distributed energy production and consumption, and transition away from heavy supply-side infrastructure investment by SOEs towards more disaggregated and consumer-controlled demand-side technologies.

Figure 18: The institutions that help and hinder China's energy transition

Institution	Factors that help	Factors that hinder
Central government	• High-level commitment • Centralized enforcement through ministries, regulations, standards, inspections • Control of local officials through Party (recruitment, communication) and promotion	• Small size of central government and reliance on input from state-owned companies • Autonomy of local officials • Certain degree of corporate autonomy in policy implementation
Provincial government	• Seek investment and economic development by aligning with central government policy goals • Officials seek recognition and promotion through implementing central directives	• Strong motivation to pursue growth via existing industries and SOEs. • Strong ties with local state-owned industry through personnel and project approval procedures • High risk aversion, short-term performance incentives not always tied to long-term energy transition or carbon emissions (increasingly connected now)
Incumbent industry organizations	• State-organized industry associations can rapidly develop standards, common designs, and roadmaps, including for new industries	• Industry silos give incumbent industries blocking power over new entrants or disruptive technologies
Civil Society	• Some elements of civil society have developed to push for environmental goals and innovation	• Strict control over media, speech, and non-governmental organizations implies civil society limited in ability to monitor or communicate on certain environmental issues

Enterprises (SOEs and Private)	• Government control and societal responsibility requirements lead SOEs to implement state policy priorities • Chinese private companies in some fields have shown ability to rapidly scale up manufacturing and adapt new technologies to market requirements, driving down clean energy costs	• Immense power of energy and infrastructure SOEs crowds out private capital and innovation • SOEs coordinate with officials at all levels to establish development plans and policies that favor existing industries and utilization of existing assets
Law	• China's legal environment has become more formal and professional	• Individuals, NGOs and private enterprises still have little recourse to law over issues of public policy or the practices of state-owned entities
Innovation	• China's national innovation system includes high R&D spending, large number of educated graduates in all relevant fields, consistent policy support, and national and private labs.	• The energy innovation arena involves a large number of conservative, risk-averse entities, such as energy SOEs focused on preserving existing assets • Energy innovation has been most pronounced in manufacturing-intensive fields, and less innovation is seen in design-intensive fields requiring high stakeholder coordination and engagement
Markets	• Policy makers have undertaken reforms to power markets and carbon emissions trading that would favor clean energy if fully implemented and open to new entrants on the supply and demand sides	• Reforms have proceeded at a slow pace, and presently play a limited role in encouraging clean energy, as compared to administrative targets and subsidies • Reforms are largely designed by energy officials with deep ties to incumbent industries, and rapid reforms that lead to higher energy prices or result in widespread asset stranding are unlikely
International institutions	• A global network of climate and energy networks has established an international climate and energy institutional regime designed to advance the low-carbon transition • International finance is shifting to promote low-carbon investments in China and China's partner countries, which also affects China's international energy investments • China's domestic officials and experts are deeply embedded in this network through educational backgrounds, professional interactions, and cooperation partnerships	• The influence of international institutions is limited to a small sphere, and highly constrained by various restrictions • China and its large energy players are also deeply engaged in the global fossil fuel regime through investments and diplomatic partnerships focused on fossil fuel extraction and high-carbon development strategies

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