Embracing the new paradigm of green development

China Carbon Neutrality Policy Framework research report

Min Zhu, Nicholas Stern, Joseph E. Stiglitz, Shijin Liu, Yongsheng Zhang, Junfeng Li, Cameron Hepburn, Chunping Xie, Alex Clark and Daoju Peng

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About the authors

This is an independent report led by:

Min Zhu, Vice Chairman of the China Center for International Economic Exchanges, Former Deputy Managing Director of the International Monetary Fund, and Former Chairman of the National Institute of Financial Research at Tsinghua University

Nicholas Stern, I.G. Patel Professor of Economics and Government and Chair of the Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science

They were supported by:

Joseph E. Stiglitz, Nobel laureate in economics and Professor at Columbia University

Shijin Liu, Deputy director of Committee of Economic Affairs at the National Committee of the Chinese People's Political Consultative Conference and Chinese Chief Advisor of China Council for International Cooperation on Environment and Development

Yongsheng Zhang, Director of Research Institute for Eco-civilization at Chinese Academy of Social Sciences

Junfeng Li, Founding Director General of National Center for Climate Change Strategy and International Cooperation

Cameron Hepburn, Director of the Smith School of Enterprise and the Environment, University of Oxford

Chunping Xie, Senior Policy Fellow at the Grantham Research Institute, LSE

Alex Clark, Doctoral Researcher, Smith School of Enterprise and the Environment, University of Oxford

Daoju Peng, Associate Professor at Capital University of Economics and Business

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Contents

Purpose and overview of the report

The 2060 carbon neutrality commitment announced by the Chinese government in September 2020 demonstrates China's determination and ambition to promote carbon neutrality. Transitioning to a carbon-neutral economy does not just mean switching away from fossil fuels. It is, rather, a paradigm shift in development, which will give rise to a new model of modernisation that can benefit both China and the world and contribute to a green and prosperous future.

This report establishes the fundamental unsustainability of the old development model dating back to the Industrial Revolution, and argues that carbon neutrality represents a profound shift in the old development narrative regarding both the purpose of development, and what and how to produce. The report rethinks basic issues in economics in describing a new development strategy, focusing on theories of value, the definition and measurement of wellbeing and wealth, and analytical frameworks for individual and collective behaviour.

The report sets out the guiding principles for the new development model and defines the actions required to reshape key productive sectors in China. It takes into account the cross-cutting systems that are critical for achieving carbon neutrality, including regulatory and supervisory institutions, finance, technology and innovation, as well as how a just transition may be achieved. The report also considers China's role in leading and promoting global carbon neutrality governance mechanisms, and discusses opportunities for China and the world to collaborate in realising a mutually advantageous, sustainable future.

1. Introduction

The Industrial Revolution, starting in Britain and eventually expanding across the globe, was the prelude to a process of industrialisation, urbanisation and agricultural modernisation that has successively transformed agrarian economies into industrial ones. Throughout the 19th and 20th centuries, many countries pursued growth and development paths that secured sustained real economic gains in the industrial era, at least in terms of conventionally-measured per-capita output and income (expressed as gross domestic product [GDP] and gross national income [GNI], respectively).

China has sustained a remarkable, consistently high growth rate over the last four decades, with infrastructure investment- and export-driven growth at centre stage. However, the extension of this approach from the earlier developers to other, less economically advanced countries, is generating an increasingly acute crisis of unsustainable modernisation. Heavy investments in physical capital, fuelled by the extensive extraction and use of unsustainable and carbon-intensive sources of energy and materials, have put the world at grave risk from climate change, and are driving the depletion of natural capital and ecological resilience, giving rise to a 'modernisation paradox'. These are challenges for every country, but particularly for China given the sheer size of its economy and population, and the intensity with which it has pursued the old, unsustainable approach. For China, the challenge now is to create development pathways that advance economic, societal and environmental outcomes in a sustainable, resilient and inclusive way.

Ever since its reform and opening-up strategy was launched in 1978, China has seen the most dramatic economic advances from following the traditional development pathway, with different themes serving as drivers of growth in different periods. The late 1970s saw key reforms in agricultural and household institutions, and the 1980s brought support for entrepreneurship, township and village enterprises and Special Economic Zones. China then moved to a formidably strong export-oriented manufacturing model to drive its economy in the 1990s and 2000s. In the more recent past, the primary growth drivers have shifted more heavily to property development and infrastructure investment. However, none of these drivers will be able to serve China's growth indefinitely, or even for the next few decades.

On 22 September 2020, President Xi Jinping announced at the 75th Session of the United Nations General Assembly that China aimed to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. These 'dual carbon' commitments were made for a number of fundamental reasons, not just to reinforce China's role in taking responsibility as a major emitter in the global fight against climate change, but also to drive forward China's strategic plan to promote the green transition and accelerate its shift towards a new model of modernisation. The 20th National Congress of the Communist Party of China (CPC), held in October 2022, identified 'Chinese-style modernisation' as China's 'central task' for future development. 'Chinese-style modernisation' in this context means not just simply learning from – and catching up with – the Western world, but rethinking existing notions of 'modernisation' established after the Industrial Revolution through the promotion of 'harmony between humans and nature'.

China's carbon neutrality announcement and focus on 'Chinese-style modernisation' parallels the emergence of a historically unprecedented global consensus on carbon neutrality, which marks the end of the development strategy established in the traditional industrial era and the beginning of a new green development narrative centred on 'ecological civilisation'. So far, over 130 countries have announced commitments to achieve net zero emissions in different ways.[1] It is now manifestly clear that for the developing world, the 'pollute first, clean up later' approach to the environment can no longer be considered a viable development option given the pace and scale of environmental degradation and destruction, and the irreversible changes and self-reinforcing feedback loops it can precipitate. Adopting a new approach to development able to

[1] https://zerotracker.net

recognise the unpriced benefits of environmental capital accumulation and the concurrent impact on wellbeing is vital not just to the lives and livelihoods of people in China but also to the rest of the world. If China can realise 'harmony between humans and nature' through the application and refinement of a new approach to development, its experience will be a vital driver of a globally sustainable future.

From a broad historical perspective and a deeper understanding of development, this report aims to demonstrate that sustaining carbon neutrality requires not just a transformation of energy systems, but the most profound change in development strategy since the Industrial Revolution. On this basis, we propose a comprehensive policy framework for achieving China's 2060 carbon neutrality goal and discuss the ways that this development paradigm shift is reflected in various sectors and necessitates reforms of the macro policy framework.

Plan of the report

The report is organised as follows:

- Section 2 demonstrates why carbon neutrality implies a comprehensive and profound change in China's development strategy.
- Section 3 sets out the objectives and guiding principles for the new development approach.
- Section 4 presents the major policy suggestions and action points for reshaping key economic sectors and systems in China, including in energy, transport, urbanisation, industrialisation, agriculture and consumer lifestyles.
- Section 5 explores key required changes in the cross-cutting issues, including institutions, finance, technology, and innovation, that are most important for achieving carbon neutrality, and proposes steps for ensuring a balanced transition.
- Section 6 discusses China's role in leading and promoting a global carbon neutrality governance mechanism, and how China and the world can work together to achieve a mutually advantageous, sustainable future.
- Section 7 presents closing remarks.

2. Sustaining carbon neutrality: a new development paradigm

Global carbon neutrality necessitates a new development paradigm

Carbon neutrality implies the most significant change in the modes of production and consumption since the Industrial Revolution. The crisis of unsustainable development facing the world is in essence a crisis generated by the traditional, old development paradigm and the traditional approach to modernisation.

The traditional development strategy, dating from the Industrial Revolution, has aimed to expand material wealth and upgrade material consumption, but the mass production and consumption of material goods especially has come at the expense of correspondingly massive overexploitation of natural resources. The severe and widespread environmental degradation that this has caused (including of biodiversity and habitats) has in turn impaired the resilience of the climate system, weakened social stability, and increased the risk of further degradation. In addition to driving the devastation of natural wealth, it has also contributed to a decline in some human health outcomes, rapid growth in inequality, and a weakening of the strength and depth of the social fabric (Stiglitz, 2013; Case and Deaton, 2020). Ultimately, materialism and consumerism have not led to the increase in wellbeing so widely expected (Easterlin, 1974, 2013; Stiglitz, 2013; Piketty, 2014; Deaton, 2015). None of the so-called 'modern' countries of today has yet succeeded in combining modernisation with harmony between humanity and nature, in terms of the UN Sustainable Development Goals (SDGs), carbon emissions, biodiversity, environment and other aspects (UNEP, 2020).

The traditional approach to development aimed in neoclassical economics to expand material wealth and upgrade material consumption, exaggerating the role of consumption of material goods and services in consumer wellbeing. It adopted a highly restrictive measure of output in the form of gross domestic product (GDP) to measure wellbeing, preventing it from accounting for the full social and environmental opportunity costs and benefits of production and consumption. Nor did the traditional approach properly articulate unsustainable pressure on the environment or associated threats to public health and social welfare (Stiglitz, 2020).

Economics has attempted to account for environmental challenges by treating them as externalities to be managed with a standard set of tools and policies revolving around prices and quantities, and focused on realising marginal gains (Nordhaus, 2019). While these frameworks have much to contribute, the current environmental crisis and the fundamental unsustainability of today's development strategy calls for more than marginal extensions of orthodox approaches into the domain of environment and ecology.[2] Tackling the underlying problems effectively, and achieving economy-wide carbon neutrality, requires rethinking and redefining the fundamental issues of development, including why we seek development, what to produce, how to produce, and how to design a new development paradigm that is as universally applicable as possible.

Why do we seek development?

Rethinking the purpose of development beyond GDP requires taking a broader view of objectives of development, and of how success is measured. While it may seem obvious that the fundamental purpose of development is to improve the wellbeing of people, the traditional development paradigm regards capital appreciation as the goal, rather than the means, of development (Weber, 1961; Richins and Dawson, 1992). It is centred on GDP, which measures the market value of goods and services, not the extent to which a society has succeeded in achieving improved wellbeing. GDP is not necessarily a measure of welfare (Stiglitz, 2020). If individuals' utility depends on factors other than material consumption, or if their preferences change over

[2] 张永生, 2021; Stern, et al., 2022

time, then growth in the monetary value of traded goods and services produced in an economy does not necessarily imply improved societal wellbeing. Getting closer to measuring 'what matters' requires shifting the objective of development from maximising GDP (as the source of income for consumption under fixed preferences in the standard model) to thinking more widely about the meaning of wealth and building a multidimensional understanding of wellbeing that reflects an empirically grounded theory of value (Stiglitz, et al., 2018). Going 'beyond GDP' also requires revisiting how an underlying theory of value responds when preferences can change. In turn, this affects our understanding of how changes in preferences affect behaviour and vice versa, leading to potentially very significant views on how to produce, and what to produce and consume.

What should we produce?

A different development objective can lead to different conclusions on what is most important to produce. Human needs go beyond material needs, and peoples' happiness does not always increase with their consumption of material goods (Easterlin, 1974, 2013; Frey and Stutzer, 2002, 2013). The traditional industrialisation model, however, is predicated entirely on the production and consumption of material wealth, which brings with it an unbalanced and inadequate set of development outcomes (Stiglitz, 2013; Piketty, 2014; Deaton, 2015). Taking a broader perspective on the sources of growth would mean pursuing both material and non-material outcomes, including environmental quality, health and social harmony (Stiglitz, et al., 2018). Shifting the production and consumption system to reflect this wider understanding of the sources of value requires implementing a wide range of incentives and policies, underpinned by updated definitions of costs, benefits, optimality and wellbeing – and correspondingly different forms of understanding of what development entails, what resources are valuable, and what business models can best exploit and grow this value, ultimately reshaping the entire economic system.

How should we produce?

In traditional models, production is a function of the accumulation of human capital, physical capital, and the conversion of natural into physical capital. It does not account for stocks or flows in natural or social capital, which in the long run impair the foundations of future growth (Stern, 2006; Stern, et al., 2020). A new development strategy would embrace a conception of the production process that better integrates human economic activities with the natural environment, recognising that sustainable growth and wellbeing are shaped by a combination of physical, human, natural and social capital. These 'four types of capital' generate value by acting as inputs for the delivery of products or services, but they can also be outputs in themselves. Natural and social capital can hold intrinsic value, insofar as they contribute to wellbeing beyond their role in producing goods and services. These assets, and their accumulation rates, also interact with each other. Accounting for these interactions could help to define a programme of balanced investment in each one, seeking stable returns on all forms of capital, and managing undesirable forms of feedback.

How can we ensure the universality of a new development paradigm?

Aggregate growth models used in standard economics over the last eight decades are based on the conversion of physical capital and labour inputs into output, leaving out a wide range of sources of value, including health, education, environmental services and inequality. This paradigm relies on material resource inputs and generates high carbon emissions. Simply extending this model from the fully modernised countries to the entire globe will lead inevitably to intensified competition for resources and environmental depletion, if not a total breakdown of humanity's life support system. A new development strategy is needed to craft a mutually reinforcing relationship between sustainable development and the environment required to support it, recognising that the sustainable generation of economic value ultimately depends entirely on natural ecosystems. Extending this new approach globally could help to facilitate mutually advantageous cooperation in investing in the ultimate source of all wealth: nature.

Making such significant changes to the development paradigm implies a fundamental re-evaluation of what economic development means, what it should focus on, how it should be done, and why. This in turn implies the most significant re-evaluation since the Industrial Revolution of what resources are; how enterprises for exploiting them should be organised and the business models they should use; and what financial, institutional and policy measures are needed. Though there have been some reflections on the unsustainable development crisis (for example, UNEP, 2011; Harangozo, et al., 2018), fostering a new development paradigm requires revisiting fundamental questions in economics, concerning the theory of value, the definition and measurement of wealth, the concepts of cost and benefit, and optimisation, and the goals and constraints driving consumer and firm behaviour. And according to Kuhn (1962), a rethink of basic economics would lead to change in the paradigm in economics.

The 'Chinese-style modernisation' proposed by the 20th National Congress is part of an ongoing process of profound reflection on the purpose of development, and the emergence of ecological civilisation and green development as key objectives of the Chinese government. It also marks a willingness to engage in redefining the idea of modernisation stemming from traditional models of industrialisation, and rebuilding the human–nature relationship. China's carbon neutrality goal, and its 'central task' of 'Chinese-style modernisation', are parallel ambitions, implying that China intends to realise modernisation through a new development paradigm based on 'harmony between humans and nature' and the mutual promotion of environmental and developmental objectives both within China and in its relations with other countries.

Challenges and opportunities for China

While carbon neutrality is a formidable challenge for almost all countries, China's challenges are unique:

- First, China is likely to continue to experience moderate to high relative economic growth rates in the coming decades. China's economy is expected to more than quadruple in size by 2060. Energy consumption will continue to grow, even as China attempts to reach net zero carbon emissions, meaning that both energy efficiency and emission intensity will have to improve dramatically throughout the transformation process.
- Second, compared with developed countries, China is still industrialising and urbanising, and is likely to remain more energy-intensive than its wealthier peers. And its energy mix is still dominated by fossil fuels, which account for more than 80% of energy consumption, making the transition even more difficult to achieve. By contrast, in Europe and the United States, the service sector accounts for more than 80% of the economy, and both have a much less energy-intensive economic structure.
- Third, compared with other developing countries at lower levels of development, China has already industrialised heavily and built a massive amount of infrastructure in doing so. That means China must both decarbonise its enormous capital stock and continue to grow in a carbon-neutral fashion.
- Fourth, China is a vast territory, with large regional differences, diverse regional economic structures, and uneven development, including large income inequality across sub-populations. Effectively balancing these factors and ensuring that the structural transformation is fair and just makes a difficult task even more so.

Though China's path to net zero implies great challenges, it also provides immense opportunities. Carbon-neutral growth will eventually become the basis for China's economy to achieve high-quality development. The pursuit of carbon neutrality within a truly sustainable development paradigm does not necessarily imply the sacrifice of economic growth. Indeed, growth can be enhanced in the process of transitioning from the old model to the new, particularly in terms of job opportunities, efficiency and economic upgrading. This is already occurring in the energy and transport sectors, with the rapid development of new energy technologies and electric vehicles (EVs) – and these dynamics are being repeated in other sectors across the economy as the

transition progresses. For instance, China's (already world-leading) installed solar PV capacity increased by 20.9% in 2021 over the previous year, while wind power increased by 16.7%. In June 2022, there were around 10 million 'new energy vehicles' on China's roads (including battery electric, plug-in hybrid and fuel cell vehicles), more than half the world's estimated total of 16 million (Paoli and Gül, 2022). Production and sales of new energy vehicles both reached 3.5 million in 2021, causing China to rank first globally for seven consecutive years. Almost 40% of global renewable energy jobs are estimated to be in China, at more than 4 million in 2020 (Stern and Xie, 2022). China has cultivated a competitive advantage in a series of other technologies critical to carbon neutrality, including Internet technologies, 5G, Artificial Intelligence (AI), Ultra-High Voltage transmission (UHV), and digital infrastructure.[3] These technologies offer potentially huge export opportunities for China. Overall, the domestic and global shift to carbon neutrality provides China with an opening to develop and sell a range of cutting-edge zero-carbon technologies, manufacturing and services.

In its pursuit of green development, China also possesses unique advantages:

- First, the capacity of China's government to coordinate and manage a systematic change in national development strategy (Harangozo, et al., 2018).
- Second, China's enormous domestic market, and its potential for future growth. China's population is larger than Europe's and the United States' combined and if it succeeds in modernising fully, China could become the largest single market in the world, overtaking the EU. This also creates favourable conditions for breeding, incubation and development of new technology.
- Third, China's existing advantage in zero-carbon technologies and production. China is already a global frontrunner in a range of carbon-neutral technologies and carbon-neutral product manufacturing, including the two largest product groups – renewable energy and EVs (IEA, 2021). With both industries on a positive trajectory, it is anticipated that this advantage will continue to grow.
- Fourth, China has built a solid foundation for research in, and applications of, digital technology – and it can exploit these advantages to accelerate low-carbon development.

By making good use of its advantages, China has the potential to surpass advanced economies and manage transition-induced stranded costs in traditional industries by steadily promoting systematic changes across the application of technology and reshaping of industrial production, underpinned by a new and updated development strategy.

Carbon neutrality and realising another '40-year miracle'

Achieving carbon neutrality is a challenge all countries will have to face. Ever more worrying climate science, together with increasingly self-evident manifestations of the effects of climate change (including more intense heatwaves and weather extremes globally), and tremendous technological progress are leading countries across the world to make clear commitments as they recognise the long-term benefits that a transition to a carbon-neutral economy can bring. These benefits go far beyond the fundamental benefits of reduced risks from climate change. They include cheaper electricity and transport supported by renewable energy sources, reduced waste and congestion, cleaner air, less polluted soils and water, and stronger, more resilient ecosystems (IPCC, 2021).

China has achieved astonishing progress in economic development and structural transformation since the 'reform and opening up' of 1978. In the next four decades, with carbon neutrality at the heart of a new development paradigm growth narrative, China's economy will have to undergo a similarly radical transformation. The announcement of the carbon neutrality target in 2020 coincided with the start of China's quest to become, by the so-called 'second centenary' in 2049,

[3] https://eecdf.org/App_UpLoad/file/20200416/20200416115934_6317.pdf

a modern socialist country. That these trajectories are proceeding in parallel signifies a new direction for China's economic and social development story (Stern and Xie, 2022). China's challenge is now to accomplish another 40-year development miracle through the adoption of a carbon-neutral development strategy.

Notwithstanding China's unique advantages, China and the West are at similar points on the path to carbon neutrality. This provides a window of opportunity for China to change gears from the past 40 years of 'catching up' with the West, to the next 40 years of 'forging ahead' of it. If the Industrial Revolution presented Western industrialised countries with the means to lead the world, the new green development paradigm implied by carbon neutrality is just as significant an opportunity for China to take the lead.

The transition from the old approach to development to the new requires fostering rapid, far-reaching, and above all enduring changes to the institutions and systems governing the economy, and how investment is allocated. Social and economic reorganisation on this scale must also go far beyond simply achieving a net zero economy by decoupling emissions and growth through large-scale deployment of zero-carbon technologies: it requires changing the way in which cities and communities function as consumers of resources; reorganising patterns of economic activity and behaviour (concerning, for example, mobility and diet); and the use of a more general definition of 'wellbeing' to guide and measure the success of development policy.

Carbon neutrality presents China with a very positive future story characterised by sustainable growth and economic development (Hepburn et al., 2021). China, with its strong savings and investment record, and a clear sense of developmental purpose, has the potential to be the largest global driver of the transformation to a new form of growth. China's ability to set an example to other countries is also critically important, particularly for developing countries for whom modernisation can no longer be achieved by following the traditional development model.

3. Guiding principles for a carbon-neutral policy framework

We have established that China must conduct a thorough re-evaluation of its framework for social and economic growth and incorporate the need for carbon neutrality into its objectives and policies. This section of the paper sets out some guiding principles for the green transition.

Design the national carbon neutrality strategy on the basis of a broader and deeper concept of growth ('paradigm change')

Since the Chinese government put forward the 'dual carbon' goals of carbon peaking and carbon neutrality, all local governments and government departments have been actively involved in proposing implementation plans. However, there are differences in the understanding and implementation of the dual carbon goals across different levels of governments, and the new development model implied by them has not been fully, accurately or comprehensively grasped. The central component of China's new development strategy is a shift away from the 'pollute first, clean up later' approach, and the old analytical and institutional framework of the traditional industrialisation model, towards cultivating a mutually reinforcing relationship between the environment and human development. This is a profound revolution in the production and lifestyle patterns built over the last 40 years – and is the single greatest strategic opportunity for China over the next 40. To assist local governments and central government departments in the implementation of carbon neutrality, China's leadership needs to conduct a thorough evaluation of its current framework for economic and social development and build a new framework for policymaking that incorporates carbon neutrality into its development strategies.

China should:

(i) **Explicitly articulate the key elements of China's new development strategy.** Going beyond the narrow principles of energy conservation, emission controls, technological innovation and environmental protection, China must consider the implications of the profound reforms this process will require that will fundamentally change China's economic structure as well as its social values. Economic and social development objectives, strategies and pathways should be formulated on this basis, particularly in the reform of macroeconomic and financial systems and policies.

(ii) **Establish a new model of economic activity and lifestyle based on 'wellbeing'.** This model should account for institutions, macroeconomic and social policy, and city and community development. It should be underpinned by updated definitions of costs, benefits, optimality and wellbeing, and use these definitions to measure the success of development policy. This new model will change the way in which cities and communities function as consumers of resources; require the provision of a wide range of incentives and policies to shift production and consumption towards a broader understanding of growth; and develop business models able to exploit and grow this more holistic conception of value – ultimately reshaping the entire economic system.

(iii) **Systematically construct a new framework for policymaking.** Achieving the carbon neutrality goal requires a coordinated transformation of each subsystem across the whole economy, with all sectors and regions playing a synergistic role. The new policy framework should incorporate carbon neutrality into its development strategy, implementation pathways, fiscal and monetary policies, financial system design, industrial policies, innovation ecosystems, market mechanisms, regulatory and political institutions, diplomatic relations and global engagement, and macroeconomic regulation and control.

Use the '1+N' policy system when establishing targets, designing polices and implementing reforms

After a year of experimentation and testing, China formally introduced the '1+N' policy system in September 2021 to aid in setting up timetables, road maps and implementation pathways for the dual carbon goals. In this system, '1' refers to the Overarching Guidance issued by the CPC Central Committee and its State Council, titled *Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy*. In turn, 'N' refers to the plans for various fields and industries that were subsequently released, starting with the *Action Plan for Carbon Peaking Before 2030*.

China's CPC 20th National Congress, held in October 2022, emphasised 'reducing carbon emissions, managing pollution, restoring ecology and promoting growth', which entails establishing three pairs of 'mutually reinforcing relationships', with carbon neutrality being the strategic focus:

- First, building a mutually reinforcing relationship between environment and development.
- Second, decoupling economic growth from carbon emissions, to prevent carbon reduction from burdening economic growth.
- Third, exploiting synergies between carbon emissions controls and pollution reduction and ecological restoration.

These three relationships are the underlying conditions required for a sustainable 'relationship between human and nature' under the green development paradigm. They are also the basis for the implementation of the '1+N' policy framework and further carbon-related policies.

However, more detailed policies are still needed, including:

(i) **A target for absolute total carbon emissions,** with a clear pathway for reducing emissions over time, as well as a clear target on total non-fossil energy supply, in addition to the existing target for the share of non-fossil energy in total energy demand.

(ii) **Explicitly linking emission reduction responsibilities to the promotion of economic growth,** compatible with the dual carbon goals.

(iii) **Further clarifying the allocation of responsibility between China's regions in the overall planning process,** and introducing appropriate incentive mechanisms into the multi-objective system for local governments to improve their motivation to reduce carbon emissions.

(iv) **Identifying areas of focus for the short and medium term**, with different stages of the transition prioritising different elements of the system.

(v) **Identifying the most important technologies and green markets in achieving the transition to carbon neutrality**.

(vi) **Reforming the relationship between government and enterprises** under the overarching guidance for achieving the dual-carbon goals, and re-examining the role that government should be playing in the real economy. This can help to build a more productive relationship between the state and the market that can better utilise the respective advantages and strengths of centralised authority and market forces.

Leverage the role of markets, while also strengthening government's role in guiding and planning the transition

Carbon neutrality is a public good provided by the government, in which the goal of carbon neutrality and the corresponding carbon markets and regulations for achieving it are not naturally formed but artificially created by the government in order to realise the benefits of carbon neutrality for human wellbeing. Transitioning to net zero carbon emissions in an economy of

China's size and economic growth rate, and managing large structural changes and regional differences, is a daunting task. Government needs to be more active in guiding and planning this process, without undermining the ability of the market to play an effective role in delivering results. This requires fully integrating market and incentive mechanisms, and effectively coordinating technological innovation, policy reform and societal transition during the transformation.

The Chinese government should:

(i) **Foster a new development paradigm, placing individual wellbeing at the centre of policy design, while retaining a focus on how society as a whole interacts with its environment.** This means translating carbon neutrality targets into quantitative criteria and implementing economic policies that support mutually reinforcing economic and environmental goals through fiscal and monetary policy, the financial system and the innovation ecosystem.

(ii) **Make large-scale investments in clean technologies to accelerate their development and deployment at an early stage of the transition.** The first five years in the long journey to a carbon-neutral economy will be an important time window for initial investments. Making substantial investments in this phase will lay a solid long-term foundation for moving the development of low-carbon technologies and business models forward, just as carbon emissions peak. Partnerships between government and business in strategic industries should be strengthened, as successful transformation requires close coordination between the use of policy, technology and capital, especially in the R&D, procurement, venture financing, and market creation stages of new technology adoption.

(iii) **Build a social consensus on carbon neutrality**, to increase public demand for innovative green technologies and induce behavioural changes. Establishing a broad social consensus can significantly reduce implementation costs and generate self-fulfilling market expectations, creating the conditions for green technological innovation to take hold.

Allow market principles in general, and the use of carbon pricing in particular, to play a leading role in resource allocation

The climate change challenge facing the world is largely due to the failures of both governments and the markets. To successfully deliver the fundamental change required for carbon neutrality to succeed, sound policy measures will involve an overall strategy to set a strong sense of direction, and further strengthening the role of the market in guiding investment and innovation. Understanding the roles that government and markets should be playing in achieving this goal is key to a successful transition.

First, one of the important preconditions for market to play an effective role is to incorporate the social cost of carbon into the decision-making systems of producers and consumers, in order to change their behaviour patterns and promote the emergence of carbon-neutral industries. A strong and predictable carbon price or its equivalent has a particularly critical role to play in the efficient management of the transition process. Due to the complexity of carbon pricing and multiple market failures, it is important to build a multidimensional market mechanism for carbon pricing including a combination of carbon taxes, carbon emissions trading, carbon derivatives trading, and carbon offset markets (Ramstein et al., 2019; Van den Bergh et al., 2020). Each of these tools has its own advantages and disadvantages, and it is important to choose a tool, or a combination of tools, such that emission reduction targets are met while keeping implementation costs as low as possible. Currently, China is relying primarily on its emissions trading scheme (ETS) in the power sector to achieve this. Further measures should be taken to expand its coverage and scale, improve implementation mechanisms, and gradually introduce derivatives trading.

Second, the ecological and environmental costs of economic activities must also be brought into the decision-making process of economic entities, in order to coordinate the cost-effective achievement of carbon reduction, pollution management and sustainable development goals.

Third, the government needs to provide clear strategic direction, policy and regulatory frameworks, and incentive mechanisms to encourage the market to play a leading role in resource allocation. This should be complemented by standards and regulations providing the direction and clarity necessary for efficient resource allocation.

Ensure a transition that is secure, well-coordinated and balanced

During the process of achieving carbon neutrality, some economic and social dislocation is inevitable. Careful management is needed to ensure a secure, well-coordinated and balanced transition is achieved where possible. In particular, it is crucial to find means of reducing emissions without disrupting energy security, industrial and supply chain security, food security or popular livelihoods, and to manage the potential economic, financial and social risks associated with the transformation process. For energy security and industrial supply chain security, policy should follow the 'establish first and break later' principle and promote structural transformation conditional on maintaining energy security and stable economic operation. Existing high-carbon capacity should be replaced as quickly as possible, but at a speed that will not cause interruptions to the industrial supply of new low-carbon capacity, in order to realise a smooth transformation.

It is also crucial to have a clear understanding of, and preparation for, the depth and breadth of the impact on the industrial system during the transition to carbon neutrality. Attention should be paid to the impact of the carbon-neutral transition on specific high-carbon industries, regions and communities in order to achieve a coordinated and balanced transition. In recognising and addressing risks, it is important on the one hand to emphasise the significant new opportunities that may arise during the transition, and on the other hand to provide compensation for the most affected sectors, justified on the basis of the improved overall economic and social wellbeing brought about by the transition.

4. Reshaping China's key economic sectors and systems

The traditional development strategy was conceived and established during an era of fossil fuel-driven industrialisation. In this section we focus on specific measures to support the transition to carbon neutrality in the five largest components of China's economy: energy, transport, manufacturing, urbanisation and land use. Dynamics in these sectors also interact closely with inter- and intra-regional development, as well as with the shaping of individual lifestyles.

Reshaping China's energy landscape and shifting away from coal

The transformation of the energy system is the primary and most fundamental prerequisite for China to transition to a carbon-neutral economy. This includes transitioning to renewable energy sources for energy production, and electrifying energy consumption (the 'two replacements'). However, to avoid replicating the unsustainable path of excessive and inefficient energy consumption observed in industrialised nations, China must continue to prioritise energy conservation measures, as well as overhauling its production system to make efficient use of renewable energy supplies and promote lifestyle changes to limit the growth of individuals' energy and carbon footprints (IPCC, 2021).

Energy – priorities and challenges

For a society to become fully carbon neutral, it must achieve a 100% reduction in net emissions from the use of fossil fuels, accounting for all territorial sinks and sources. China's power sector should achieve net zero emissions by 2050, featuring at least 80% non-fossil-fuelled power generation (IEA, 2019), with interim targets of peaking in the medium term of the 15th Five-Year Plan period[4] and maintaining a good balance between clean energy development and energy demand growth.[5] At a minimum, China's energy reforms will need to establish an entirely new energy supply system centred on renewable energy capable of meeting demand from an increasingly electrified economy. The new energy supply system will feature wind and solar power as its core components, with nuclear power and hydropower playing a supporting role, and carbon capture, utilisation and storage (CCUS) technologies addressing remaining emissions.

Three significant obstacles must be overcome to accomplish these goals:

- The first is the substantial 'stranded' costs resulting from the early retirement or underutilisation of power sector infrastructure constructed during the fossil fuel era.[6]
- The second is the technical bottlenecks in developing and deploying the expertise and advanced technology necessary to safely maintain the stability of a power system powered largely by intermittent renewable energy sources, and to remove emissions from remaining fossil fuel power generation sources, through as-yet not well-established CCUS or direct air capture (DAC) technologies.
- The third is resolving incompatibility and lack of interoperability of power management, trading and distribution systems. There are wide geographical imbalances in the supply and demand of renewable energy across regions even while power management systems remain highly localised. This gives rise to a need for large-scale, high-quality and high-capacity transregional power transmission lines, as well as a much more fully integrated power dispatch and management system for efficiently distributing excess power across regional borders (Greenblatt et al., 2017). China is a world leader in UHV transmission and

[4] 张希良等, 2022

[5] 林伯强, 2022

[6] According to estimates by McKinsey & Co. (2021), by 2050 stranded assets in the power sector alone could reach $2.1 trillion globally, and China is estimated to face up to $700 billion of coal-related asset stranding.

deployment, but it still needs to improve corresponding power system scheduling, dispatch, and management. Meanwhile, the number of end users of electricity will expand as electrification proceeds across the industrial and transport sectors and the built environment, accentuating the need to prepare the grid to efficiently manage distributed renewable power generation.[7]

These are formidable obstacles but they can be overcome with the careful application of advances in key technologies. Higher short-term costs and environmental damage induced by a shift to clean energy sources can be partially or fully compensated in the longer term by lowering the levelised cost of power through greater use of solar and wind, and steadily lessening, then ultimately eliminating, dependence on domestic and international fossil fuel supplies for energy security. As renewable energy technologies expand, the overall material footprint of energy generation needs will decline. Although competition for some specific materials necessary for new energy technologies will intensify, China has established a dominant position in the supply chains for most of them.

Finally, the ongoing electrification of end uses of energy is giving rise to major market development opportunities for businesses, particularly in the transport sector. According to the Ministry of Public Security, by the end of March 2022 China was home to 400 million cars, fewer than 9 million of which were electric. For electric vehicle developers and retailers, this represents an enormous market opportunity.

Energy – policy recommendations

(i) **Establish a comprehensive energy consumption control system consistent with the move towards carbon neutrality.** China should adjust the current energy consumption control system by putting a cap on fossil fuel energy consumption rather than total energy consumption. Then, it should gradually extend this to carbon dioxide emissions, based on the roll-out of carbon labelling standards across different energy technologies. In the meantime, China should continue to reduce the energy intensity of GDP, which is crucial for enhancing China's competitiveness in industrial manufacturing through the transition. The existing strategy of prioritising energy efficiency and limiting energy demand growth should continue in parallel.

(ii) **Establish rules and mechanisms to guarantee security of energy supplies during the energy transition, following the principle of 'establish first and break later'.** This entails:

- Devising a clear timeline and roadmap for the creation of a new energy system and a new power system with renewable energy as its core component;
- Meeting incremental energy demand with as much non-fossil power generation sources as possible. During the 15th Five-Year Plan, replacements for non-fossil energy, particularly coal consumption, should be gradually deployed, including as replacements for existing coal-fired power plants.
- Allowing traditional thermal power generation to maintain an interim role in stabilising base power supplies and meeting peaks where appropriate, even as new large-scale energy storage technologies are developed and deployed to enable renewable energy to ultimately substitute for traditional power sources. The percentage of non-fossil energy power generation integrated into the grid should be compatible with reliable power supplies at all times.

(iii) **Establish a fair and practical target management system for all non-fossil energy.** To balance the development of renewable energy sources across China's regions, a fair and reasonable aggregate target system should be implemented to allow some regions greater flexibility than others. The responsibility and accountability of developed

[7] 李俊峰、李广, 2021

regions should be reinforced, and a long-term strategic cooperation system for the central, eastern and western regions put into place.

(iv) **Closely coordinate the governance of energy, environment and climate and provide internally consistent guidance promoting mutual progress in all three areas.** Beginning in the 14th Five-Year Plan period, this approach should focus on environmentally-friendly, low-carbon power market optimisation, stringent environmental governance standards, and collaborative governance by the different bodies responsible for implementation.

(v) **Establish and progressively optimise micro-incentive mechanisms, government subsidy mechanisms, and market mechanisms for the energy transition.** This requires recognising, quantifying and regulating for the premium associated with building new energy infrastructure for the energy transition, and allowing this premium to be reflected in power price formation, which should be increasingly market-driven and follow principles of least-cost dispatch already in use in many jurisdictions outside China, as well as progressively internalising the externalities of fossil fuel use. The levelised cost of new clean electricity generation (even after accounting for storage and intermittency) is in some regions already below fossil-fuelled power (and even excluding the very significant costs and negative impacts of local pollution from fossil power). Where clean generation is not yet lower-cost, it will likely become so as technological advances proceed and power sector reforms increasingly allow the true relative value of renewable and fossil-fuelled power generation sources to be realised. As long as a clean power premium does remain, it risks prompting substitution back towards fossil-fuelled power in the short term. Countervailing measures should be taken to persuade consumers to change their energy preferences, establish social norms around the use of clean energy, and complement this with an appropriate compensation mechanism for clean energy consumers, based on the carbon content of their power consumption. Effectively allocating resources for the transition requires constant enhancement of these and other market mechanisms for allocating carbon, electricity, and technological innovation across the Chinese economy. These mechanisms should remain focused on reforming the current system of setting electricity prices, and persuading customers to pay a higher market price, where necessary, for the use of low-carbon electricity.

The transformation of transport

Transport is an essential enabler for market transactions and a key driver of economic growth. The current spatial configuration of production and consumption reflects China's historically energy- and carbon-intensive industrialisation strategy, and the evolution of transport patterns and networks in China today remains heavily influenced by traditional industrial activity, complicating efforts to adjust to the demand of a carbon-neutral transport system. Governments at all levels, and businesses, are presented with the challenge of encouraging the use of low-carbon modal choices as well as decarbonising all existing and future transport modes.

Transport – priorities and challenges

Transport sector emissions in China are continuing to increase, although the total and per-unit emissions of the various modes of transport (measured in passenger-km, or ton-km for freight) vary greatly. In terms of emission abatement potential, the industry's low-carbon transition centres on road transport, which comprises more than 80% of the sector's carbon footprint. In 2019, emissions from transport (including personal and commercial vehicles and domestic travel but excluding international air travel and international maritime travel) totalled 1.18 billion tons. Of this total, road transport emissions (personal and commercial) comprised 1.03 billion tons, or 87% of all emissions. Civil aircraft accounted for 6.1%, rail for 0.7%, and water transport for 6.5%.

Demand for all forms of transport is rising steadily, alongside improvements in living standards and general economic growth. Demand from both passengers and freight in China is expected to increase by a factor of two by 2060,[8] and is likely to be mostly met through increasing rail and air travel for passenger transport, and waterway travel for freight transport. As the availability, personalisation, comfort and general convenience of transport options increase, the energy consumption associated with its growing use will rise proportionally as long as alternative propulsion options remain unadopted.[9]

Reducing carbon emissions from transport is challenging, as uncertainties remain over how the process of modifying the energy structure to accommodate zero-emission transport options will play out. In the short term, a lack of clarity remains over how commercial and industrial transport modes will decarbonise and what changes in the energy supply structure will be needed to support this. Existing technological options for the decarbonisation of heavy-duty vehicles and large ships lack maturity and commercial viability. This is even more evident in the aviation sector. While future emissions growth will be largely concentrated in the aviation industry, there are no established technological options for decarbonising air travel. Biofuels, hydrogen-based fuels and DAC are three possible solutions, but all remain in the development stage and have very significant limitations and drawbacks.

In the road transport sector, which will shoulder the largest share of the emission reduction burden, prospects are brighter. Even with China's existing, relatively high-emissions power mix, the carbon dioxide emissions of China's battery electric vehicles (including from energy extraction, transport, power generation and power transmission), are 35% lower on average than their fossil-fuelled counterparts.[10] China's passenger vehicle electrification programmes have been very successful in bringing 'new energy vehicles' to market and enabling a rapid acceleration in sales and penetration rates. Recent years have seen tremendous advancement in global lithium battery technology cost and sophistication, and the cost of battery systems will continue to decline through the 2020s, attaining true 'price parity' with internal combustion engine vehicles before the middle of the decade (BloombergNEF, 2022). The international market for EVs is also flourishing, with a growing number of countries adopting more aggressive policy measures to promote EV adoption, and some 19 states or regions proposing timetables for ending the sale of cars with internal combustion engines. China's position as a recognised market leader in EV production and in a range of underlying technologies places it in a strong position to benefit from an accelerated transition to electric mobility.

Transport – policy recommendations

(i) **Introduce structural adjustments to incentivise a shift towards low-carbon transport modes,** in accordance with the principles of demand reduction, modal transfer and system optimisation, and making full use of digital data gathering and AI capabilities to design and implement efficient transport systems. These measures can be particularly effective for freight logistics on roads, in ports and in freight yards. China should ensure the availability of low-carbon transport options is comprehensive and take steps to mandate greater prominence for public transport services and in urban transport development planning processes, particularly for the integration of trunk and branch services ensuring good coverage of both local and cross-city/interregional public transport. The transfer of long-distance freight transport from highways to railways should accelerate, along with a broader expansion of rail infrastructure. Investment in dedicated bicycle paths, bicycle rental schemes and footpaths in urban

[8] *Research on Carbon Dioxide Emission Reduction in China's Transportation Industry* by the Research Group of China Transport Planning and Research Institute Ministry of Transport (phase report).

[9] http://www.gov.cn/zhengce/content/2022-01/18/content_5669049.htm

[10] China Society of Automotive Engineering, 2018 Life-cycle Assessment of Greenhouse Gas and Air Pollutants of electric vehicles (EVs): http://www.sae-china.org/news/society/202005/3694.html

and rural areas should be expanded to enhance the capacity for low-carbon local travel in urban and rural areas.

(ii) **Actively promote emission-reducing behaviours and choices among the general public and key public institutions.** To reduce travel-related carbon emissions, China should require public institutions to prioritise the acquisition and deployment of EVs where possible and promote environmentally-friendly travel among the general public through education campaigns and incentives to ride-share and use public transport and rail, particularly to dissuade business travellers from flying where alternatives are available. Steps should also be taken to eliminate older, less efficient vehicles and raise standards across the remaining fleet. Coordinated efforts to reduce transport emissions among different regions will help to ensure consistency between local and national policies.

(iii) **Accelerate research and development, innovation, and deployment of core and ancillary technologies for transport decarbonisation.** With electrification playing a central role in transport decarbonisation, including for heavy duty applications, advancements in system design, materials, and safety and efficiency of powertrains (such as lithium battery packs and hydrogen fuel cells) are vital to improving performance and bringing forward parity on price and quality with conventional options. Electrification of ports and airports should be accelerated. Where electrification is not possible and liquid fuel options are not yet available, innovation should focus on both developing suitable fuels (likely hydrogen- or ammonia-based), and on deploying carbon dioxide removal technologies (CCUS and DAC) required to compensate for remaining emissions from non-electrified modes of transport, particularly aviation.

(iv) **Coordinate the electrification of road transport with the growth in supply of low-carbon electricity to urban and rural areas.** China should accelerate development of a new type of power system featuring high penetration of renewable energy, and expand construction of charging infrastructure, and battery swapping and hydrogenation facilities. This should be carefully coordinated to respond to EV sales statistics, in order to ensure the availability of clean electricity for zero-emissions transport options and improve the usefulness of infrastructure siting decisions, maximise the rate of utilisation, and reduce the risks of making stranded or otherwise wasteful investments. Further, standards for bi-directional charging and discharging 'vehicle-to-grid' capabilities should be urgently introduced to ensure EVs are able to fulfil their potential as a vast flexible, distributed energy storage resource, and to make effective use of locally generated clean energy.

(v) **Devise a roadmap and timetable for banning the sale of fossil-fuelled vehicles nationwide.** This can take several forms, including the gradual withdrawal of fossil-fuelled vehicles in specific sectors from the sales market; clear mandates for the electrification of public sector vehicle fleets by 2025, including public transport; and setting targets and incentives for the demonstration and deployment of electrified or hydrogen-fuelled freight transport technologies. Large and relatively advanced metropolitan areas such as Beijing, Shanghai, Guangzhou, Chengdu and Shenzhen should take the lead in implementation.

The transition in manufacturing

China's manufacturing industry is the principal driver of its economic growth and lies at the heart of the traditional industrialisation approach. China's rapid ascent as a global economic superpower and the world's largest exporter of goods has been driven mostly by manufacturing, which has also been a major contributor to the country's environmental difficulties. Global carbon neutrality does not mean deindustrialisation, but it will require driving a ground-up reengineering of the manufacturing sector in terms of its organisational configuration, energy and material

inputs, processes, outputs and recycling/reprocessing such that the creation of environmentally-friendly value becomes the dominant source of manufacturing growth. This will require a fundamental change in how material outputs are manufactured, what those material outputs are, and the lifestyles they are designed to fulfil. While this approach will improve China's ability to meet the manufacturing needs of a sustainable domestic and international economy, it also presents severe challenges.

Manufacturing – priorities and challenges

Reform of China's manufacturing sector is essential if the country is to achieve carbon neutrality. The National Bureau of Statistics estimates that in 2021, the added value of China's manufacturing industry was 31.4 trillion Yuan: almost 27% of China's GDP and representing close to 30% of the world's manufacturing industry. Manufacturing is also highly carbon-intensive per unit of GDP relative to other sectors and is responsible for around 45% of all carbon emissions nationwide, with exports accounting for 20–30% of these emissions.

To achieve carbon neutrality in manufacturing, a wide range of long-established industries must be demolished and rebuilt, which presents the risk of stranded investments and severe disruption in industries that fail to transition. However, this also presents Chinese manufacturing in general with the potential to 'overtake on the bend' and lead the world in meeting future demand for sustainable manufactured goods and components.

The automobile sector is a clear example. China is already the world's largest producer and consumer of electric vehicles.[11] China accounted for more than half of global sales of new energy vehicles in 2021 and is home to 12 of the top 20 EV producers globally (Pontes, 2022). Chinese firms' investments in developing manufacturing capabilities in EVs, as well as underlying drivetrain, robotic and battery technologies, have given its manufacturers the capacity to challenge and surpass industry leaders across the world, with hundreds of years of cumulative experience in the sector.

Similarly, China's widespread deployment of solar and wind technologies domestically has contributed to it becoming the world's largest manufacturer and exporter of renewable energy equipment.[12] China supplies about 90% of photovoltaic industry modules for the global market. With a 50% share of the international market, China is also the biggest producer of wind turbines. China leads the world in the development and deployment of technologies with multiple applications in a carbon-neutral future, including those relating to unmanned aerial systems, advanced robotics, 5G networks, and the Internet economy.

However, playing this 'overtaking' role in other areas of the manufacturing sector will prove challenging. China's manufacturing industry is constrained by its need to simultaneously maintain a stable contribution to GDP, thus growing at the same rate as GDP; and to compete with other large energy-consuming industries for limited supplies of the clean energy required to decarbonise its operations. China's 14th Five-Year Plan and its Vision and Goals for 2035 stress the need for manufacturing to retain its current share of national GDP growth (about 27% in 2021). China's GDP is estimated to be more than double from 2020 to 2035, meaning the absolute size of China's manufacturing industry will also double, making the challenge of reducing absolute emissions significantly harder. This absolute growth will also increase the sector's clean energy requirements and intensify competition for zero-carbon power sources.

Successfully decarbonising while doubling in size is an unprecedented feat in the history of industrial manufacturing in developed countries and can only be accomplished if the manufacturing industry greatly decreases its energy intensity and contributes to the accelerated development of non-fossil energy sources. In addition to this decline in energy intensity among traditionally high energy-consuming manufacturing industries like steel, cement, non-ferrous

[11] http://www.caam.org.cn/tjsj

[12] http://www.gov.cn/xinwen/2021-03/31/content_5597134.htm#1

metals, petroleum and chemicals, growing green manufacturing industries (e.g. solar, wind, EVs) must also focus on lowering energy intensity and procuring clean energy to avoid compounding the manufacturing sector's difficulties.

Effecting a transition to carbon neutrality in manufacturing is not just a matter of replacing energy sources and updating technologies, however. It also requires a shift in the concept of value creation in manufacturing, and in how production is organised. To remain viable and nimble, and to take advantage of the technical possibilities offered by electrification, the manufacturing sector can optimise and digitise its processes to enable single assembly lines to flexibly meet the diversified and personalised needs of consumers. Helpfully, the share of material resource input in product value is declining even as productivity increases, while the contribution from intangible inputs such as knowledge, design, experience, ecological services and culture has been increasing, indicating some progress in the decoupling of manufacturing activity from energy resources and environmental damage.

The development trajectory for manufacturing is changing in light of the global consensus on carbon neutrality. As the green transformation of manufacturing industry happens globally and as the international division of labour is reshaped, the share of manufacturing in a country's GDP could increase or decrease according to its role in global supply chains. Scope for a 'race to the bottom' on environmental standards that in the past encouraged the movement of companies facing environmental pressures to less regulated jurisdictions will no longer exist, and the allocation of environmental and emission burdens of global manufacturing to developed and developing countries respectively will change. Countries may find that the optimal share of manufacturing in economic growth and output will shift as the ecological and environmental costs of manufacturing are fully taken into account and as the preferences of its citizens evolve.

Manufacturing – policy recommendations

Achieving the transformation of the manufacturing sector will be difficult but key to carbon neutrality. As China moves away from a growth model that prioritises GDP to one that prioritises public welfare, it should place the decarbonisation of manufacturing at the core of the country's carbon neutrality strategy, given the sector's enormous energy consumption and important contribution to the national economy.

(i) **Expand green manufacturing and prevent a 'hollowing out' of China's manufacturing sector.** The guiding principle for policies supporting the transformation of manufacturing should be the avoidance of first, over-industrialisation, which is what would happen if China maintained the global market for manufacturing and manufactured goods at the cost of excessive ecological damage; and second, 'hollowing out', which is where industries unable to meet the demands of a carbon-neutral development trajectory simply outsource their operations. Following this principle requires a gradual shift away from export-oriented growth and adequate incentives to encourage manufacturing firms to maintain their operations in China while also meeting decarbonisation targets and complying with applicable regulations.

(ii) **Provide appropriate incentives to encourage manufacturing enterprises to seek less carbon-intensive means of creating value,** including through increasing the proportion of intangible factors of production in the value of final products, making full use of industrial Internet and digital technologies to transform their business models.

(iii) **Force the transformation of manufacturing industry through introducing strict environmental constraints.** Currently China is using a regulatory system with 'three lines and one list': a red line for ecological exploitation, a baseline to ensure a minimum acceptable level of environmental quality, and an upper resource usage limit; and a negative list of environmentally-damaging activities that are not permitted. It has also enforced stringent regulations on absolute energy consumption, energy intensity, carbon emissions and material resources. These 'dual control' consumption and

intensity-based measures will send strong signals to the manufacturing sector that it must change in response to China's new development trajectory.

(iv) **Promote the transformation to high-end green manufacturing.** This involves introducing regulation to limit exports of low-value-added products with high energy consumption, pollution and resource footprints, and products that fail to meet minimum environmental and resource consumption criteria. The greater productivity and lower resource-intensiveness of manufacturing methods linked to digital technologies, knowledge economies and personalisation can help to offset losses from the decline in exports of resource-intensive, low value-added goods.

(v) **In the longer term, shift away from being a major exporter of manufactured goods to a major investor in zero-carbon overseas investment to enhance the global competitiveness and market influence of China's manufacturing industry and its economy.** Investment in new markets, including through the Belt and Road Initiative (BRI), is the primary means through which the manufacturing sector in China can expand its influence over, and contribution to, decarbonisation pathways internationally. Specifically, China can leverage its substantial advantages in the manufacturing of new energy goods and ancillary technologies, and its capacity for state-backed foreign lending and investment, to help developing countries avoid sinking investment into traditional industrialisation and 'leapfrog' into development that is based in renewable energy and is energy efficient.

Urbanisation and carbon neutrality

Urbanisation on a large scale began only after the Industrial Revolution took hold and as a result has been largely shaped by the traditional development approach in terms of urban design, infrastructure development and spatial distribution. This approach is not sustainable in the long term. As the traditional approach of industrialisation lying at the foundation of today's urban areas undergoes transformative changes, a set of principles are needed to move the cities of the future towards sustainability. The traditional industrial era is characterised by the mass production and consumption of material goods, and on achieving returns to scale that demand the progressive geographical concentration of production activity and resources. The fundamental unsustainability of this development approach needs to be addressed if it is to resolve the challenges stemming from China's current approach to urbanisation.

Urbanisation – priorities and challenges

Over the past four decades, China has experienced an historically unprecedented wave of development, fuelled by a combination of rapid industrialisation and rapid urbanisation. In 1978, China was still a largely agrarian economy, only 17.9% of the population living in urban areas. By 2021, this had climbed to 64.7%, and is expected to peak at 75% or more. Today, China's cities are responsible for 70% of the country's carbon emissions and are large contributors to environmental degradation both within and beyond their political boundaries.

At the same time, several major developments are contributing to a reshaping of the economic and spatial distribution of activities, especially in high-density urban areas. These include the ubiquity of the Internet and smart devices as modes of private communication and interaction with public services; the rapidly accelerating use of digital transactions in commercial and governmental public services; highly sophisticated industrial technologies and networked infrastructure governing the production and distribution of goods and services; tightly interconnected transport networks; and distributed renewable energy. Accordingly, both the characteristics of urban life, and the scope of economic activities, can exist in a more expansive digital and physical environment. Organising complex networks of divisions of labour no longer necessarily depends as strongly on the geographical concentration of factors of production as it once did, opening up new avenues for the growth of China's cities and rebuilding or reconfiguring existing infrastructure.

The 'greening' of China's urban areas remains, however, an enormous task – and it faces at least three major challenges.

- **First, the transformation of existing urban infrastructure.** Currently, 64.7% of China's population live in cities. Existing urban infrastructure stocks are concentrated primarily around energy- and carbon-intensive industrial goods and manufacturing. The resulting spatial organisation of the urban areas designed and built around these industries has in aggregate locked in a vast quantity of inefficiently distributed and unsustainably resourced urban infrastructure, making its transformation exceedingly difficult and very cost- and time-intensive. Thus, the transformation of existing physical infrastructure stocks through a combination of rebuilding, reengineering and reconfiguring of urban spaces is crucial for achieving China's climate goals.
- **Second, additional urbanisation as more people move into cities should happen in a green way.** The urbanisation rate has increased steadily in China over the last few decades and is expected to rise further, by around 10% from current levels. Although the bulk of population is concentrated in China's megacities, the underlying trend is more towards localisation.[13] Meanwhile, most of China's industrial facilities are located in small and medium-sized cities or on the periphery of large cities. Shifting the urban-industrial complex towards a more sustainable approach, therefore, requires attention to be paid to smaller cities built around heavy industries, as well as larger megacities built around commercial centres.
- **The third challenge is the revitalisation of rural areas.** Under the conventional view of development, rural areas primarily exist to supply labour, food, raw materials and markets for selected manufactured goods, with the purpose of economic development focusing on progressively greater industrialisation and urbanisation. This characterisation of rural roles and urban–rural connections limits the capacity for rural areas to flourish as stewards of natural capital, providers of ecosystem services, and sources of added material, social and environmental value (He and Zhang, 2022). To properly integrate these valuable economic contributions into the process of making urban planning and expansion sustainable, a reappraisal of the economic role of rural areas is required.[14]

The overarching challenge in accomplishing these three tasks is the effort required to move beyond the traditional modes of thought on how industrialisation and urbanisation contribute to economic development. For instance, cities that have seen some success in decoupling their production-based carbon emissions from economic growth have relied primarily on upgrading industrial value chains (e.g. through energy efficiency measures and electrification) and 'leakage', that is relocating low-quality industries to other urban areas with less stringent environmental requirements. However, with the core tenets of the traditional approach remaining in place, consumption-based emissions have not decreased in tandem. The steps taken to date in making China's urban areas more sustainable remain representative of the conventional idea of industrial upgrading and have not yet represented a significant shift in the development paradigm.

Urbanisation – policy recommendations

Traditional industrial thinking is not an appropriate framework for advancing a carbon-neutral, highly digitalised approach of sustainable urbanisation. At the core of the required paradigm shift is a decisive move away from the GDP-driven urban growth model that still dominates policymakers' incentive structures in China, towards a people-centred development approach that acknowledges and caters to multidimensional measures of wellbeing.

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[13] The apparent expansion of megacities reported in the 7th census (2020) is caused partly by the adjustment of administrative divisions (notably the subsuming of county-level cities into districts), so it may not be reliable to conclude that the proportion of the population living in small and medium-sized cities in China is shrinking, while that living in megacities is expanding.

[14] 张永生, 2022

(i) **With the integration and modernisation of city clusters and county-level urbanisation as two of China's highest strategic priorities, concentrate on promoting new types of urbanisation**, allowing technological developments to shape how new urbanisation is spatially configured, and how an appropriate balance of distributed and centralised industries can be struck in building China's urban future.

(ii) **Apply the 'dual carbon' targets to urban areas to drive forward green urbanisation.** Enforcing binding constraints on urban development, including absolute carbon emissions and intensities, thresholds for the regenerative capacity of natural capital resources, and utilisation of key resources like electricity and water, can provide cities and businesses operating within them with the impetus required to measure and assess the ecological and environmental effects of urban infrastructure and urban buildings, drive changes in the planning and design of new urban infrastructure and dictate the manner in which existing infrastructure stocks are replaced and renewed.

(iii) **Promote urban renewal as an opportunity to transform the infrastructure and resource footprint of existing cities and towns.** In renewing or refreshing physical infrastructure, city planners are provided with opportunities to introduce new concepts into their urban development models. Urban renewal projects should avoid major demolition and construction projects, focusing instead on the efficient reconfiguration of existing infrastructure to ensure resilience to future resource constraints, and driving behavioural change in urban environments. City and local governments have a range of policy tools at their disposal to accompany urban renewal projects and promote behavioural changes and foster the growth of the green economy, including targeted taxes and subsidies, pricing urban activities according to their resource and spatial footprint (e.g. use of personal vehicles and parking charges), and regulation and education campaigns.

(iv) **Recognise and support the role of county-level urbanisation and small towns in the revitalisation of rural areas.** Alongside the growth in megacities, a large proportion of the population still lives in relatively rural counties that are experiencing local urbanisation through the development of new, relatively small towns. To allow these small towns to flourish and improve the quality of life in surrounding rural areas, they should be included in the process of urbanisation through the provision of key services, such as sewage treatment, distributed energy generation, and carbon-neutral building construction.

(v) **Integrate digital technologies into the development of new 'smart cities'.** With the coordinated development of 'green', 'digital' and 'smart' as the goal, China should promote the construction of a new type of smart city, with a new way of urban life and urban governance reshaped by the use of next-generation information technologies such as 5G, AI, cloud computing, big data and blockchain. In the meantime, the economic vitality and quality of life in rural areas can be enhanced by combining sustainability with smart technology. In particular, this refers to areas where high-capacity cloud-based digital, networking technologies (e.g. 5G, distributed ledgers) and AI can be combined to support the design, construction and management of sustainable cities, as well as the monitoring of resource use and resource intensity.

Redefining the relationship between humanity and land use

Agriculture, forestry and other land use activities account for 23% of global greenhouse gas emissions. More than half of the world's grain is used for animal feed, and more than 77% of farmland by area is used, directly and indirectly, for animal grazing. The land requirements of an agricultural structure rich in animal products continue to be a major driver of deforestation globally. Furthermore, the rise of industrial agriculture and forestry has incurred attendant losses on the natural capital stored within the world's arable land and natural forests and changes in land use patterns have been clearly identified as a major contributing factor to both climate

change and diversity loss. Nature-based solutions (NbS) describe a set of tools and practices designed to protect, restore and change land use to reduce emissions associated with land, or to increase its capacity to absorb emissions in acting as a carbon sink. Any successful implementation of NbS or equivalent measures requires radical changes to production and consumption of agricultural goods and services, which in turn require a re-evaluation of what a sustainable relationship between humanity and land looks like.

Land use – priorities and challenges

Two key features define the evolution of agriculture in China: (i) a shift in the primary content of agricultural production from plant-based products to the direct (as livestock) or indirect (as animal feed) production of animal-based products; and (ii) the replacement of crop diversity with monocultures supported by the application of industrial chemicals in the form of fertilizers and pesticides. While this modernisation of agriculture has dramatically improved crop yields, it has also transformed vast tracts of land and generated a range of environmental problems (habitat loss, biodiversity loss, agricultural runoff, flood risks) and health problems for human consumers (from exposure to industrial chemicals and antibiotics, and excessive meat consumption). China's production of meat, chicken eggs and grain has increased significantly, while excessive use of pesticides and fertilizers, and overgrazing on grasslands, remain common as means of increasing short-term output.

China's meat production increased eight-fold from 10.6 million tons in 1979 to 88.9 million tons in 2021. The production of eggs increased more than ten-fold, from 2.8 million tons in 1982 to 34.1 million tons in 2021. Grain output more than doubled from 304.8 million tons in 1978 to 682.9 million tons in 2021, with half of this being used for animal feed. In the meantime, China's agricultural fertilizer use rose from 8.8 million tons in 1978 to a peak of 60.2 million tons in 2015, falling to 52.5 million tons in 2020 after measures were introduced to reduce usage. Similarly, pesticide use rose from 1.1 million tons in 1995 to a peak of 1.8 million tons, before falling back to 1.4 million tons in 2019.[15]

Globally, the environmental pollution induced by the industrial use of fertilizers and pesticides has been accompanied by a rise in disease and morbidity in human populations, and a huge increase in the cost burden of medical treatment (Dieleman et al., 2020). China's agricultural production methods, dietary patterns, disease burden and ecological conditions are steadily converging with those of industrialised countries and reflect the uncritical application of the traditional industrial development approach to the agricultural sector. Addressing the perverse commercial incentives brought about by the consolidation of the agricultural sector requires the re-centring of human wellbeing in the development of the agricultural sector, a focus on using limited arable land to meet the nutritional requirements of a balanced diet, and measures to limit the power of vested interests in these sectors.

Redefining the relationship between humanity and land use requires China to protect, restore and change land use. China has made substantial progress in this regard. Deforestation, as well as grassland and lake reclamation, has been curbed, though not eliminated. China's forest cover, for example, is expanding even as global forest resources decline, with China alone increasing the amount of green space globally by more than 25% over the past 30 years.[16] China's forest area has now reached over 1.7 million square kilometres, including 13.6 billion cubic metres of living trees and 18.2% forest cover nationwide. At the Climate Ambition Summit in December 2020, President Xi Jinping announced that China would increase its forest stock by six billion cubic metres in 2030 relative to 2005. The 14th Five-Year Plan requires that by 2025, China should have forest cover of 24.1% and a forest stock of 19 billion cubic metres, 57% vegetation cover in grasslands, a 55% protection rate for wetlands, and protected natural areas (primarily national parks) covering more than 18% of the country's land area. China has also committed to planting

[15] http://www.stats.gov.cn/

[16] http://www.forestry.gov.cn/main/393/20210312/175043478886085.html

and conserving 70 billion trees by 2030 within its own territory. All these measures, if managed well, will serve as significant carbon sinks.

Land use – policy recommendations

(i) **Redefine the concept of food security and its use in policy formulation.** The term 'food security' is most commonly used in reference to the commercial requirements of agricultural firms rather than to the production of food required to provide the population with a balanced diet. China should re-evaluate its own food production requirements and attendant food security concerns in light of health standards. China's government should focus on ensuring food security as a matter of public health. Corresponding regulation to guide the activities of the agricultural sector can be implemented without hindering the market's role in allocating resources efficiently.

(ii) **Revisit ethics in sustainable agriculture.** Based on the principles of ecological civilisation, China should gradually mandate agricultural companies and farmers to transform the net effect of their operations from being carbon sources to carbon sinks. This will require progressive reductions in the production and consumption of animal products, greater production of plant-based and cellular meat and dairy substitutes, and the gradual substitution of chemical usage and of monoculture crops with biodiverse crop growth using natural fertilizers and technology-assisted climate-smart techniques.

(iii) **Rethink the relationship between agriculture, nutrition and public health.** A revised national health strategy should focus more clearly on promoting a healthy eating lifestyle, based on the principle of disease prevention rather than treatment. Government supervision of the agricultural industry should not only focus on food safety, but also expand to provide much clearer policy guidance on the composition of a healthy diet.

(iv) **Rebase the prices of food products to reflect externalities in production and consumption.** Taking inspiration from carbon labelling and carbon taxation systems internationally, China should establish a comprehensive mechanism to account for the carbon, water and resource intensity of different food products and progressively reflect these costs in market prices of different goods, as a means of guiding dietary choices.

(v) **Provide financial incentives for firms and public institutions to implement nature-based solutions across agricultural lands, woodlands, grasslands and wetlands.** This will be necessary in the short term (before externalities are fully priced) to make the protection and restoration of natural capital profitable. This should be accompanied by improved technical guidance on the conversion of farmland to forests, the remediation of ecologically damaged land, and reduction in the use of chemical fertilizers and pesticides.

The transformation of consumption patterns

Carbon neutrality requires fundamental changes in lifestyle and consumption patterns from their present state. Replicating consumption patterns in developed industrialised countries based on material consumerism and overconsumption is at the root of a range of environmental and social pressures, and it has also failed in generating a generalised, universally shared increase in wellbeing (Easterlin, 1974; Easterlin et al., 2010; Case and Deaton, 2020).

Consumption patterns – priorities and challenges

Following the Industrial Revolution, mass production brought substantial improvements in material productivity. Sustaining these new industries required correspondingly high consumption

and constant expansion into new markets as productivity improved further. This phenomenon, built on mass consumerism, is the cornerstone of the modern economy.[17]

Since China introduced its market reforms and opening up policies 40 years ago, living standards have risen dramatically, along with rapid economic development and China's integration into a globalised economy. The Engel coefficient in China, which measures the share of food expenditure in households' total consumption, fell from 64% in 1978 to 30% in 2021.[18] The living standards and consumption patterns of Chinese people are gradually converging with those of developed industrialised countries.

This high-consumption lifestyle is, however, clearly not sustainable in environmental and resource terms, nor is it necessarily conducive to holistic wellbeing. For example, estimates suggest that if the global population had the average consumption footprint of the United States, it would outstrip the Earth's annual regeneration capacity by a factor of five.[19] The proportion of adults that are overweight or obese (closely associated with chronic diseases) in China increased from 9.9% in 1975 to 32.3% in 2016, and is still rising rapidly.[20] During the same period, these figures were 41% and 67.9% respectively in the United States. The high incidence of disease has given rise to high public and private expenditure on treatment. Perversely, this has made disease treatment an important source of economic growth. In 2016, total health expenditure in the United States accounted for about 17.9% of GDP (Dieleman et al., 2020). This is considered 'high quality' growth in purely GDP terms, even as it reflects low-quality wellbeing outcomes. This prompts a need to fundamentally rethink the concept of the 'good life' and to reorient the priorities of development policy accordingly.

Achieving lasting sustainability, beyond technical measures and upgrades to the production system, cannot entirely replace the need for a transformation of values, consumption patterns and lifestyles. Just as the transition from agricultural to industrial society was accompanied by a dramatic shift in popular values and lifestyles (Rostow, 1960), the transition to a sustainable development narrative will require a shift of similar magnitude and speed. Changing lifestyles to reduce material consumption does not preclude a flood of new consumer demands and economic opportunities emerging in the service and information economies, or of demand for goods and services (including natural goods and ecosystem services) not currently captured in market prices and GDP figures but which contribute to multidimensional measures of wellbeing.

Consumption patterns – policy recommendations

Profound changes in contemporary consumption patterns and popular lifestyles are a necessary component of sustainable development. These changes can feasibly be implemented where government promotes sustainable consumption as part of a national development strategy, making use of tools like relative prices, environmental regulation, macroeconomic policies, industrial policy, taxes and subsidies, and financial regulation, to support efforts to transition away from unsustainable levels of consumption, and from products that do not contribute to human wellbeing. This can be accompanied by supply-side structural reforms focused on promoting the supply of sustainable products, and fully decoupling growth in the supply and consumption of these products from carbon emissions and, where possible, environmental damage.

(i) **Promote sustainable consumption as part of a national development strategy,** making use of pricing, fiscal and regulatory tools to encourage profound changes in consumption patterns and lifestyles. In the meantime, target-setting and performance evaluation at all levels of government should be shifted away from the GDP-oriented

[17] 张永生, 2020

[18] http://www.stats.gov.cn/

[19] https://www.overshootday.org/how-many-earths-or-countries-do-we-need/

[20] https://ourworldindata.org/obesity

development that still dominates decision-making, to development centred on a measure of wellbeing comprising a range of social and economic indicators.

(ii) **Advocate China's traditional cultural values and rethink the concept of a 'good life'.** The traditional concept of being 'moderately prosperous'[21] in China reflects the fundamental purpose of development – pursuing moderate material consumption while also paying attention to spiritual satisfaction. This should acknowledge the merits of material consumption, while also recognising the importance of natural capital and ecosystem services as direct contributors to human wellbeing.

(iii) **Actively encourage the development of new business models.** The dominant business model in China today relies heavily on the traditional approach of industrialisation, in which the inherent sustainability of products is not valued by the market. Government support for innovative business models should include the internalisation of externalities into product prices but should also extend to facilitating changes in market structure, modes of exchange, the organisational structure of enterprises, and direct support to sustainable businesses. Government should also embed the pursuit of consumption patterns in line with the carbon neutrality goal into macroeconomic policy design and evaluation. This should extend beyond direct consumption and encompass investment, credit, fiscal expenditure and export policies. Existing macroeconomic policies seldom consider environmental factors. Carbon neutrality, as a key constraint on long-term government policy, should naturally be regarded as a constraint on macroeconomic policymaking. Initial steps would include progressively stricter regulation and eventual elimination of high-emission, high-energy consumption, and resource-intensive products, especially those performing badly on all three metrics, and those with low added value.

(iv) **Provide educational guidance to the general public and business sectors and introduce a series of high-profile pilot policies to support the green economy,** accelerating public adoption of healthy, sustainable consumption patterns. These pilot programmes could include limitations on working hours, flexible working arrangements and the aforementioned ban on the sale of fossil-fuel-powered vehicles. Where these are implemented at the same time, they can compensate for lower material consumption by encouraging the growth of cultural, touristic, sporting, leisure-based and other less resource-intensive economic sectors.

[21] '小康' in Chinese.

5. A carbon-neutral support system

Successfully pivoting to a new paradigm for development requires the government to provide strong institutional, financial and technological support for the transition. China's current system of institutions, financial services and technological innovation ecosystems was, however, formed by (and is still served by), the traditional development model. For a truly carbon-neutral support system to emerge, all these components should undergo a process of transformation guided by the requirements of the new development strategy. These systemic transformations must also be based on principles of equity, such that China's various socioeconomic and ethnic groups, geographical regions and economic sectors can share the costs and benefits of transformational change fairly.

Building a comprehensive carbon accounting system

Addressing global climate change requires the government to take on the role of providing public goods in the form of policies and regulation capable of overcoming market failures in the provision of these goods. The key characteristic of carbon neutrality is its status as a public good provided by the government, supported by regulatory enforcement and market design. An essential prerequisite to the effective delivery of both is a statistical and accounting system capable of supporting efficient carbon-neutral policy design and tracking its implementation. In neoclassical economic theory, the relationship between economy and environment is almost entirely decoupled, with the value of ecological environment not systematically considered. While the integration of environmental factors has improved as ecological and environmental analysis gradually makes its way into economic policy frameworks, a solid intellectual foundation for linking ecology and economics is still lacking. Building a fit-for-purpose carbon accounting system can help to create a systematic empirical basis for building this micro-foundation.

China's carbon neutrality ambitions have taken a firm hold at a strategic and macro level, but greater efforts are needed at the micro-mechanism level to make macro targets self-enforcing. Existing transition policies are primarily geared towards controlling carbon emissions across China's administrative regions by applying direct targets to each layer of government and enforcing administrative orders. This system of administrative intervention has induced higher-than-necessary economic costs, and hindered markets' ability to play their resource allocation role effectively. Creating a robust carbon accounting system is critical for implementing efficient carbon-neutral strategies and enhancing the effectiveness of market mechanisms in achieving them.

The most basic function of a carbon accounting system is to account for carbon emissions, carbon assets and carbon liabilities for every enterprise and institution, including governments at all levels, and businesses of all sizes (with a priority focus on those with high absolute carbon emissions), as well as individual carbon 'responsibility'.[22] This is a prerequisite for determining the attribution of carbon emission rights and forming a fully functional revenue and cost accounting system based on the coordinated development of economy, society and ecology. It also aids in tracking the transition's progress and identifying its characteristics, using indicators for carbon emissions, energy consumption, and so on.

Carbon accounting system – priorities and challenges

The establishment of a sound carbon accounting system faces several challenges. One is the lack of a unified carbon accounting framework for emitting entities. From the perspective of economic theory, the object of analysis should be goods and services that provide a specific utility that can be measured through pricing or revealed preference methods. For carbon accounting to succeed, however, it needs to take into consideration the role of carbon emissions in driving or impeding economic, social and ecological development, in order to coordinate carbon reduction, pollution

[22] 刘世锦, 2021, 2022

control and green growth policies. Eventually, the carbon accounting system should be capable of representing a measure of sustainable development, something that is still not reflected in current carbon accounting standards. In addition, current carbon accounting methods are underpinned by greenhouse gas inventory compilation methodologies at the national level, accounting for energy consumption by type, and corresponding carbon emission intensity of economic activities on the basis of emission factors calculated at the national and provincial levels (including autonomous regions and cities). These are complemented by voluntary (and increasingly mandatory) carbon emission reporting by key industries and enterprises. In this existing model, the scope for generalised or aggregated assumptions to drive variation in accounted emissions is too broad for it to be the basis of an effective monitoring, evaluation and incentive mechanism for specific carbon-emitting entities (from individuals to enterprises).

A second challenge is that there is no effective carbon emissions allocation system. On the one hand, the current top-down allocation of carbon responsibility and the administrative interventions that come with it result in an efficiency loss. The government does not have sufficiently granular or accurate internal information on enterprises' decision-making in terms of production and energy use. Improperly allocating carbon responsibility on the basis of this flawed and incomplete information risks interfering unproductively with business decisions and raises the potential for perverse emission reduction outcomes. On the other hand, it is important to ensure that all levels and branches of government have mutually aligned interests and take concerted action on carbon reduction. Top-down allocation is often accompanied by problems such as insufficient incentives to invest in long-term decarbonisation, high implementation costs and poor inter-regional coordination. For a sound carbon accounting system to be successful, it is also necessary to establish carbon emission accounts for governments at all levels (national, provincial, municipal, district, etc.), enterprises and individuals, linked to standard economic accounting tools (such as input-output tables), so as to clearly and transparently determine each entity's emission reduction responsibility.

Third, there is still no sound market mechanism for carbon pricing. Accurate accounting of carbon emissions from individual emitters, and effective allocation of carbon responsibilities, should allow for a sound market mechanism for carbon pricing to be established for all entities, with prices being adjusted to reflect differences in preferences, emissions allocation and unequal distribution of carbon responsibilities. This market needs to be created and supervised by the government. The existing national carbon emission trading market represents a very soft constraint on trading entities, and the externalities of carbon emissions are yet to be internalised in any meaningful sense.

Carbon accounting system – policy recommendations

(i) **Develop a national statistical system based on 'social wellbeing'** to be used alongside the existing accounting system based on material output and GDP, as a basis for the implementation of a full carbon accounting system based on the impact of carbon emissions on wellbeing. This requires adopting adopt a more universal and multidimensional set of 'wellbeing' indicators to measure the effectiveness of development policies. It will also require clear pricing and market trading mechanisms (to determine the value of 'wellbeing'), thereby pushing ahead the construction of carbon accounting and carbon market across all economic entities.

(ii) **Establish carbon accounts for every enterprise and institution.** These will serve as a functional basis for the implementation of a carbon neutrality accounting system. Governments at all levels (national, provincial, city, district) should be involved in determining the scope of the accounting system, and the allocations granted to each entity. The system should be designed to be extendable to ecological accounting of environmental impacts other than carbon, including other pollutants and natural capital stocks and flows, and policy experiments should be conducted to assess its effectiveness and accuracy.

(iii) **Build a carbon accounting system and corresponding assessment and reporting mechanisms.** This should include a statistical carbon accounting system operating at local and national levels of government, a transparent mechanism for assessment and reporting, and a schedule that requires all enterprise and government entities to publish their assessment reports on carbon emissions in an open and transparent way.

(iv) **Facilitate a greater role for carbon markets in driving efficient resource allocation.** The construction of the carbon market should be actively expanded to cover a larger share of the economy and more enterprises. At the same time, over-the-counter transactions should be actively promoted, and market operations should be used by banking authorities to balance supply and demand in carbon markets and promote carbon-neutral innovation and investment by maintaining consistent carbon pricing signals.

(v) **Specify clear targets on total carbon emissions for each phase over the long term (to 2060),** to guide the expectations among economic entities, promote the initiative of market trading and progressively harden the carbon budget constraint for regulated entities.

Building a macro-management framework for zero-carbon finance

Achieving the goal of carbon neutrality requires the construction of a zero-carbon financial macro-management framework. China has a unique opportunity to lead the world in this regard. For China's financial sector, a zero-carbon framework will require profound changes in terms of the targets of financial policy, financial products, the scale of the financial system, strategic and operational frameworks, the macro-management framework, and supporting financial infrastructure.

Zero-carbon finance – priorities and challenges

Finance will play several leading roles in delivering the 2060 carbon-neutral strategy. First and foremost is financing green investment. During the carbon-neutral transition period, new long-maturity, high-risk investments of an estimated 186 trillion Yuan need to be financed. China will also have to manage the impact of the transition on 382 trillion Yuan of existing financial asset stocks,[23] requiring extensive financial restructuring and risk transfer mechanisms to prevent the destabilisation of balance sheets held by countries, industries, enterprises and residents. The financial system also has a key role to play in providing high-risk, patient early-stage investment for carbon-neutral technological innovation, and providing financial products designed to help high-carbon industries adapt to a carbon-neutral policy environment. Externally, China should also directly participate in international competition and cooperation around the construction and interoperability of zero-carbon financial markets. The government should seize this historical opportunity to 'overtake on the bend' and lead the world in building a zero-carbon financial system in China.

These objectives come with formidable challenges. Over the past decade, China's green finance policies have delivered remarkable achievements in terms of expanding markets for green financial instruments and capital flows, but China still falls far short of the financial requirements for a carbon-neutral economy. By the end of 2021, China had 15 trillion Yuan in outstanding green loans, ranking first globally, and 1.1 trillion Yuan of green bonds, ranking second globally. However, green loans still only account for 4.5% of China's total social financing market, and green bonds account for just 0.7% of China's total domestic bonds by value. These remain a very long way from what is needed to meet the investment and financing requirements of the carbon-neutral transition. At the same time, 90% of green financing is comprised of bank loans with

[23] http://www.gov.cn/xinwen/2022-03/16/content_5679310.htm

mismatched maturities and no associated derivative structures, which does not meet the needs of the carbon-neutral transition in terms of financial product structure and risk control.

The Chinese government and its financial regulators should promote a comprehensive shift in China's financial system and take the initiative in building a world-leading zero-carbon financial system in China accompanied by a fit-for-purpose macro-management policy framework. This should be established as soon as possible to provide financial participants and the market with long-term policy signals and clear policy guidance, to provide the incentives and stable market expectations required to release new investment.

Zero-carbon finance – policy recommendations

(i) **Accelerate the overall transition to 'zero-carbon finance',** starting with a clear strategic target of establishing a new financial system in line with the carbon neutrality goal. National policies should provide guidance and rules for environmental and natural capital protection standards, the measurement, management and pricing of climate risks, the transition from carbon-intensive assets to low-carbon assets, and the development of carbon-related financial products tradable in carbon markets.

(ii) **Update existing definitions of 'green finance' to 'zero-carbon finance'.** A definition of zero-carbon finance should be established that encompasses the environmental protection component of green finance, the resource protection and sustainable development component of sustainable finance, the climate risk impact and endogenous financial pricing components of climate finance, the risk management component of transition finance (for transitioning carbon-intensive assets to low-carbon assets), and the trading of carbon-related products and market regulations component of carbon finance.

(iii) **Develop a world-leading macro-management framework on 'zero-carbon finance'.** First, this requires expanding the scale of fiscal support for zero-carbon finance, enriching the suite of tools deployed to support zero-carbon finance and clarifying the long-term pathway for fiscal and financial coordination under carbon neutrality. Achieving carbon neutrality requires large-scale financial support for infrastructure investment, scientific R&D, and transformation incentives for existing high-carbon industries. The most effective way to increase structural fiscal support for these purposes is to strengthen coordination between government spending and financial markets and improve the policy frameworks guiding this coordination.[24] Second, monetary authorities should implement policies consistent with carbon neutrality. The Central Bank should correct market errors with non-neutral price and quantitative monetary policies, to support carbon-neutral transformation, and maximise social utility. The Central Bank should also ensure its structural forecasting model is compatible with the carbon-neutral transition in terms of designing macroeconomic monetary policies, financial stability policies, market operation policies, and stress tests.[25]

(iv) **Build world-leading regulatory and disclosure management mechanisms.** First, China should push for the establishment of new regulatory principles for zero-carbon capital management under the Basel Agreement framework. These should be accompanied by the launch of a new zero-carbon investment classification standard in China, guidance for the changing contribution of zero-carbon and high-carbon assets to risk-weighted capital adequacy ratios over time, and guidance for the inclusion of zero-carbon assets as collateral in credit markets. Second, the government should design a zero-carbon financial information disclosure framework that builds on China's current practices. This should focus on determining the content and implementation schedule of China's

[24] 朱民等, 2022a

[25] 朱民、彭道菊, 2022

zero-carbon financial information disclosure requirements; promoting classification systems in line with international standards to significantly improve standardisation, transparency and mainstreaming of ESG portfolio and zero-carbon finance; steadily raising corporate disclosure standards; and promoting the construction of zero-carbon financial information disclosure infrastructure.

(v) **Improve the innovation finance ecosystem for carbon-neutral technologies to attract much more extensive private funding.** China should consider establishing a carbon-neutral technology bank for the purpose of using public capital to strategically leverage private investment in carbon-neutral innovation. The establishment of project-based mixed ownership structures, and reasonable multi-party benefit distribution mechanisms, should be explored in dialogue with the private financial sector. A variety of direct financing methods should be made available to assist entrepreneurs in accessing the full spectrum of the venture capital market, and to guide venture capital providers towards carbon-neutral product development and innovation. At the same time, the government should leverage China's deep experience in providing indirect financing through the banking sector and provide guidance to banks on credit policies favouring carbon-neutral technology investments.

(vi) **Implement a complex zero-carbon financial market ecology.** This system should include the overall framework of zero-carbon financial market, reasonable zero-carbon financing structures for banks, bonds and stock markets, carbon financial derivative trading markets, and the development of a zero-carbon financial services sector. This requires providing clear information to financial market participants to promote better allocation of financial resources to help achieve the carbon neutrality goal.

Promoting breakthroughs in critical carbon-neutral technologies

Breakthroughs in a range of as-yet immature critical technologies are key to achieving carbon neutrality. Technological innovation should therefore promote not only the reduction of emissions intensity in production, but also the decarbonisation of final consumption, to achieve the ultimate decoupling of economic growth and carbon emissions as much as possible and avoid the Jevons Paradox (Jevons, 1865), in which technological progress leads inexorably to ever-greater resource and energy consumption as the scope of consumption choices expands.

Carbon-neutral technologies – priorities and challenges

Technological innovation is a constant process of 'creative destruction', driving structural shifts in production and consumption. Large-scale and system-wide replacement of existing technologies with carbon-neutral ones provides a leapfrog development opportunity for China's technological innovation across a range of fields essential to achieving carbon neutrality (Grubb et al., 2021). China is a global leader in technological innovation for carbon neutrality in many areas, but still faces prominent problems including insufficient innovation spending as a share of retained earnings, insufficient availability of investment and financing, and a low conversion rate of technological achievements to commercial successes. The driving force for investment in new technology research and development is the expectation of higher profits for enterprises. However, with numerous available options for technological innovation, investment in carbon-neutral technologies is not always the most rewarding option for enterprises, especially given that markets for these technologies are not fully developed and the externalities of high-carbon activities are not yet effectively priced. The government must therefore play an important role in guiding innovation activities.

While carbon neutrality requires technological innovation in many areas, renewable energy and related technologies were among the first to take hold. In terms of renewable and low-carbon energy products, China is already a global leader in technological know-how, equipment manufacturing capacity and deployment. According to China's long-term energy targets, the share of non-fossil energy in total final demand will exceed 80% by 2060, with solar and wind

power the main sources of renewable energy. China's installed renewable energy capacity is expected to rise to 1,200 gigawatts by 2030 from about 600 gigawatts today. Solar and wind technologies are now mature and commercially viable.

Sufficiently flexible storage technology is vital for solving the problems of intermittency and instability in power grid systems induced by a high share of on-grid renewable capacity. The rapid development of flexible, long-duration energy storage and conversion technologies is needed to meet the needs of economic development, mainly in heavy industry and transport. Battery storage technology is still facing four bottlenecks that further innovation should work to resolve: low energy density, unstable or inconsistent performance, high costs and high levels of exposure to critical mineral supply chain risks.

In tandem with energy storage and conversion technologies, green hydrogen fuel and its derivatives (such as ammonia and methanol) will be needed in large volumes to meet the thermal and fuel diversity of industries in which electrification is not feasible or not economic. The use of zero-carbon electricity to produce hydrogen and its derived fuels for use as liquid fuels, and for energy storage, is an important direction for technical innovation.

Global carbon neutrality cannot be achieved solely through reducing emissions: it needs to be complemented by large-scale decarbonisation technologies. These technologies are broadly divided into carbon capture, utilisation and storage (CCUS) and direct air capture (DAC). CCUS technologies have long suffered from high costs and limited effectiveness and scale, as well as technical issues in guaranteeing the permanent storage of captured carbon and its reuse for other applications. DAC remains very expensive and has not yet been deployed at scale either (Nakano, 2022; Liu et al., 2022).

While the general technological requirements of carbon neutrality are clear, the specific evolution pathway for some energy-related technologies and the eventual scope and scale of their applications is still highly uncertain. In these cases, the government should focus on creating favourable conditions for technological competition among multiple options. Carbon neutrality provides a leapfrog development opportunity for China's technological innovation across a range of fields essential to achieving it.

The government has a critical role to play in promoting general carbon-neutral technology innovation – but should focus its efforts not on 'picking winners' but on providing the institutional conditions for innovation to take place, and selectively incentivising technological innovation and deployment on the supply- and demand-side. These measures promote the emergence of new technologies and also open up market conditions for the rapid development and deployment of new technologies in real-world settings.

Carbon-neutral technologies – policy recommendations

(i) **Government should play a leading role in incentivising the development and deployment of carbon-neutral technology.** On the supply side, the government should provide fiscal incentives to encourage innovation, provide financing mechanisms (such as unconditional credit lines), fund early applications of emerging technologies, and support the development of supply chains for carbon-neutral products. Specific actions include issuing strategic roadmaps for key sectors, instituting a certification scheme for enterprises engaged in carbon-neutral innovation, establishing a dedicated early-stage financing facility backed by public capital for supporting carbon-neutral innovation, establishing public–private partnerships to promote the commercialisation and deployment of new technology, and making use of market-based incentive mechanisms to create initial sources of demand for new technologies.

(ii) **Adopt a two-pronged approach to technological substitution.** First, China should work to maintain its leading position in technologies such as wind power, solar photovoltaics, and solid-state batteries. It should focus on increasing their deployment in domestic and international markets, and their integration with existing energy and

production systems. Second, for emerging technologies such as hydrogen production and fuel cells, large-scale energy storage and CCUS, China should develop a comprehensive innovation system to support all stages of the innovation process covering 'technology development – technology transfer – reproduction/ industrialisation', with consideration of commercialisation and application integrated into each stage.

(iii) **Integrate digital and intelligent technologies into the carbon neutrality ecosystem.** The widespread availability of digital and AI technologies can be useful in improving the performance, interoperability and monitoring capabilities of carbon-neutral technologies. Digital technologies can also play a role in reducing emissions from existing infrastructure by optimising output and improving efficiency (e.g. heating and traffic controls in smart cities), and give rise to new service industries dedicated to the management and transformation of emissions-intensive activities.

(iv) **Adopt additional demand-driven policies for technology deployment.** The main tools available to government include tax credits, subsidies, tradable permits and carbon trading markets. Regulatory options include clean energy technology standards and renewable energy portfolio standards. The government can further stimulate demand for green technologies through green procurement policies.

Building a management mechanism to ensure a balanced carbon-neutral transition

Ensuring a balanced carbon-neutral transition is the key to its long-term success. There were various approaches to making the transition equitable under the traditional approach of industrialisation, but all focused on deciding how to share the economic burden of emission reductions fairly. Under the new development strategy articulated earlier in this report, carbon neutrality will enable an economy to be more competitive in the long term by undergoing structural changes, while environmental improvements will also increase non-monetary wellbeing. The issue of carbon equity, to a large extent, therefore, becomes a question of how to distribute the costs and benefits of the transition fairly.

Balanced transition – priorities and challenges

The transition to a carbon-neutral economy will bring substantial net benefits to society, but will also trigger major structural changes, in terms of employment, industrial activity, local finance, the social security system, the ecological environment and financial markets, all of which should be carefully managed.[26] Market participants tend to overestimate the risks faced by some specific sectors on the one hand, and yet underestimate the depth and breadth of the impact of carbon neutrality on traditional industries on the other. For instance, while most of the attention has been focused on the consequences of phasing down coal, the switch from fossil-fuelled vehicles to electric vehicles would not only decimate producers of traditional vehicles, but also eliminate at least one-third of the fossil fuel-powered car parts industry, and more than half of the revenues of the vehicle maintenance industry. At the same time, many of the risks associated with the transition, including the structural challenges faced by high-carbon industries, have less to do with short-term policy targets and more to do with the underlying disadvantages of the traditional development approach.

To be specific, in the process, different groups will benefit or lose to different degrees, and some specific regions, industries and groups will be particularly negatively impacted – at least in the short term. If these costs and benefits are not redistributed according to principles of equity, advancing the process of carbon neutrality will be likely to encounter much more opposition. One clear challenge for China is the impact of emission reductions on key coal areas. According to the

[26] https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202101/t20210113_817221.html

China Coal Association,[27] there will be 2.85 million direct employees in China's coal industry in 2020. The regions likely to be the most heavily affected by coal phase-down are Shanxi, Inner Mongolia and Shaanxi, which account for 35%, 30% and 20% respectively of China's coal output. These and other coal-producing regions are facing systematic transformation of their entire industrial base (not only in the power sector, but also manufacturing and services industries reliant on coal), their fiscal and financial base, and the loss of major sources of employment. In Inner Mongolia, 80% of industrial output is in the energy and raw materials sectors, and the six highest energy-consuming industries alone account for about 90% of its output. Energy consumption per unit of GDP is three times the national average, and carbon emissions per unit of GDP are four times the national average.[28]

A second challenge is the impact on heavy industry of reducing emissions. Industrial carbon emissions account for more than 70% of China's total emissions (about 40% of which are emissions from industrial power consumption), and industry accounts for more than 60% of China's total energy consumption. The most prominent of these are the six most energy-intensive industries (power, iron and steel, cement, non-ferrous metals, petroleum and chemicals). Between them, they account for about 80% of industrial carbon emissions. Carbon neutrality will have a profound and potentially destabilising impact on these industries.

The final major challenge is the impact of carbon neutrality on asset owners, including on individual investors' savings. As China's carbon neutrality targets and associated policies change market expectations, a revaluation of assets in specific industries (especially fossil energy and carbon-intensive industrial facilities) will likely materialise. This will bring about major and potentially disruptive changes in the capital markets, stock markets and balance sheets of key enterprises, with knock-on effects for individuals – especially those with savings and/or pension plans tied to enterprises' performance – and a systemic impact on the economy that may require government intervention to stabilise.[29]

Balanced transition – policy recommendations

Realising a balanced carbon-neutral transition requires breaking away from the traditional industrialisation approach and re-evaluating the issue of coordination and balance in the carbon-neutral transition from the point of view of the new development strategy. It is important to recognise that an unbalanced transition would risk failure of carbon neutrality efforts, condemning current and future generations to the impacts of climate change due to an institutional inability to respond to the unsustainable consequences of the traditional development approach. At a time when global economic growth is facing obstacles, policymakers should maintain and even increase their strategic focus on carbon neutrality, firmly and consistently promote it, maximise opportunities for high-carbon industries to implement transformational changes, and provide well-resourced assistance to specific regions, industries and individuals where support in transitioning to carbon-neutral economic activities is most needed.

China should:

(i) **Build a national macroeconomic management and control system for managing the transition and establish sound coordination systems for addressing systemic imbalances.** It is necessary to promote institutional and policy frameworks and changes commensurate with the goal of carbon neutrality. For example, China could further strengthen the role that the Leading Small Group (LSG) plays in guiding China's transition to a carbon-neutral economy; establish a national expert committee and a

[27] China Coal Association, 2021 Coal Industry Corporate Social Responsibility Report, http://www.coalchina.org.cn/index.php?m=content&c=index&a=show&catid=182&id=129154

[28] 包思勤, 2021

[29] 朱民等, 2022b

specialised policy research institute on carbon neutrality; and improve coordination among different functional systems, including the fiscal system, finance system, science and technology departments and local governments.

(ii) **Combine macro-level strategy with policy and institutional experimentation.** Institutional flexibility and adaptability will be essential for the efficient implementation of a carbon-neutral transition strategy. Government should encourage institutional innovation, relax restrictions on policy experimentation by local governments, and use the information gathered through this process to identify and constantly adjust effective implementation modalities, policies and specific practices suitable for the specific conditions of different regions, industries and enterprises.

(iii) **Require governing institutions to account for both short-term and long-term policy objectives, and balance different interests among regions.** Targeted and flexible policies can be adopted in the short term to achieve this. For high-carbon industries, differentiated policies combining (carbon) market liberalisation, stabilisation of asset stocks, and restrictions on operation should be implemented sequentially. In the long run, transition risk prevention and control measures, and industrial employment transformation plans and policies, should be formulated and applied in affected areas.

(iv) **Prioritise employment as the focus of equitable transition policies.** Support should be directed to people on low incomes and those most heavily affected by carbon neutrality. These include relocating and retraining industrial workers in zero-carbon industries, closing or restructuring relevant high-carbon enterprises, and ensuring the adequacy of social security support and other forms of social assistance for those made redundant as a consequence.

(v) **Allow different regions to peak emissions in succession according to their development status and industrial composition.** Achieving carbon peak and carbon neutrality is a national goal. To achieve this national goal with the participation of every region in China, cost minimisation measures and flexibility over different rates of progress are required. Roadmaps for realising carbon neutrality goals should be formulated in accordance with the industrial structures and resource endowments of different regions, to avoid uniform emission reduction schedule requirements for all regions.

(vi) **Establish a flexible and cooperative mechanism for achieving emission reduction targets across different regions and industries.** Regions or companies with high emissions should be able to purchase carbon quotas to reduce their emissions. This flexible trading mechanism should also be extended to electricity markets, to encourage trading across provincial borders and avoid the irrational use of 'power rationing' to meet top-down emission targets.

(vii) **Increase vertical transfer payments from the national public budget, as well as inter-regional and inter-sectoral horizontal compensation mechanisms.** These include transfer payments, taxes and subsidies to help resolve the financial, social security, employment and retraining challenges faced by high-carbon regions, and help them to realise the benefits of enhancing the provision of ecological services and restoration of environmentally damaged areas. Government should also take the lead in clarifying and improving budgetary compensation mechanisms for different regions. For example, Inner Mongolia, Shanxi and Shaanxi are all big exporters of coal and coal power, and a large proportion of their carbon emissions are generated through the export of energy to other provinces, even as they bear the environmental costs. Where the environmental cost of these emissions is not reflected in the price of the energy they export, it should be compensated by budgetary transfers intended to support the cost of transitioning away from high-emission industries.

(viii) **Promote carbon-neutral development strategies in areas with abundant reserves of fossil fuels.** China's largest coal areas also, in most cases, have rich endowments of

renewable energy resources, and enjoy good conditions for carbon-neutral development. The central government can play a more active role in guiding the planning and layout of strategic emerging carbon-neutral industries in these regions and promote their development through a combination of financial, tax, industrial regulation and pricing policies.

6. Global climate collaboration and governance: sharing the benefits of carbon neutrality

In the traditional development approach, global climate governance is framed as a zero-sum game between countries bargaining to reduce their share of the burden of emission reductions (Zhang and Shi, 2014). The global consensus on carbon neutrality, however, has led to a major historical turning point for national sustainable development strategies and the global climate governance system. In a marked shift from their position just a few years ago, many countries now openly acknowledge that emission reductions are not necessarily a burden of development, and indeed that carbon neutrality will be accompanied by more robust and sustainable economic development and growth. Carbon neutrality is not only suitable for developed countries but can also become an attractive new development path for developing countries to achieve modernisation. In this context, multilateral cooperation has never been more important, as only through successful multilateral cooperation can the full benefits of carbon neutrality be realised, and mutually advantageous outcomes achieved.

Due to its size, technologies and strategies, China will be playing an increasingly important and leading role in climate action and promoting global climate change collaboration and governance towards carbon neutrality (Kyriakopoulou et al., 2022). Over the next four decades, China's sustainable modernisation will move it towards the centre of the world stage: politically, economically, financially, scientifically, technologically and culturally. As its status evolves, China should seize the opportunity to achieve carbon neutrality by stepping up cooperation with the rest of the world, learning from the experiences of other nations, sharing and explaining China's vision for a sustainable future, and fulfilling its responsibilities as a major international player in charting a shared future for mankind.

Promoting global carbon neutrality governance mechanisms

Guided by its vision of a shared, sustainable future, China should take a leading role in global climate governance, and firmly support the building of a global carbon neutrality governance mechanism under the framework of multilateralism. China needs to develop a national strategy for fully participating in global climate negotiations and international rule-making processes, promoting a fair and equitable global climate governance system consistent with the new development framework.

To demonstrate its leadership in global climate governance and promote practical cooperation among countries, China should emphasise the following steps towards information-sharing and economic cooperation:

(i) Promoting the international convergence of basic methods and standards of carbon and environment-related information disclosure among stakeholders of all parties

(ii) Ensuring the comparability, compatibility and consistency of zero-carbon policies

(iii) Eliminating non-tariff barriers to environmental trade and participating in the reform of global trade rules and implementation of carbon border adjustment mechanisms

(iv) Developing and coordinating international carbon pricing mechanisms, supporting implementation of carbon markets and offset mechanisms, and linking carbon trading markets across borders

(v) Establishing a global system for the monitoring and financing of resilience and adaptation needs, the strengthening of early warning systems, and the enhancement of disaster risk preparedness and response.

China should also promote global cooperation in science and technology in several key areas:

(i) Achieving a comprehensive transition from coal to clean energy

(ii) Global research and policy cooperation in low-carbon technologies, including related technologies such as energy storage and transmission technologies

(iii) Cooperation on climate science research and policy analysis to reach a shared understanding of climate change-related issues, and develop consensus over the impact of climate change on the natural environment

(iv) Investing in science and technology R&D centres, carrying out joint technology research, facilitating transfer, penetration and commercialisation of cross-border key scientific and technological breakthroughs

(v) Developing and sharing low-emission technologies and supporting infrastructure

(vi) Protecting natural capital within and beyond China's borders (Stern et al., 2020; Stern and Xie, 2020).

Participating in global net-zero finance cooperation and competition

Finance serves as the catalyst for demand-led change and plays a central role in the transition. With a particular focus on finance, the 26th session of the UN Climate Change Conference of the Parties (COP26) in Glasgow proposed some early principles and initiatives on the development of net-zero finance standards and global green bond market, and scaling up private sector investment and financing activities, including the launch of the Glasgow Financial Alliance for Net Zero (GFANZ). Net-zero finance has increasingly become a crucial area for policy development and lies at the leading edge of global climate cooperation and competition. A growing set of dialogues and practical frameworks for net zero finance cooperation are covering the development of net zero finance standards, the flows of net zero finance, and the communication, collaboration and transparency between financial regulators and financial institutions.

China should actively participate in, lead, promote and strengthen a global framework for net zero finance governance. China could, for instance, take steps to:

(i) Take green bonds as the starting point for promoting Shanghai as an international green bond centre, and continue to support the development of China's green bond market to improve its scale, product innovation, disclosure standards, and implementation of preferential policies.

(ii) Support the People's Bank of China in taking a more active role in the G20 Finance Ministers and Central Bank Governors (FMCBG) forum and in other financial alliances where central banks feature, to promote the harmonisation of global norms for information disclosure standards.

(iii) Actively collaborate and trade with Western countries and international organisations to promote data convergence and product exchange, and capital flow among all stakeholders.

(iv) Promote the development of net zero finance in Belt and Road Initiative (BRI) countries through increasing support for net zero finance capacity-building and strengthening cooperation on green infrastructure, green energy and green finance.

Advancing international collaboration around the global carbon-neutral transition

China–EU cooperation on climate and environment dates back to the 1990s. The China–EU Environmental Policy Ministerial Dialogue has been held eight times since it was first established in September 2001. China and the EU have strengthened their cooperation over the past few decades, and they should continue to deepen and intensify existing cooperation mechanisms and continue to diversify points of cooperation between the respective governments, advisory think

tanks and experts. This is particularly important in areas such as energy transition pathway selection, carbon market development, technological innovation (especially energy storage and energy digitisation), catalytic climate finance, carbon emission reductions, and biodiversity protection. Both parties should assume greater leadership responsibilities in global climate governance.

China and the US also share an interest in facilitating the transition to carbon neutrality, and climate will become a priority area for the China–US bilateral relationship. In industry, science and technology, there are many opportunities for China–US cooperation across zero-carbon financial products and markets, low-carbon agriculture and food processing, power grid integration and CCUS. Better coordination on research, deployment and market-making efforts between China and the US is needed to create a strong and resilient global supply chain that is more conducive to trade in low-carbon goods and technologies, such as the production of batteries and solar power equipment. More importantly, as major powers, cooperation between China and the US should go beyond their own interests and focus more on promoting global public welfare. China and the US should jointly support the global climate agenda in terms of carbon-neutral technology, infrastructure development and climate governance, and build a new model of major-country relations.

Supporting developing countries in the transition to carbon neutrality

It is no longer feasible for BRI countries to follow a high-carbon development pathway. By utilising its advantages in green technology, financing, and transition experience, China could play a significant role in supporting this large group of (mostly) developing countries in charting a new road to zero-carbon growth.

China should strengthen cooperation with BRI countries in terms of green infrastructure, green energy and green finance, and share its own experience in net-zero technology development and policy innovations during the transition. China should also encourage, or even mandate, financial institutions to invest in BRI countries in accordance with zero-carbon financial standards. This requires withdrawing from, or facilitating the early retirement of, high-carbon projects such as coal- or gas-fired power generation, and high-carbon infrastructure. It also requires increasing investment in hydropower, wind power, photovoltaic power and smart grids.

China should also increase capacity-building support for carbon neutrality to developing countries in the BRI, which will have to adapt to profound changes in the structure and functioning of the global economy. During the transition, these developing countries will be faced with challenges including insufficient knowledge of zero-carbon technologies, poor data collection, a lack of policymaking and monitoring capacity, and underdeveloped zero-carbon product innovation ecosystems. China should make full use of its experience with implementing green development strategies to provide these countries with technical support on transition planning, policy formulation, environmental and climate risk assessment, climate and environment information disclosure, technological innovation, and broader development policy design. This will also help China expand its international influence and help to amplify developing countries' participation in building a global carbon-neutral governance mechanism.

7. Closing remarks

Since 1860, China has been exploring the pathway to modernisation. The standards of mature industrialised countries still underpin popular understanding of what modernisation means. China has learned from the development experience of developed countries, integrated itself into the global trading system, and spearheaded a development miracle unprecedented in human history since its reform and opening up in the late 1970s. Today, China is one of the countries that has benefited most from following the traditional industrialisation strategy. China was also the first country to put forward the concept of ecological civilisation and stands ready to adopt a new development paradigm predicated on recognition that the traditional development approach is unsustainable, and that zero-carbon growth is the strategy of the future.

China has gone through a difficult process of discovery and paid a high price for developing a full understanding of the relationship between environment and development. Contrary to general global perception, China is currently one of the countries taking the most active measures in addressing environmental and climate change issues. Embracing a paradigm shift in development strategy can help to lay the necessary foundations for China to peak carbon emissions by 2030 and become carbon-neutral by 2060. Indeed, China's dual-carbon pledge is not a tactical move, but a conscious strategic decision; and China has full confidence in its capacity to fulfil these commitments.

China sees carbon neutrality as a strategic approach to achieve its sustainable modernisation, as well as an important geopolitical and commercial opportunity, despite the significant challenges still to come. In President Xi Jinping's speech to the 75th session of the UN General Assembly, he pointed out that 'humankind should launch a green revolution and move faster to create a green way of development and life'. This 'revolution' requires an orderly but profound reform in the way China develops its economy, and a wholesale effort to redefine key development concepts, focuses, approaches and purposes. In turn, this entails profound changes in China's existing approach to resource exploitation, enterprise organisation, business models, financial models, institutional mechanisms and policy systems. In fostering the process of change and the new growth story, we must recognise the strong role of the multilateral institutions, particularly the multilateral development banks (MDBs), in supporting the conditions for investment and enabling its finance, in a context where risk management and reducing the cost of capital will be of special importance.

This report has explained why a radical and profound change in development strategies is needed if human society is to emerge from the current global crisis. It has outlined the basis for a carbon-neutral policy framework in China and described how a paradigm shift in development strategy is capable of transforming the Chinese economy. If China can solve its deep ecological and environmental problems through zero-carbon transformation and successfully move its economy onto a modernisation pathway of 'harmonious coexistence between man and nature', its experience will be of great significance – and bring a range of zero-carbon growth opportunities – to the rest of the world.

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