UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

China's Policy Strategies for Green Low-Carbon Development: Perspective from South-South Cooperation

ADVANCE COPY

United Nations

United Nations publication issued by the United Nations Conference on Trade and Development

UNCTAD/GDS/2023/6 (advance copy)

eISBN: 978-92-1-358611-2

Foreword

In 2022, UNCTAD published the volume of "China's Structural Transformation: What can developing countries learn? " The purpose of the volume was to facilitate peer learning among countries in the Global South by sharing policy experiences. That publication examined diverse policy aspects including macroeconomic framework, trade, industrialization, digital transformation and debt management, shedding light on the factors contributing to China's economic transformation.

Nevertheless, there exists another dimension of China's story. The rapid industrialization and urbanization have resulted in resources and environmental challenges for the country, which calls for the transformation of development strategies. Currently, China is the world's largest emitter but has committed to peak emission by 2030 and reach carbon neutrality by 2060. Considering China's income level, economic structure, energy mix and the economic growth, achieving the goals poses significant challenges. What policy strategies can be implemented to achieve green low carbon transition while ensuring sustained economic growth for China?

This "updated" volume, China's Policy Strategies for Green Low Carbon Development: Perspective from South-South Cooperation, adds some valuable insights to the ongoing discussions on this topical issue. It aims to make a substantial contribution to the current discourse on China's transition process, encompassing both economic and climate aspects. Furthermore, it will enhance the understanding of the binding constraints developing countries encounter at national level, and how to advance green structural transformation through proper policy strategies formulation.

This publication is initiated and designed by UNCTAD, under the project of "Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda" funded by UNPDF Sub-Fund for SDG.

Richard Kozul-Wright

Director

Division on Globalization and Development Strategies

United Nations Conference on Trade and Development

Acknowledgements

This publication was prepared under the supervision of Richard Kozul-Wright, Director of the UNCTAD Division on Globalization and Development Strategies. Dawei Wang (UNCTAD Division on Globalization and Development Strategies) coordinated the research and collaborated on the drafting of the report text with external contributors. Substantive comments were received from Igor Paunovic and Gül Unal, of the UNCTAD Division on Globalization and Development Strategies.

UNCTAD gratefully acknowledges the substantive contributions to the draft text from Jifeng Li and Xue Han (Development and Research Centre of the State Council of China), Chengjun Zhou (Research Institute of the People's Bank of China), Xiaojiang Li (China Academy of Urban Planning), Li Li, Xiuli Xu and Feng Ba (China Agricultural University), Chenmin He (Zhejiang University of Technology), Pianpian Xiang (Beijing University of Technology), and Ji Chen and Xinyue Lin (Global Institute of China International Capital Corporation). The insights and support from Kejun Jiang, Yongbo Zhang, Jian Zhai, and Yi Qin to the draft text are also acknowledged.

The UNCTAD team thanks Rose Osindealabaster and Carter Dougherty for copy-editing and formatting the document, and Florence Hudry for administrative support.

The research was conducted under the project "Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partners to Achieve 2030 Sustainable Development Agenda", supported by the United Nations Peace and Development Trust Fund (2030 Agenda for Sustainable Development Sub-Fund).

Table of content

Chapter I. Greening China's development: background, constraints, and policy strategies 6

A. China's economic rise and developmental challenges 6

B. China's climate agenda and binding constraints 9

C. China's policy strategies towards green low carbon development 13

Chapter II. China's green and low-carbon urban development under the "30-60" targets 16

A. China's urbanization process and resource and environmental impacts 16

B. The challenges of carbon emission reductions in China`s cities 17

C. Vision for green and low-carbon urban development and the transformation of development approaches 21

D. Policies and strategies towards green and low-carbon urban development 22

Chapter III. Energy transition in China: policy perspectives 30

A. China's energy trend and CO2 emission from 1990 to 2021 30

B. Energy transition for the 30-60 targets 33

C. China's Policies strategies for energy transition 36

D. Conclusion 41

Chapter IV. Promoting green transition in China's industrial sector 43

A. Context setting 43

Chapter V. Policies and practices in advancing green agricultural development in China 55

A. Taking climate challenges into China's agricultural agenda 55

Chapter VI. Facilitating green transformation through macro policies in China 68

A. Introduction 68

B. The role of macro policies in addressing green transition 68

C. An integrated approach to strategy development in China 69

D. Monetary policy tools 76

E. Conclusions 77

Chapter VII. Brief introduction on China's green finance and policies 79

A. Definition and institutional arrangements 79

B. Green finance policies: Green credit 81

References 86

Figures & Tables

List of Figures

Figure 1.1 Real GDP growth rate: China and selected groups 7

Figure 1.2 Real GDP PC growth: China vs. the world average 7

Figure 1.3 CO2 emission from energy activities in China 9

Figure 1.4 Environmental kuznets curve (EKC) flattening 11

Figure 1.5 Selected industrial product output index (1978=1) 12

Figure 2.1 Trends in China's total population, urban population, and urbanization rate 16

Figure 2.2 Carbon emissions diagram of 10 typical cities (million tons) 18

Figure 2.3 Direct carbon emission composition of 10 cities based on CCG data 19

Figure 2.4 Household electricity consumption in different countries (kWh/year) 20

Figure 2.5 Composition of per capita carbon emissions in five typical communities 21

Figure 2.6 Proportion of green building area in China's new urban buildings in those years 24

Figure 2.7 Sales and ownership of China's new energy vehicles, 2014-2021 ... 28
Figure 3.1 Primary energy demand in China from 1990 to 2021 ... 31
Figure 3.2 Energy use by sectors, 1995-2014 ... 32
Figure 3.3 Installed capacity of renewable energy ... 32
Figure 3.4 CO2 emission in China and carbon intensity, 1990-2020 ... 33
Figure 3.5 Primary energy demand in China, energy transition scenario ... 34
Figure 3.6 Power generation scenarios for China, energy transition scenario ... 34
Figure 3.7 Installed capacity for power generation in China ... 35
Figure 3.8 CCS in power generation sector ... 35
Figure 3.9 Final energy demand in transport sector in China ... 36
Figure 3.10 Solar PV and wind capacity in the world ... 39
Figure 4.1 CO2 emissions by sector, 1995–2020 ... 44
Figure4.2 CO2 emissions intensity by industrial sector, 1995–2020 ... 44
Figure 5.1 GAD-Relevant Top-Level Comprehensive Policies in China (1978-2022) ... 55
Figure 5.2 Composition of China’s Agricultural GHGs as Carbon Sources ... 60
Figure 5.3 China’s GHG Emission in Agriculture and Its National Share (1990-2018) ... 61
Figure 5.4 Agricultural Emission Reduction Policies in China (2005-2022) ... 62
Figure 5.5 Policies Promoting Sequestration by SOC Sink in China (1984-2025) ... 64
Figure 5.6 Potentiality of China's Carbon Neutral Agriculture ... 65
Figure 5.7 Scenarios of GHG from Agricultural Activities in China (2020-2060) ... 66
Figure 6.1 China’s macroeconomic policy framework for environmental protection and climate change ... 72
Figure 6.2 China' green tax system ... 73
Figure 6.3. Public expenditure osn energy conservation and environmental protection (2012-2022) ... 75

List of Tables

Table 2.1 List of the full-mode travel structures in key cities ... 26
Table 3.1 Newly installed capacity of solar PV and wind power in China and the world, GW ... 31
Table 3.2 Key sectoral energy conservation policies in the 12th and 13th FYP period ... 37
Table 4.1 Major policy documents related to China’s green industrial development since 2021 ... 49
Table 4.2 Industry categories encouraged or restricted under green industrial development ... 50
Table 4.3 Direct CO2 emissions by sector (1995–2020) ... 53
Table 4.4 CO2 emissions intensity by industrial sector (1995–2020) ... 54
Table 5.1 Main Index of GAD for “14th Five-Year Plan” (2021-2025) ... 56
Table 5.2 China’s Agricultural Water Conservation Targets Outline by 2020 ... 57
Table 6.1 Main binding indicators in environmental protection and green development ... 70
Table 6.2 Practical information on the current green taxation ... 73

Chapter I. Greening China's development: background, constraints, and policy strategies

China's transition to a green, low-carbon economy is among the most essential elements needed to achieve the climate goals set down in the Paris Agreement. China has pledged it "will strive to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060".[1] Given the currently high emissions level in China and an economic structure with significant share of industrial sector and fossil fuel consumption, it remains a formidable challenge to realize such steep emission reduction for the 30-60 goals, as we call them in this paper.

Meanwhile, China remains a developing country with the population of 1.4 billion people and development challenges in economic growth, social development, and environmental protection (SCIO, 2021a). In particular, the shock from the Covid-19 pandemic and cascading crises since 2020 have placed extra challenges to Chinese economy. Lifting the remaining Covid-19-related restrictions has helped sustain China's economic recovery, which is expected to see an improvement this year. But China is also facing some persistent challenges such as financial stress, constrained consumer spending (UNCTAD, 2023). Still, it must sustain strong economic growth and achieve the climate goals.

Since about 2015, China has expedited the process to transform its development strategies. Concepts such as High-Quality Development (HQD), New Development Paradigm (NDP), Eco-civilization, and others have been proposed and integrated in multiple economic policy documents, notably the ongoing *14th Five Year Plan*, *2035 Vision Outline* and the *1+N Policy Framework for Carbon Neutrality*. Together, they lay out the Chinese government's roadmap to promote green structural transformation in the country.

This first chapter provides the overall context to understand China's green low-carbon development strategies as a prelude to a more detailed discussion for some key policy areas.

A. China's economic rise and developmental challenges

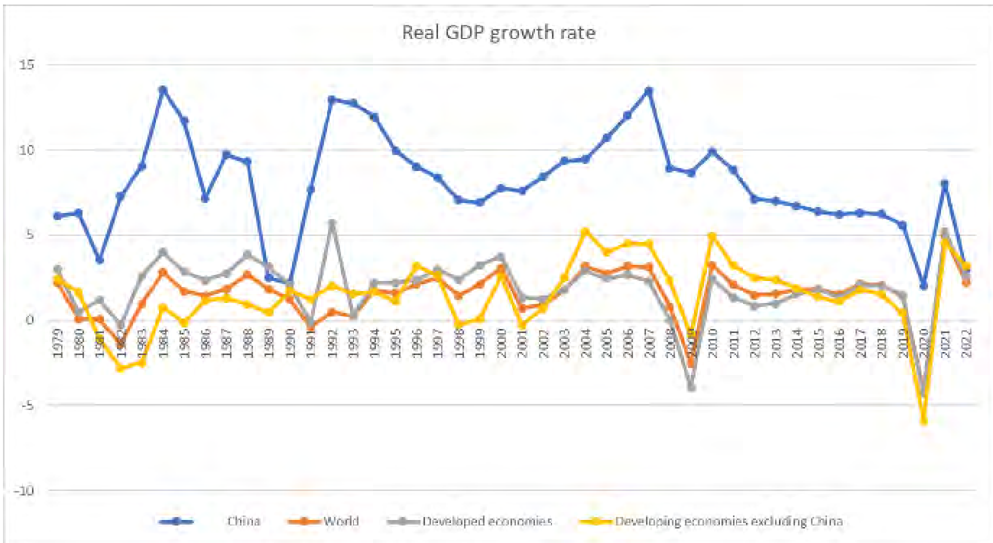
1. Structural transformation and economic growth

Whether China has fully realized a structural transformation remains an open question (UNCTAD, 2022), but there's little doubt that China has achieved remarkable economic growth since 1978 when the country began the process of reform and opening up. China's economic rise is characterised by the growth of per capita income, increased economic complexity, an expanded manufacturing sector, upgrading of science and technology, and dynamic foreign trade and investment.

The last four decades witnessed very rapid income growth of China. From 1979-2018, real GDP grew from USD 326.2 billion (in constant 2015 USD) to USD 16.3 trillion, expanding almost 42-fold. As figure 1.1 illustrates, in the last 4 decades, China's economy grew much faster than the rest of the world, though the gap has been narrowed in recent years notably from the Covid-19 pandemic shock. Since mid-1990s, for the periods of 1995-2000, 2000-2005, 2005-2010, 2010-2015, 2015-2020, the average real growth rate of China was 8.51%, 9.80%, 11.20%, 7.86% and 5.97% respectively. For the world average, the rate in the same periods was 3.56%, 3.21%, 2.52%, 2.97%, and 2.07%.

[1] Xi Jinping's speech at the General Debate of the 76th session of the United Nations General Assembly in 2021, http://www.news.cn/english/2021-09/22/c_1310201230.htm accessed on 11th October 2023.

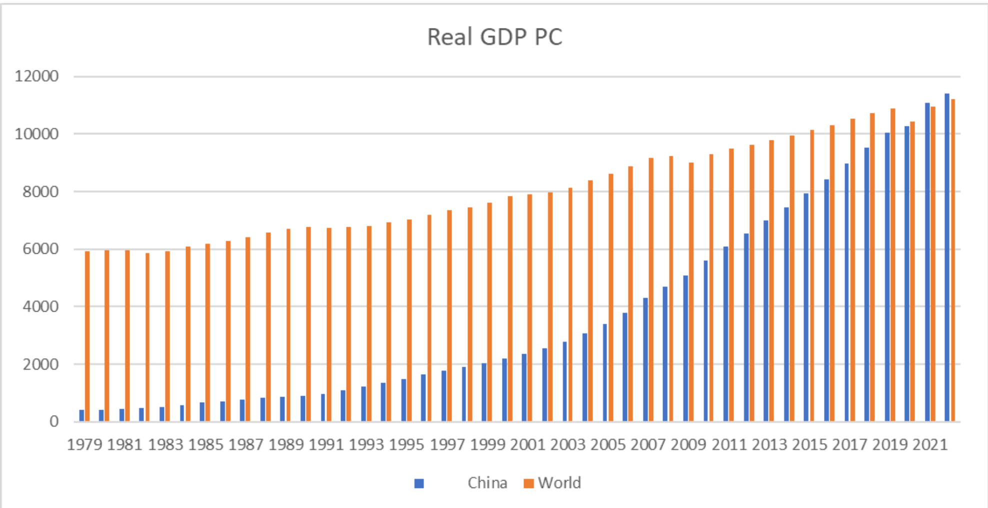
Figure 1.1 Real GDP growth rate: China and selected groups



Source: UNCTADStat.

The rapid growth is also reflected by the increase of income per capita. In 1979, China's real GDP per capita (USD 405) was only 6.8% of the world average (USD 5,942). It was even just 73% of the average of Least Developed Countries (LDCs) (USD 555). But since 2022, China has exceeded the world average in real GDP per capita which stood at USD 11,414, very close to the high-income country threshold by World Bank standards. But compared to developed economies, China lags far behind, with 30% of their per capita income (UNCTADStat).

Figure 1.2 Real GDP PC growth: China vs. the world average



Source: UNCTADStat.

China's economic success has been driven by rapid industrialization, particularly in the manufacturing sector. China now accounts for over 31% of the world manufacturing value-added, while the figure was just 3.4% in 1979. In fact, since 2013, China alone has accounted for about 62.5% of the combined manufacturing value-added of all 40 OECD members states.

On the back of its rise as a manufacturing powerhouse, China has emerged as one of the world's leading trading economies, particularly following its accession to the WTO in 2001. It is now the major trading partner for over 140 economies, according to the Chinese Government.[2] China's foreign trade has also become more complex. According to Harvard Growth Lab data, China ranked 46th in the Economic Complexity Index, which is based mainly on the structure of a country's exports, in 1995; it rose to 18th in 2021. Driven by the industrial growth and growing share of international trade, China also managed to increase the domestic value-added content of its exports, became a major player in forming global value chains, and emerged as one a global digital leader (UNCTAD, 2022).

(a) Progress on poverty reduction and social development challenges

Benefiting from the rapid economic growth, China has been able to lift close to 800 million people out of poverty in the past four decades according to the USD 1.9 per day poverty line, which accounted for about 75% of the world's total poverty reduction headcount in the same period (DRC & WBG, 2022).

However, the country still faces many developmental challenges. Among them, rising income inequality is one of the most daunting ones, reflected by relatively high Gini Coefficient and significant gap in per capita disposable income between rural and urban households (UNCTAD, 2022). Furthermore, in social development, China still needs to improve the fairness and accessibility of basic health services, pre-school education inclusion, gender equality in education and employment, etc. (CIKD, 2021).

(b) Resources demand, environmental concerns, and carbon emissions

Rapid economic growth, industrialization and urbanization has been associated with huge demand for land, water, energy, minerals and other natural resources – all of which cause raise environmental concerns.

Chapter II of this study will present an in-depth analysis of China's urbanization process and impacts. The number of cities in China has increased from 226 in 1981 to 687 in 2020, with expansion of urban built-up areas growing over seven-fold, from 7,438 km^2 to 60,721 km^2. By 2022, 65% of Chinese people lived in urban area, while the rate in 1981 was only 20%.

Urbanization facilitated investment in industrial sector. Along with the expanded urban area, a significant number of development zones have also been established since the 1980s. As of 2021, there were 217 national economic and technological development zones, 168 national high-tech industrial development zones and close to 2,000 provincial-level development zones across the country, with an approved area accounting for 14% of the land use in urban areas.

Infrastructure investment grew very quickly to keep pace with urbanization. In 2020, the total length of urban water supply pipeline reached 1,005,000 km, which was 4.0 times of that in 2000. The length of natural gas pipeline was 849,300 km, which was 25.2 times of that in 2000. The inhabited dwellings space that are heated in cities was 9,833 million m^2, which was 8.9 times that of 2000.

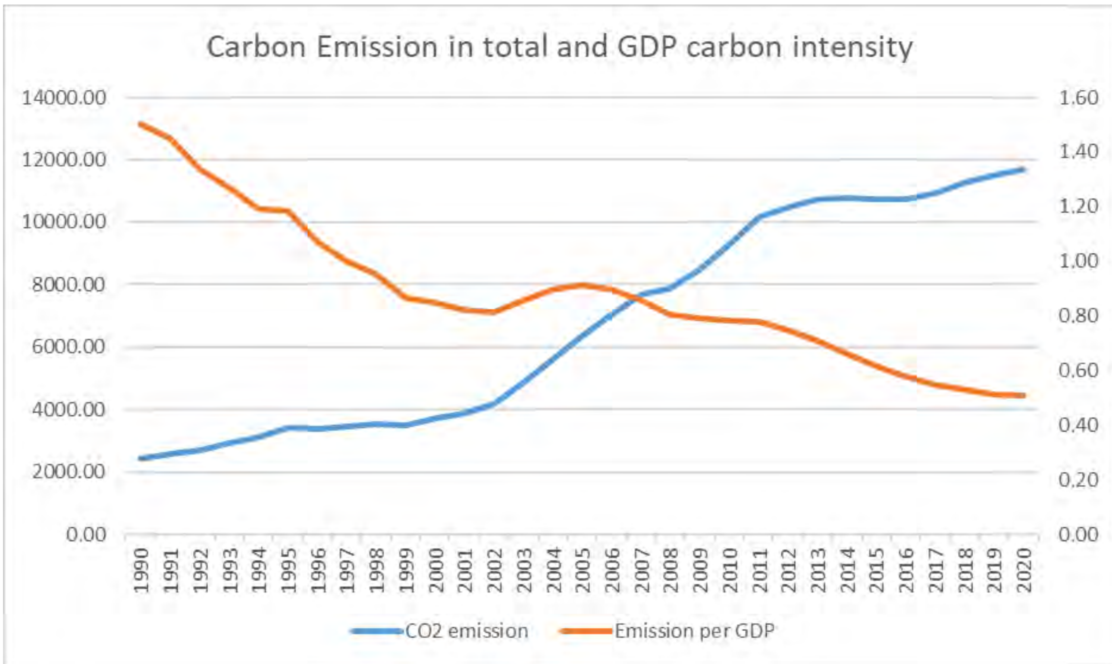
Fast urbanization and expansion of energy intensive industries such as steel making, building materials, non-ferrous metals, and chemical products, among others, have led to enormous energy demand. In 1990s, the total primary energy consumption was 691 million TOE[3], then increased by 5-fold to 3,486 million toe in 2020. China's energy mix is dominated by fossil fuels, particularly coal, even as renewable energies have emerged. In 1990s, coal accounted for about 79% of energy use. The rate was 56.8% as of 2020. Chapter 3 of this book will present more detailed information and analysis.

The large scale of energy use and coal-dominated mix result in soaring greenhouse gas (GHG) emissions of China, which has made the country the world largest emitter since around 2006. Figure 1.3 shows the trend of China's total emission (in MtCO2/yr) and the GDP carbon intensity (emission per GDP in t CO^2eq/kUSD/yr). It illustrates that China experienced a fast increase of total emission alongside its economic rise, but the GDP carbon intensity also dropped significantly.

[2] https://www.gov.cn/xinwen/2022-11/23/content_5728355.htm accessed on 25 September 2023.

[3] TOE refers to "tonne of oil equivalent," which is a unit of energy, defined as the amount of energy released by burning one tonne of crude oil.

Figure 1.3 CO2 emission from energy activities in China



Source: EDGAR.

B. China's climate agenda and binding constraints

1. Key climate commitments and goals

The climate crisis has become one of the world's most serious challenges. According to the IPCC (2022), global mean surface temperature (GMST) for the decade 2011-2020 is 1.09°C above the 1850-1900 period. If the current rate continues, global warming is likely to reach 1.5°C between 2030 and 2052. Earth had its hottest month on record in July 2023, being about 1.5°C warmer than the pre-industrial average for 1850-1900. The UN Secretary-General Antonio Guterres has warned that "the era of global warming has ended" and "the era of global boiling has arrived" and underscored the need for global action on emissions, climate adaptation and climate finance – the three pillars of the Paris Agreement.[4]

As the world's largest emitter, China's climate agenda is a key part of the international actions in response to climate change. Following the signature of Paris Agreement, China submitted to UNFCCC secretariat *Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions* in 2015 and updated version, *China's Achievements, New Goals and Measures for Nationally Determined Contributions* in 2021. Further to these international commitments, China also released several policy documents to align the national economic agenda with climate goals. National leaders, notably President Xi Jinping, reaffirmed the country's climate goals in various occasions such as UN General Assembly, G20 and BRICS Summits, and the Climate Ambition Summit.

The documents abovementioned outline key targets of China's green low-carbon transition among which are:

- peaking CO2 emissions before 2030;
- achieving carbon neutrality before 2060;
- by 2030, lowering CO2 emissions per unit of GDP by over 65% from the 2005 level, increasing the share of non-fossil fuels in primary energy consumption to around 25%, increasing the forest stock volume by 6 billion cubic meters from the 2005 level, and bringing total installed capacity of wind and solar power to over 1.2 billion kilowatts;

[4] https://news.un.org/en/story/2023/07/1139162

- by 2060, increasing the share of non-fossil fuels in primary energy consumption to over 80%;
- developing adaptation strategy to enhance the resilience of natural ecosystem and economy;
- strengthening institutions including government work mechanism, laws, regulations, and capacities; and
- engaging actively with international cooperation including supporting South-South cooperation and not to build new coal-fired power projects abroad.

Many more detailed targets in various economic industries or sectors, some of which will be discussed later in this study.

Among all those targets and roadmaps, the most important overarching commitments are peaking emission and reaching carbon neutrality which is usually referred as the "30-60" or "dual carbon" goals in China. Since 2021, it has become a buzzword and is widely discussed, helping raise the social awareness of the significance of the country's green, low-carbon transition. Almost all leading universities in China have, in the last three years, established an academy aiming for strengthening science, technology and policy research centred on the theme of carbon neutrality. Almost all ministries in the State Council have formulated action plans in their respective policy domains. Private sectors have also viewed the 30-60 goals as a game-changer for investment and market opportunities in China in the next few decades. Such high social awareness supports the government's policy strategies and actions, but also indicate that the country may face enormous challenges towards the goals that need revolutionary technology breakthroughs and application and extensive policy actions to guide the transition.

(a) The binding constraints for balancing economic growth and decarbonisation

The committed 30-60 targets will be a formidable challenge for China given its emission levels, development stage, and economic and energy structure.

The first challenge is that, achieving the 30-60 targets will require probably the most drastic emission reduction in human history. According to the data included in China's National Communications to the UNFCCC (China, 2004, 2012, 2017 & 2018), in 1994, its total GHG emissions was 3,649.5MtCO2, with the share of CO2 at 73.05%, CH4 at 19.73% and N2O at 7.22%. In 2005, 2010 and 2014, the total emission increased to 7,467.09 MtCO2, 10,544 MtCO2, and 12,301 MtCO2 (without LULUCF). Including LULUCF, the number was 7,046.29, 9,551 and 11,186 MtCO2.

The EDGAR data (Figure 1-3) shows similar trend. From 1990 to 2020, the total CO2 emissions grew from 2,426 MtCO2 to 11,680 MtCO2, increasing about 3.8-fold within 3 decades. During this period, China's contribution to the world total emissions also increased from about 11% (1990) to 32% (2020) accordingly.

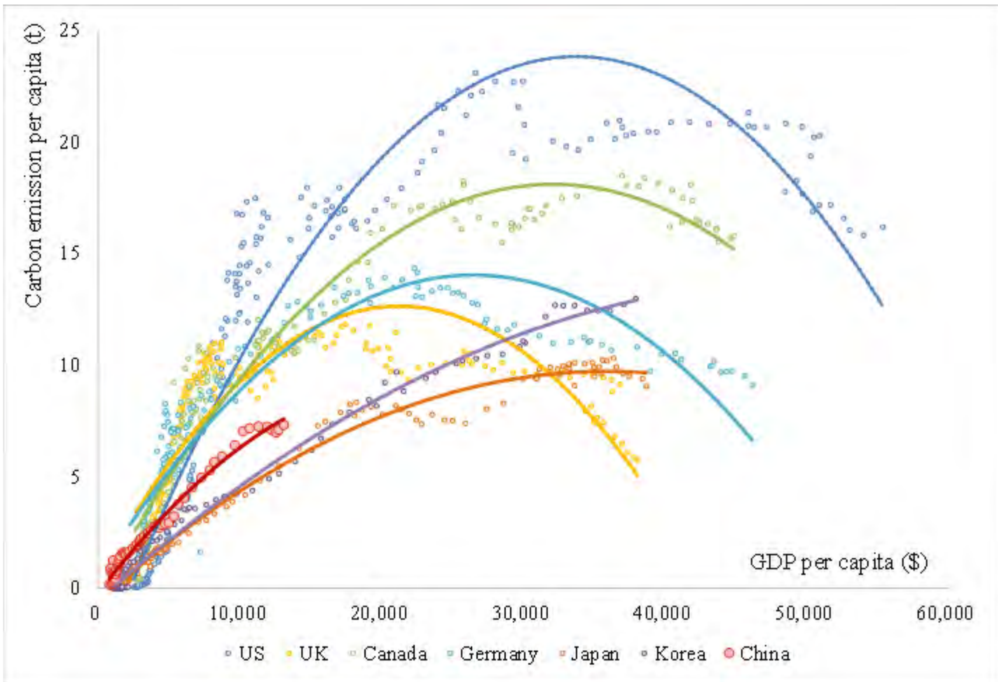
Many studies have produced estimates of the levels and timelines for Chinese emissions to peak and the variance among them is not very large. Taking one as an example, Chen et al., (2022) estimated that China may reach its carbon peak without any exogenous shocks during 2021-2026 at 11.7-13.1 Gt with high probability (> 80%). If the peaking year is 2026, then China may take about 34 years to shift from peaking level to net zero emission, which would be very short compared to many advanced economies. According to Levin & Rich (2017), emissions in the EU as a whole peaked by 1990; the EU aims to be carbon neutral by 2050, which means the timespan of transformation would be about 60 years. Given the level of China's emissions, the reduction curve will be much steeper.

The second major challenge is that such steep decline of emission will generate significant impacts on China's economy, positive and negative alike. China then must find a way to reach carbon neutrality but not at the expense of economic growth. Given its economic and energy structure.

China's emissions and its share of the global total may have been driven by the expansion of China's economy. But China has a long way to go to catch up with the developed economies in terms of per capita income, advanced technologies, public health system, education, and all the other factors that allow a country to sustain economic growth.

If China maintains the current GDP per capital growth trend, which was an annual average of 5.49% from 2015-2022, China's GDP per capita would be slightly above USD 14,000 USD (at constant 2015 prices) by 2030. While in 1990, when EU peaked its emission, its GDP per capital was USD 22,615 USD (at constant 2015 prices). Therefore, China may hit peak emissions at much lower income per capita level than developed economies. Figure 1.4 may, to some extent, illustrate the possible trend through Environmental Kuznets Curve (EKC).

Figure 1.4 Environmental kuznets curve (EKC) flattening



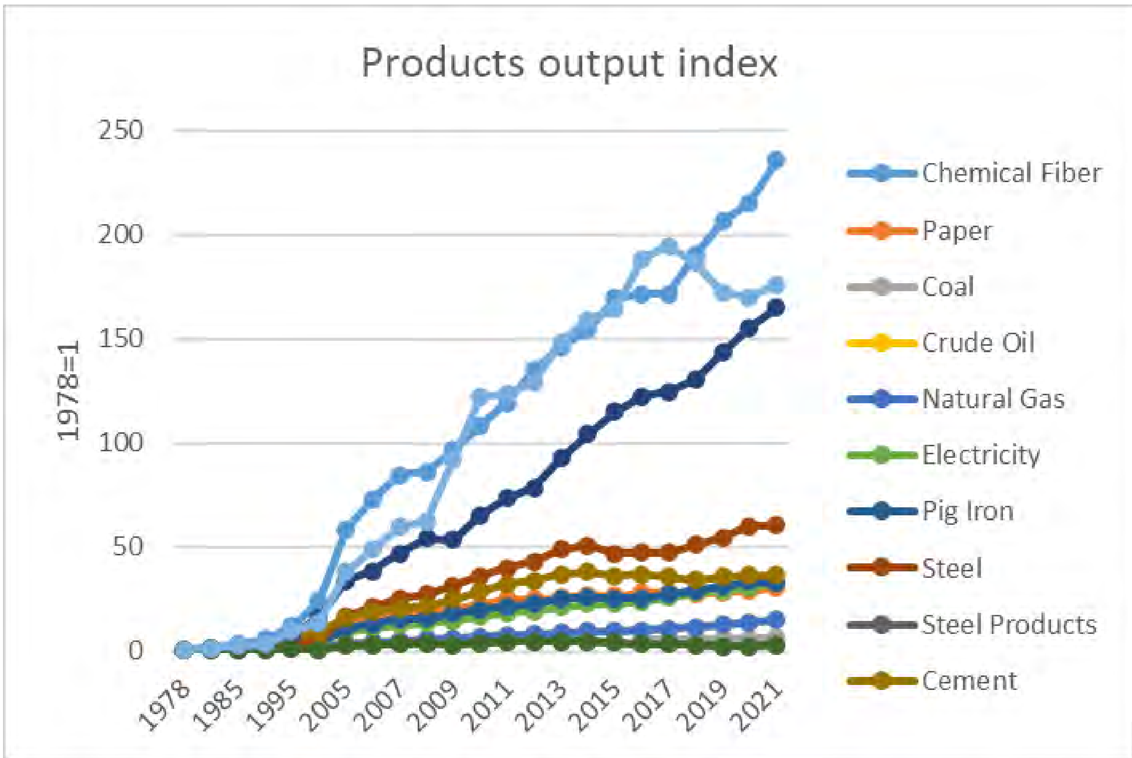
Note: Contributed by Ji Chen, Xinyue Lin, Xiaojiang Li, and Yi Qin with data from Word Bank and Global Carbon Project (2022) This measures CO_2 emissions from fossil fuels and industry. GDP per capita is expressed in international-$ at 2011 prices.

China's growth in the past decades has featured the growth of secondary sector and export of manufactured goods. In 2022, the industrial sector accounted about 33% of value added in China's economy including 27.7% from the manufacturing sector, with very rapid expansion of some emissions-intensive products, including steel, cement, glass, non-ferrous metals, ammonia, and ethylene etc, as shown in Figure 1.4. With the expansion of the industrial sector, China became the leading exporter of manufactured goods. In 2001, China's share in global merchandise trade and manufacture goods exports was 4.3% and 5.1%, which increased to 14.5% and 21% in 2022. As of 2022, 92.6% of China's goods exports are manufactured products.

A dynamic industrial sector, plus rapid urbanization, infrastructure construction, transportation, and other factors have made China the largest consumer of energy in the world. And its energy mix is still dominated by fossil fuels, notably coal (56.8% of primary energy demand in 2022), which is higher than world average. After 2013, China saw the decreased consumption of coal for three years, but then an uptick from 2017.

According to the *Third National Communication of China* to the UNFCCC, energy use (78.6%) and industrial process (12.3%) are the main sources of emissions, accounting for over 90% of the total GHGs.

Figure 1.5 Selected industrial product output index (1978=1)



Note: Contributed by Chenmin He based on the data from Chinese National Statistical Bureau.

The third challenge is that though China has progressed very fast in developing renewable energies in recent years, controlling fossil fuel especially coal while meeting the massive energy demand supporting the economic growth will require enormous investment and innovation to support the low carbon transition of its economic and energy system.

Financing and technologies are the two common challenges for developing countries in delivering on their climate goal including China. Advancing transition, mitigating the negative economic impacts, and ensuring the just process all need massive investment. A study conducted by Tsinghua University (2020) estimated that the cumulative investment demand for the transition of energy, industrial, construction and transportation sectors would be about RMB 175 trillion (roughly USD 25 trillion) from 2020-2050. Another study conducted by NDRC estimated the annual investment needs for 2030 carbon peaking purpose is about RMB 3.1-3.6 trillion, but the current gap might be as high as RMB 2.5 trillion annually.

On the other hand, China also needs to further boost the development and application of green technologies that are essential for decarbonisation, an area where developed countries have much greater advantages. China indeed leads in many green technologies such as solar PV, hydrogen, electronic vehicle, etc, but is still facing constraints in developing and deploying some key green technologies. For example, China's Ministry of Industry and Information Technology identifies several key low-carbon technologies in industrial sector that need further R&D, including energy storage, hydrogen energy, CCUS (carbon capture, use, and storage), etc.

In *China Vision 2035*, released in 2021, China outlined plans to bring overall output and per capita income to a "new stage". But it will also have to control fossil fuel energy and carbon intensive sectors, which currently take quite large share in its economy, to meet the 30-60 goals. China therefore needs to find the right balance of the dual goals of economic development and climate protection, the central theme of this volume.

C. China's policy strategies towards green low carbon development

Chinese efforts in highlighting environmental sustainability in its development strategies can be traced back to the 1980s and a subsequent scaling up in 1990s (CSIO, 1996). China participated in the Rio Conference and issued the country's 21st Century Agenda. But the economic growth targets outweighed environmental concern in 1990s and early 2000s as analysed in Chapter II.

Since 2015, when participating in the Paris Agreement and then later committing the 30-60 targets, China has adjusted economic policy strategies to achieve the dual goals of sustained economic growth and a green, low-carbon transition.

As a guiding principle, China's green low-carbon development strategy could be considered as an integral part of the conceptual High Quality Development framework, which aims to promote "innovative, coordinated, green, opening and shared" development. Specifically for the green low-carbon transition, China has formulated quite comprehensive policy framework that is mainly composed of "Top-level design" and sectoral level action points.

Such policy framework is broadly described as the "1+N" policy framework in China. The "1" refers to overarching policy document that sets the guiding principles for all policies towards China's peaking and neutrality targets. The "N" stands for a collection of complementary policy documents that aim to reduce carbon emissions and facilitate the transition to a green economy in various sectors. To mobilize the resources to safeguard the transition process, China has also recalibrated its macroeconomic policy framework, in part by building the green financing system.

1. Mainstreaming green low-carbon transition in national economic policy making through "Top-level design"

Following the pledge that is contained in both China's NDCs and President's speeches in the UN General Assembly, China issued two key documents: *Opinions of the Central Committee of the Communist Party of China and the State Council on Completely, Accurately, and Comprehensively Implementing the New Development Concept to Well Implement the Work of Carbon Peaking and Carbon Neutrality* (the *Opinion*) and *Action Plan for Peaking Carbon Emissions before 2030.* Together, they constitute the most important top-level assessments of Chinese policy.

The *Opinion* identifies 5 principles, 10 key targets, and 35 policy areas as the main direction for action; the *Opinion* does not contain any situation analysis or action-oriented policies. But as a top-level policy document, the *Opinion* demonstrates the clear political willingness of the Chinese central government in advancing a green, low-carbon transition to reach the 30-60 goals, which will help to mobilize public awareness and urge coordinated actions across the government system. Unlike many other large economies with federal political system, in which local governments have more autonomy, China's policy making is mostly a top-down process, so the *Opinion* is essential to bringing the green, low-carbon development concept into the mainstream.

In addition to the *Opinion*, China's State Council sent a notice to all Ministries and provincial governments requesting them to implement the *Action Plan (AP)*. The *AP* highlights the top 10 areas for action to reach peak – and then lower – carbon emission levels. It covers 43 tasks in energy transition, industrial development, urban and rural construction, and other areas. For example, the *AP* highlights important steps in several emission-intensive sectors such as steel, non-ferrous metals, construction materials, and petrochemical industries, as well as building a green manufacturing system. The *AP* also include the dimension of international cooperation and institutional and capacity development, including strengthening South-South Cooperation, improving the carbon emission statistical system and building a strict monitoring and evaluation system.

Compared with the *Opinion*, the *AP* focuses on the actions that can be undertaken for the 2030 target of peaking carbon emissions. Under this plan, prior to 2030, the priority is to improve energy conservation and efficiency so as to reduce the carbon intensity in this period, a step that may pave the way for controlling the total emission to net zero by 2060. But in July 2023, China went further with a policy entitled "dual control of carbon emissions." This policy uses both the total emissions and GDP carbon intensity as the binding indicator to assess the local government performance.

After the release of the *AP*, local governments across China have all put forward local action plans to reduce carbon emissions by 2030 in their respective jurisdictions. Various Ministries have also formulated multiple APs in various policy areas. For example, in July 2022, Ministry of Industry and Information Technology (MIIT), National Development and Reform Commission (NDRC), and Ministry of Ecology and Environment (MEE) jointly published the *Implementation Programme of Peaking Carbon Emissions in Industrial Sector* that proposed detailed tasks for 17 Ministries (or national level agencies) and all provincial governments.

2. Low-carbon transition strategies in 4 key action areas

Though green development is a cross-cutting issue that involves many dimensions, this volume focuses on exploring China's policies in promoting a low-carbon economy. China's actions target 4 key areas: energy, industry, urban and rural construction, and transportation.

Energy use is the single largest source of emission. China experienced soaring energy demand in the past three decades, but growth has slowed since 2013. For the periods of 1990-2000, 2000-2010 and 2010-2020, the average annual growth rate was 4.06%, 9.39% and 3.28% respectively. By 2020, China's energy mix was dominated by coal (56.8%), followed by oil (18.9%), natural gas (8.4%) and others (15.9%) including renewables and nuclear.

China's energy transition strategy involves three main approaches. From the demand side, the country is pursuing energy conservation and electrification. From supply side, the country has set a target to reduce the fossil fuel consumption and develop renewables. Finally, China is pursuing energy security with measures that include diversifying supply and building strong smart grid.

China has become a global leader – and largest investor – in renewable energies, which would help the country downsize its total emissions. Since 2015 China has been the world's largest consumer of modern renewable energy. In 2022, the newly installed renewable capacity reached 152 GW, about 52% of the world total (295 GW according to IRENA). Such trend will keep going in the next few years. IEA (2022) estimates that China is to invest almost half of new global renewable power capacity over 2022-2027.

Energy transition is also the main component for China's strategy in building a green, low-carbon **transportation system**. In this area, China is focusing on two areas: improving renewable energy use in transportation sector and electrification and building a more efficient and systemic transportation system.

In **industrial sector**, on top of *the Opinion* and *Action Plan*, China's Ministry of Industry and Information Technology (MIIT) has published *Green Development Plan in Industrial Sector during the 14th Five Year Plan*, which also highlight three aspects, namely adjusting industrial structure and layout, improving energy efficiency, developing circular economy and improving green manufacturing systems. Specifically, the *Plan* states that China will establish a roadmap to peak emission for the four highest emissions-intense industries: steel, petrochemicals, nonferrous metals, and building materials.

Unlike developed economies, where household contributes the largest emission in urban area, industrial processes are the main source of emission in China's cities. Therefore, in terms of green low carbon transition in **urban area**, China might see the decreasing emission from industry sectors, with the adjustment of industrial structure and slowing infrastructure development, but the increasing emission from household sectors like residential space heating, city transportation, and other facilities. Like industrial sector, China's State Council also issued a policy document on advancing green development in urban and rural construction, in which green buildings, strengthening systemic infrastructure, green construction, and green lifestyle have been identified as key measures to transform the structure of urban and rural development.

3. Macroeconomic policy framework and green financing system

Green, low-carbon development requires a thorough transformation of economic systems, including ways of both production and consumption. So, advancing this transformation calls for appropriate macroeconomic policies from government. Furthermore, the initial costs of implementing green, low-carbon transition practices and technologies can be high, and many countries face limited domestic financial resources. (UNCTAD, 2023b). Though China has relatively large fiscal space comparing to other economies (UNCTAD, 2023a), financing gap remains a big challenge.

Since 1978, China has successfully managed its structural transformation process through proactive macroeconomic management to maintain economic stability, mobilize financial resources, manage its capital account, and promote investment, trade and industrial upgrading (Feng, Li & Wu, 2019). This experience may, in the end, help equip the Chinese government to formulate the right macroeconomic policy framework for green development.

Against the backdrop of climate change and the 30-60 targets, China's macroeconomic policy may perform two key functions. Firstly, climate change and associated extreme weather or disaster may cause serious damages and shock to the economy. Macroeconomic policy should help to support economic stability from climate-related shocks and build more resilient economy. Secondly, macroeconomic economic policy should be able to mobilize resources and encourage investment to facilitate the transition.

China has adjusted its macroeconomic policy framework for the green, low-carbon transition with various tools in both fiscal and monetary policies (see, Chapter V).

China has also established a national level green financial system. At institutional level, China's green financial system includes established green finance standards and environmental information disclosure mechanism, through policies like *Green Bond Endorsed Projects Catalogue*, and *Environmental Equity Financing Instruments, Guidelines to Establish the Green Financial System, Guidelines on Environmental Information Disclosure for Financial Institutions* etc. In practice, China's green financing system includes pillars such as macroprudential policies, monetary policies, and green finance policies that covers bond, insurance, investment funds, and national emission trading markets.

Thanks to the advancement of green financing system, China is one of the largest green financing markets. By 2020, the balance of national green credit was RMB 11.95 trillion, and in a single year, 2020, RMB 258 billion has been issued by domestic entities. In terms of green funds, as of 2020, there were 80 green-themed public funds in China's capital market, with a total scale of RMB 169.4 billion.

This volume presents an analysis on several key pillars of China's policy strategies in advancing green, low-carbon development. Chapter II analyses the challenges of reaching 30-60 targets in cities and discuss how to transform city development and urban planning in China. Chapter III focuses on the energy transition, which is essential in addressing climate change. Both chapter II and chapter III also include some analysis on transportation sector. Chapter IV highlights China's policies in advancing green development of its industrial sector. Chapter V explains China's policies in building resilient agriculture through adaptation and mitigation practices. Chapter VI examines China's macroeconomic policy framework against the backdrop of the 30-60 targets. Chapter VII introduce China's green financing system and related policies and latest development.

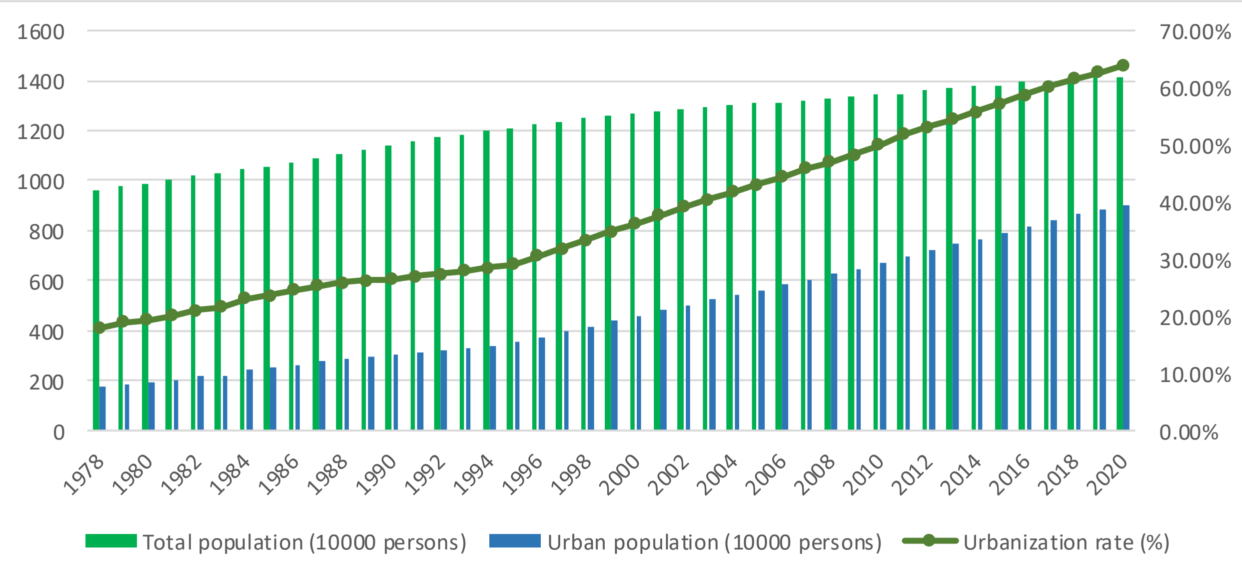
Chapter II. China's green and low-carbon urban development under the "30-60" targets

A. China's urbanization process and resource and environmental impacts

1. China's urbanization process

With the onset of reforms in China, in the late 1970s, a 40-year process of rapid urbanization was set in motion, with the urban population surging from 170 million in 1978 to 900 million in 2020, and the urbanization rate going up from 17.9% to 63.9%.[5]

Figure 2.1 Trends in China's total population, urban population, and urbanization rate



Source: China Statistical Yearbook, National Bureau of Statistics Notes: The charts drawn by the by research group.

From the mid-1990s to the mid-2010s China witnessed rapid progress in industrialization. This was driven by its fast economic growth and industrialization process resulting in fully-implemented urban reform with urbanization rate surging from 29.0% in 1995 to 57.3% in 2015. At the same time, a government assessment and evaluation system has been established, as well as a tax, fiscal and financial system. This encourages growth and municipal government competition, while leading the socio-economic advancement to follow a pattern of high energy consumption, high consumption, and high emissions. From mid to late 2010s, China's urbanization has slowed down, amid slowed population growth and other factors such as decreased working-age population.

[5] Source: *China Statistical Yearbook*. If not specifically indicated, all data in the article are from national and provincial statistical yearbooks, as well as studies and calculations by the research group.

2. Resource and environmental impacts of rapid urbanization

While the 40-year urbanization and rapid urban development boosted economic growth in China, it has placed significant and enormous demand pressure on resources and environment, as summarized below:

(a) Development of urban construction land

China experienced a seven-fold increase in urban built-up areas from 7,440 km^2 to 60,720 km^2 between the years 1981 and 2020. According to the 2019 National Land Survey, the total area of China's urban, rural, industrial and mining land was 353,000 km^2 - an increase of 104,300 km^2 compared with that in 2000. However, frequent imbalances also emerged in the utilization of construction land, especially in the industrial land and the high plot ratio of residential land.

(b) Industrial parks and industrial development

The past four decades saw a rapid increase of construction of tens of thousands of industrial parks at all levels. In 2018, 552 national-level development zones and 1,991 provincial-level development zones nationwide were established, in addition to an approved area in the zones of 18,200 km^2 representing 14% of China's urban industrial and mining land.[6] Similarly, more municipal (prefectural) development zones and industrial parks were dotted in rural industrial lands, causing high energy consumption and emissions in numerous farmlands. This resulted in bare-bone utilization and severe waste.

(c) Urban housing construction

Since 2000, China's average new residence in urban and rural areas each year has exceeded 180 million square meters, with approximately 110 million square meters of urban residence built annually. As of 2020, the per capita living area of urban households in China had reached 36.5 square meters.[7] The rapid increase of housing construction has improved the living quality of urban and rural residents. This has also resulted in increased development of construction land and consumption of building materials.

(d) Urban municipal infrastructure and transportation construction

Urban infrastructure and transportation construction are also key drivers of resource consumption and carbon emissions for building materials. In 2020, there was a marked increase in the urban water supply pipelines (reached 1,005,000 km, 4.0 times that of 2000); the natural gas pipelines (reached 849,300 km, 25.2 times that of 2000); and in the urban heating area (which reached 9,833 million m^2, 8.9 times that of 2000).[8]

B. The challenges of carbon emission reductions in China`s cities

1. High and rising total carbon emissions increasing energy consumption and carbon emissions

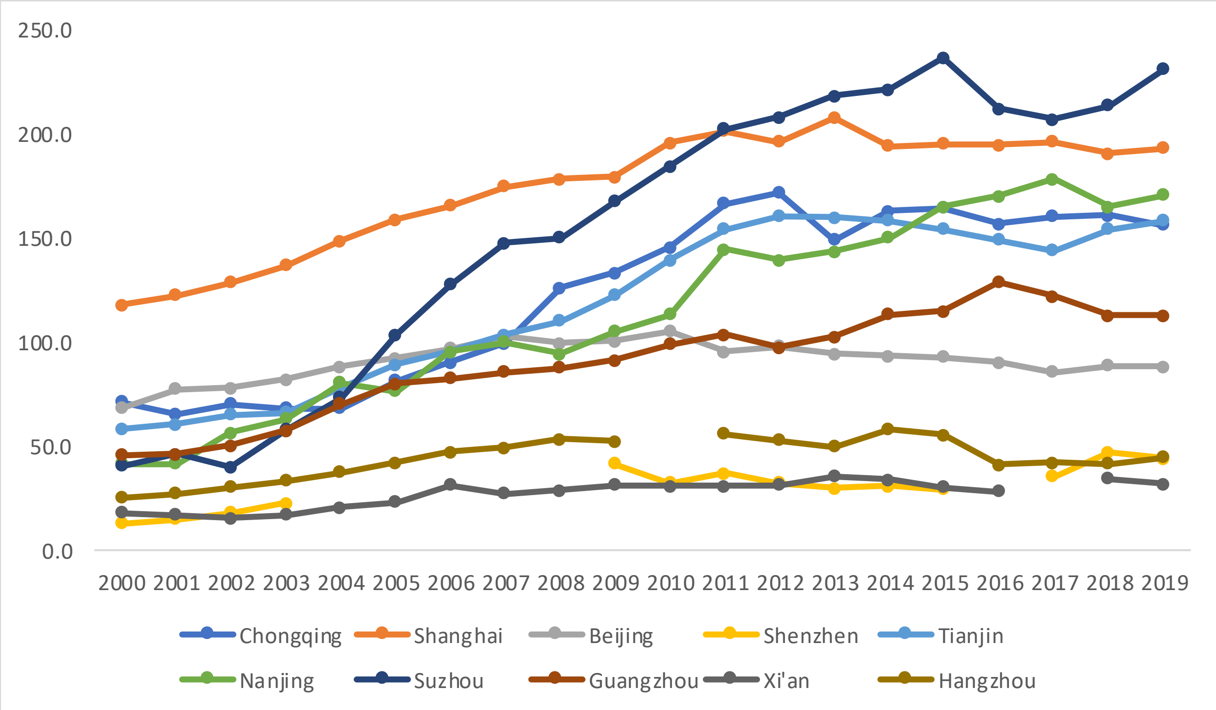
According to recent research (Liu,2023), China's total carbon emissions were approximately 11 GtCO2e in 2022, representing 28.87% of global carbon emissions,[9] with a per capita carbon emission of 7.8 tons.

For city area, As China's urban carbon emission statistics is not available, this chapter features ten cities[10] for analysis and is based on two different sources of monitoring data for urban carbon emission. From Figures 2.2, it can be noted that significant differences exist in carbon emissions, even among those more developed

[6] Source: *Review Announcement Catalogue of China Development Zones (2018 Edition)*
[7] Based on the 7th census
[8] Source: *2020 Statistical Yearbook of Urban-Rural Construction, and 2020 Statistical Yearbook of Urban Construction*
[9] Source: China Emission Accounts and Datasets (CEADs)
[10] Ten cities are Beijing, Shanghai, Tianjin, and Chongqing (four municipalities directly under the central government in China), and Shenzhen and Guangzhou in the Pearl River Delta region, as well as Nanjing, Hangzhou and Suzhou in the Yangtze River Delta region, together with Xi'an in the west. All these 10 cities are relatively economic prosperous ones.

places, which has a bearing on their economy and industrial structures. The emission growth has been slowing down since 2010 particularly after 2015.[11]

Figure 2.2 Carbon emissions diagram of 10 typical cities (million tons)



Note: Carbon Emission Accounts and Datasets. [12]

2. Urban living sector is difficult to achieve carbon emission peak by 2030

Recent research, the *2020 Emissions Gap Report* of the United Nations Environment Programme (UNEP),[13] confirms that the current household consumption of greenhouse gas emissions, accounts for about two-thirds of the global total emissions. This is based on the consumption-based accounting method of greenhouse gas emissions. China's urban carbon emissions, in contrast, are mainly from the industry and fixed assets investment (figure 2.3).

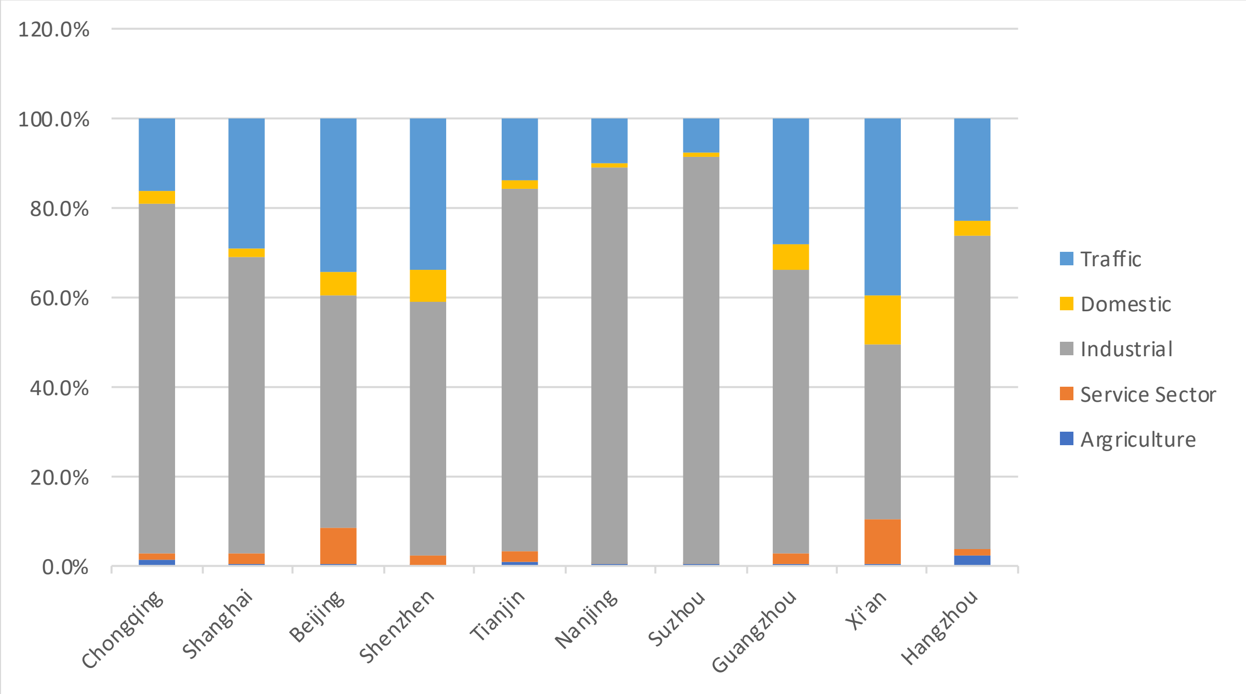
Based on the structure of carbon emissions in the ten cities, the industrial sector accounts for 40-90%, while those in urban life, transportation and service industries, account for a relatively smaller part. This is because the economy of most of China's major cities are manufacturing-oriented, with 30-50% share in the GDP. Whether the dual carbon strategy in cities can be delivered, therefore, depends on transformation of economic structure, energy mix and GDP energy intensity.

[11] Note: China's regional statistics are based on administrative divisions, so this is the scope of the "cities" in this paper, i.e., the administrative region of prefectural-level cities. However, unlike the United States and other countries, there are still a large number of non-urbanized areas in China, even within the prefectural-level city boundaries, and it is the municipal boundaries of prefectural cities that are really more comparable to the Metropolitan Statistical Area of the United States.

[12] "Carbon Emission List of 290 Chinese Cities" of China Emission Accounts and Datasets (CEADs). https://www.ceads.net.cn/data/city/

[13] UNEP, 2022. Emissions Gap Report 2022. https://www.unep.org/resources/emissions-gap-report-2022

Figure 2.3 Direct carbon emission composition of 10 cities based on CCG data

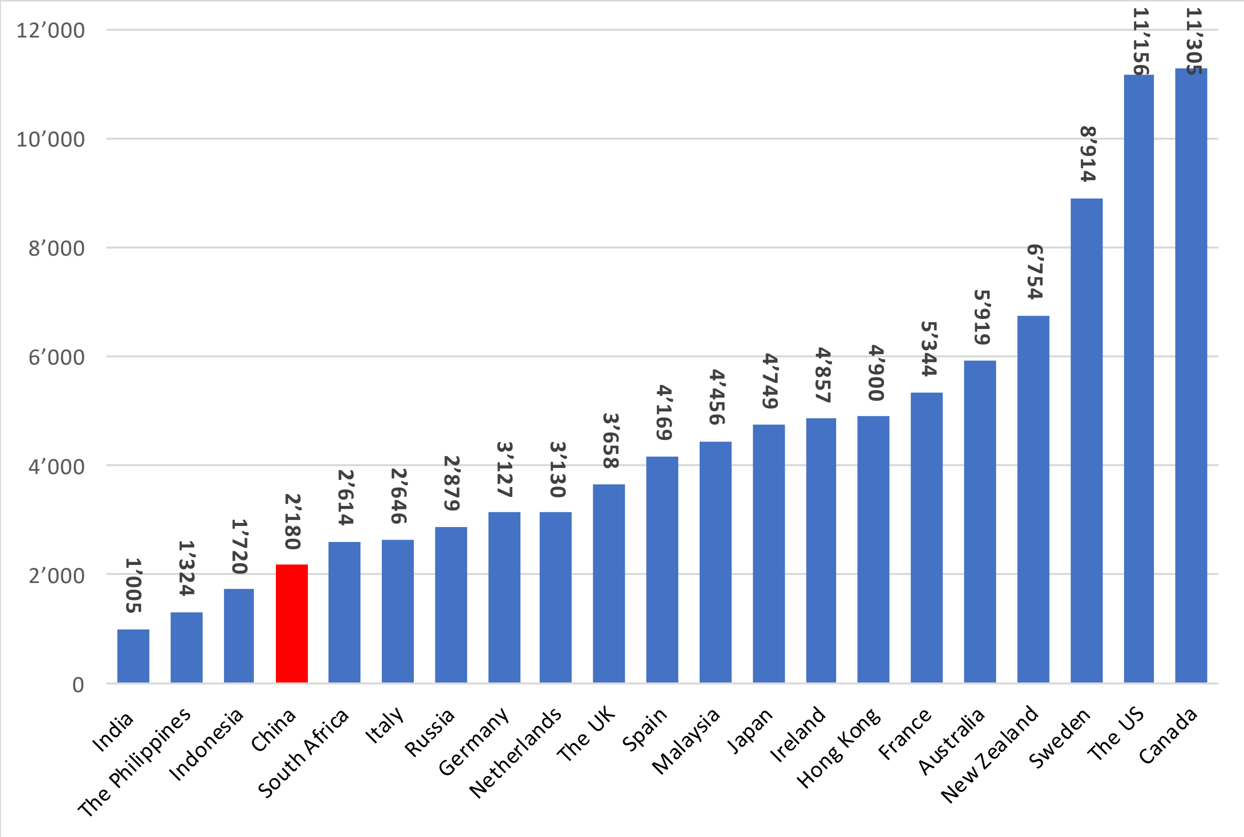


Source: Based on the "China City Carbon Dioxide Emissions Dataset" (2020) of the China City Greenhouse Gas Working Group.

Over the past twenty years, the per capita living energy consumption in these ten cities has increased by two to three times. However, compared to the developed countries (2,000-3,000kWh/person/year), the per capita living energy consumption in these ten cities, were only one-third to one-fourth of that of EU countries. According to International Energy Agency (IEA)[14], China's level of household energy consumption of urban and rural residents remains low. Hence, the demand for daily consumption will continue to increase sharply as their income and consumption capacity increase, which would present extra challenges for China's efforts to reduce carbon emissions.

[14] International Energy Agency, 2021. An energy sector roadmap to carbon neutrality in China. Available at: https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china?language=zh

Figure 2.4 Household electricity consumption in different countries (kWh/year)



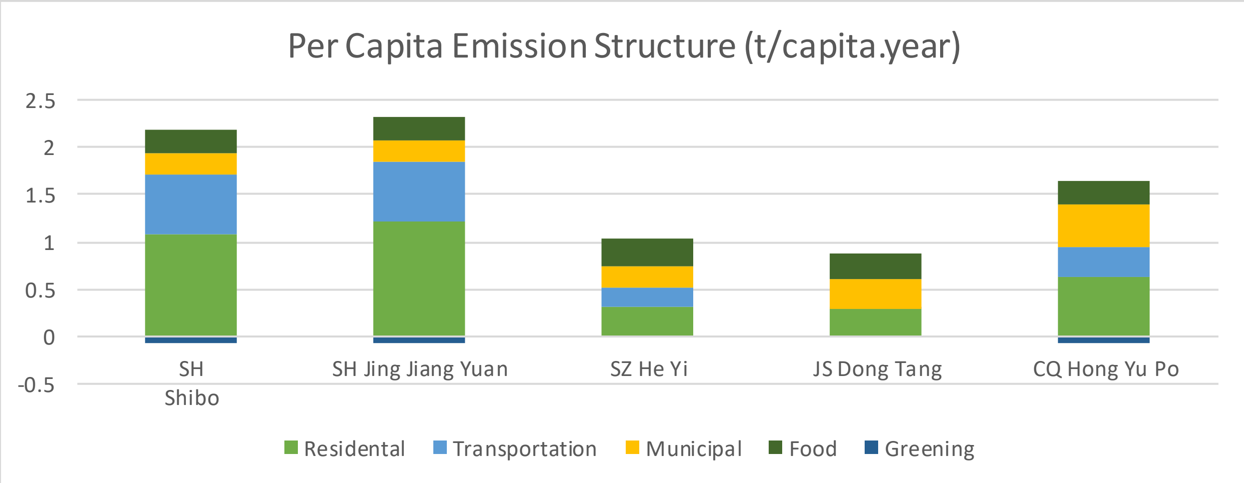
Source: Enerdata via World Energy Council[15]

A special policy study conducted between 2019 and 2020, on *Major Green Technology Innovation and Its Implementation Mechanism* of China Council for International Cooperation on Environment and Development (CCICED) assessed the carbon emissions in urban life and at community level for five types of communities in three mega-cities of Shanghai, Chongqing, and Shenzhen, as well as a smaller city of Jiangshan.[16] Initial first-hand data calculated residential energy consumption, transportation energy consumption, municipal energy consumption, and carbon footprint of daily life and diet in the five communities (Figure 2.5), which demonstrated a low carbon emission from China's urban living consumption which accounted for one-third to one-fourth of those in EU countries. Additionally, there was a significant difference in per capita carbon emissions among communities, which was related to differences in corresponding income levels, living conditions, family form, age structure and among other factors.

[15] https://shrinkthatfootprint.com/average-household-electricity-consumption

[16] Note: As an invited advisor to CCICED, the author led a two-phase special policy study (SPS) on green urban development in 2019 and 2020, which was jointly completed by the China Academy of Urban Planning and Design (CAUPD), the World Economic Forum (WEF), and the German Environment Agency (UBA). The SPS was released to the international community in September 2020 by CCICED, together with the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP), and some of its key policy recommendations were included in the CCICED's policy recommendations to the State Council of China.

Figure 2.5 Composition of per capita carbon emissions in five typical communities



Source: Special policy study Major Green Technology Innovation and Its Implementation Mechanism of CCICED.

Achieving the target of 30-60 in Chinese cities remains challenging, considering the intricate interplay between socio-economic development, energy consumption and carbon emissions. Additionally, the structure of energy consumption and carbon emission in Chinese cities, the standard of living and consumption patterns of urban residents and the projected increase in demand further complicates this task.

C. Vision for green and low-carbon urban development and the transformation of development approaches

The rapid economic growth in China has resulted in an expansionary urban development path that has put greater pressure on resources and environment. Cities in China need to promote the transformation of urban development through comprehensive policy measures in order to realize the 30-60 goal in urban areas.

The CCICED (2020) report proposed a vision for green urban development in China:

- promoting green production and lifestyle as mainstream values in society;
- building beautiful, green, prosperous cities;
- low-carbon and energy-saving, recycling-oriented, equitable and inclusive, safe and healthy.

To realize this vision, China needs to adopt more comprehensive policies and measures in the urban sector, to promote the transformation of urban development and overcome the lock-in effect of the traditional development model, through the promotion of green production and lifestyles, including conservation and reduction of the use of public resources and energy, recycling of production and construction methods, responsible consumption and use behavior, and harmless decomposition and recycling of waste.[17]

Overall, China has been promoting the transformation of urban development in three areas:

1. Legal and institutional development

Currently, China is initiating legislative work related to the low-carbon development strategy for urban and rural construction. At the same time, some cities are trying to develop local regulations for urban carbon reduction. Moreover, China is in the process of formulating and revising a standardized system for urban

[17] Li Xiaojiang, Dominic Waughray et al. 2021

green and low-carbon development. According to relevant studies[18] China has cumulatively formulated and revised more than 3,000 standards related to green development. For urban green development, a series of standards have been promulgated, such as the *Standard for Calculating Carbon Emissions from Buildings* and the *Evaluation Standard for Green Ecological Urban Areas.*

2. Green development-oriented planning system

In 2015, the central government put forward the general requirement of improving the spatial planning system - scientifically and rationally laying out and regulating production space, living space and ecological space. Subsequently, in 2018, the central government established a new spatial planning system for the national territory, which integrated urban-rural and land planning. This approach prioritizes natural resources management and urban development with stricter controls in place. This institutional reform is a significant step towards sustainable city development. This new territorial spatial planning emphasizes more integrated planning and control of the whole area and all elements including delineating rigid urban growth boundaries and farmland protection boundaries - which play an obvious role in curbing the blind expansion of cities, the disorderly growth of urban and rural construction land and the over-occupation of farmland.

In the new territorial spatial planning, the new concepts of green and low-carbon development, energy transition, ecological security, and the use of natural solutions to optimize spatial layout to cope with climate change and reduce carbon emissions have become the new content of urban planning. In addition, the new planning system requires environmental impact assessment of territorial spatial planning, to minimize the negative impact of planning on the environment.

3. Research, development, and promotion of green technologies

The development of applicable, efficient and low-cost green technologies and products in response to urban needs is necessary for the realization of the 30-60 goal. This will not only promote the growth of green and low-carbon industries but also contribute to economic revitalization, creating a mutually beneficial situation for both the 30-60 strategy and the economy.

D. Policies and strategies towards green and low-carbon urban development

To advance green low-carbon urban development, China has now formulated and made progress in the implementation of a series of specific policies and strategies.

1. More stringent control of resource and energy

(a) Strict control of the growth of construction land

In 2008, China introduced *strictest land conservation system* to effectively regulate the expansion of construction land. This, along with the *adherence to the strictest farmland protection system*, formed the two strictest land management systems, namely:

- *Outline of the 13th Five-year Plan for Land and Resources* in 2016, issued by the Ministry of Land and Resources of the People's Republic of China, proposing to protect the red line of 1.8 billion mu of arable land; and
- Implementation of the dual control policy over the total amount and intensity of construction land.

China has achieved a 40.85% reduction in construction land use area per unit GDP, resulting in ownership of 1.865 billion *mu* of arable land by 2020. The development method of incremental expansion has been phased out, with the increasingly stringent land resource management policies, which have pressed urban governments to pay more attention to utilization of untreated wastes and organic renewal.

[18] State Council Information Office, 2023. China's Green Development in the New Era. Available at: https://www.gov.cn/zhengce/2023-01/19/content_5737923.htm

(b) Shifting from dual control of energy consumption to dual control of carbon emissions

China's goals of controlling the total amount of primary energy consumption and cutting energy consumption per unit GDP are proposed for the first time in the 11th Five-year Plan (FYP) of 2006. In 2011, the reduction rate of carbon dioxide emissions per unit GDP was included as a binding indicator in the *Outline of the 12th Five-year Plan*, and carbon emission control goals were classified and determined for assessment.

During the National Conference on Ecological Environmental Protection in July 2023, a central policy was introduced to progressively transition the binding indicator of *dual control of energy consumption* to *dual control of carbon emissions.* This entails incorporating both the overall carbon emissions and carbon emissions per unit of GDP, into the binding indicator utilized for evaluating assess local governments.

2. Promoting the utilization of the existing stock of buildings and spaces with organic renewal

At the urban level, the demarcation of urban growth boundaries presses urban development to shift from incremental expansion to utilization of untreated wastes and organic renewal. *Beijing Urban Master Plan,* for instance, requires the reduction in construction land as well as population density in the downtown area. In Shenzhen, however, secondary development of industrial land has been made according to the needs of industrial transformation, and high-rise-building-based industry has been employed to improve the utilization rate of industrial land.[19] The city of Shanghai, on the other hand, formulated its local legislation to 'never widen' 64 roads in the old urban area, with a proposed requirement that buildings of over 50 years cannot, in principle, be demolished.[20]

At the neighbourhood level, in line with national policies, the urban renovation featuring large-scale demolition and reconstruction has been stopped, with the requirement that building demolition in renewal areas should not exceed 30 per cent. In the heart of the historic district of Beijing, expropriation and demolition activities have been completely halted. Instead, an organic renewal approach has been adopted, encouraging voluntary participation from residents. This method aims to enhance the living standards of the indigenous population, foster social symbiosis and integration, and invigorate the vitality of the esteemed city's heritage.

Many large and medium-sized cities, however, have also seen difficulties in providing substantial financial support for extensive large-scale organic renewal. Consequently, there is a lack of institutional and policy support for the comprehensive implementation of urban utilization of untreated wastes and organic renewal. Additionally, it is crucial to undertake reforms and innovations in the tax, fiscal and financial systems.

3. Green building and building energy efficiency retrofits

(a)Promotion of green buildings

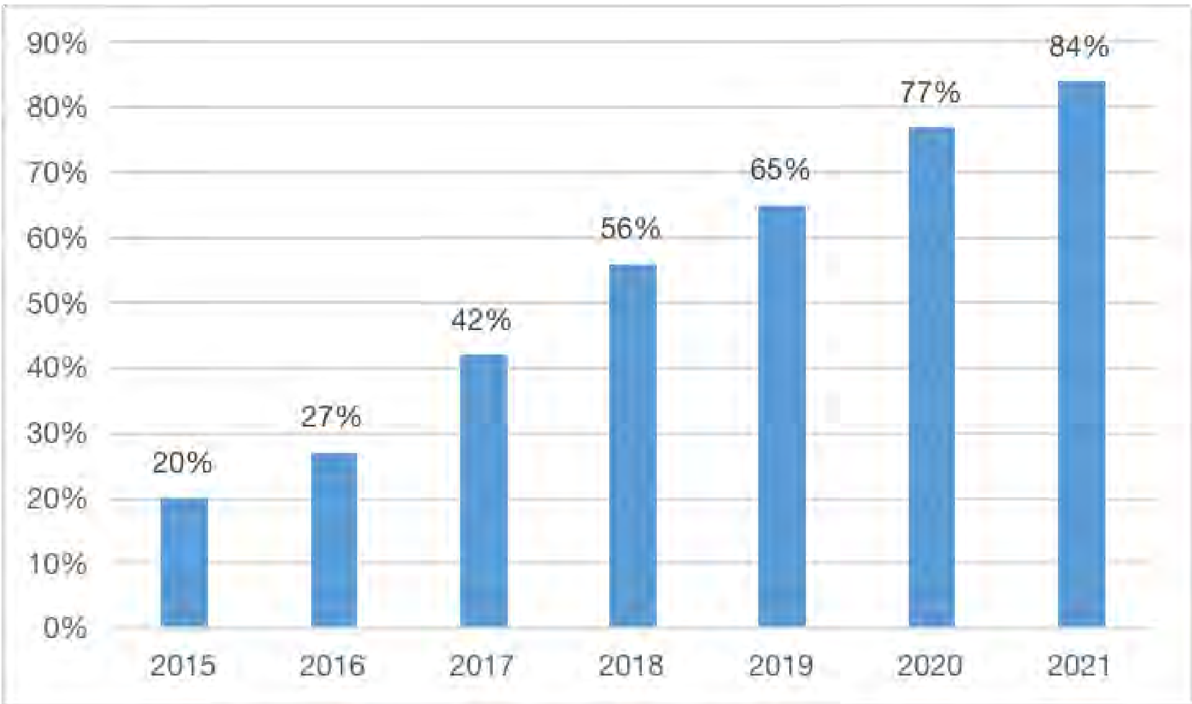
The utilization of energy and the consequent discharge of carbon are pivotal determinants in the domain of urban energy consumption and carbon emissions. China has witnessed green building and building energy efficiency in the construction industry since the 2000s. The first national standard assessment standard for green building was issued in 2006, with the inception of *100 Green Building Demonstration Projects* and *100 Low Energy Building Demonstration Projects* in 2007. Subsequently, in 2008, *Regulation on Energy Conservation in Civil Buildings* was promulgated. These documents and demonstrations served as the impetus for the initial implementation of green building and building energy conservation programmes. In 2016, the Central government proposed the national building policy of *affordability, cost-effectiveness, green and aesthetics*, followed by the national *Standard for Building Carbon Emission Calculation (BB-T51366-2019),* issued in 2019. According to *Implementation Plan for Carbon Peaking in Urban-rural Construction* issued in 2022, green building standard shall be implemented for all new urban buildings by 2025, and star-rated green buildings shall account for 30% of all buildings.

[19] *Shenzhen Pilot Reform Program for Quality Industrial Space Supply*《深圳市优质产业空间供给试点改革方案》, 2021; *Implementation Program for Approval of Shenzhen "Industry to Buildings" Projects*《深圳市"工业上楼"项目审批实施方案》, 2023

[20] *Several Opinions on the Planning and Management of Roads (Streets and Alleys) for Landscape Protection in the City of Shanghai*《关于本市风貌保护道路（街巷）规划管理的若干意见》, 2007

The government has actively advocated for green buildings, resulting in substantial increase from 4 million m2 in 2012 to 2 billion m2 in 2021.[21] The proportion of new green buildings nationwide has consequently exceeded 90%. Overall, however, the proportion of top star-rated green buildings was not very high.

Figure 2.6 Proportion of green building area in China's new urban buildings in those years



Source: The white paper China's green development in the new era.[22]

(b) Accelerating energy-efficiency in buildings

Most buildings completed in China prior to the year 2000 have poor insulation performance, demonstrated in the energy consumption through windows, consuming 2-3 times more energy and the exterior walls and roofs consuming 3-5 times more energy than those in developed countries. During the winter season, the heating energy consumption in the northern part of the country accounts for 36% of the total building energy consumption nationwide. The average heating energy consumption per unit area is equivalent to 20kg/m^2 of standard coal, which is 2-4 times that of Europe under the same latitude conditions.[23]

China commenced pilot project for building heating metering since the 1980s, aimed at reducing energy consumption through metering and charging methods. In the 2000s, Beijing, Shenzhen and other first-tier cities began to have energy consumption metering and monitoring platforms in government buildings and large public buildings for less heating and air-conditioning (AC) energy consumption.

Additionally, since the 2010s, big cities in the north represented by the capital city, have begun energy-saving renovation of existing buildings. The refurbishment of external walls and roofs, coupled with the insulation of doors and windows, has significantly reduced the consumption of heating and AC energy, as well as carbon emissions. This has resulted in improved user experience and a reduction in living expenses for the residents.

[21] CCTV, *China's new building "greening" has exceeded 90 percent*, https://www.gov.cn/xinwen/2022-07/10/content_5700331.htm

[22] The white paper China's green development in the new era by the State Council Information Office of the People's Republic of China, Jan. 2023.

[23] Zhang Tengfei, 2023: Analysis of the energy-saving transformation situation of China's existing residential buildings [J]. *Sichuan Building Materials*, 1-3.

Based on calculations, China's recently constructed and refurbished buildings have the potential to significantly reduce energy consumption by nearly 300 million tons of standard coal, reduce carbon dioxide emissions by 740 million tons as of the end of 2019, thus slowing down the growth rate of total building energy consumption.[24]

4. Green construction and green building materials

(a) Promotion of prefabricated buildings

The carbon emissions from building materials and construction processes account for about 30% of the total carbon footprint throughout the entire lifecycle of buildings. In China, most buildings and municipal facilities are constructed on-site, exacerbating the issue of energy consumption and carbon emissions.

In 2015, the country initiated the promotion of prefabricated buildings and in 2017, the *Action Plan of Prefabricated Buildings for the 13th Five-year Plan Period* was released. Subsequently, a catalogue of experience promotion for prefabricated buildings was issued in 2022 emphasizing factory-based production and prefabricated construction of building components. According to *Implementation Plan for Carbon Peaking in Urban-rural Construction,* prefabricated buildings shall account for 40% of the floor area of new buildings that year by 2025. By 2021, the floor area of new prefabricated buildings nationwide had reached nearly 740 million m^2, an increase of 18% compared with the previous year.[25]

Some municipal governments have subsidized the incremental costs of prefabricated buildings and incorporated these costs into government investment budgets and other incentives. The efficacy of energy-saving and carbon reduction in the current prefabricated buildings continues to be a subject of controversy within the business and academic communities. Furthermore, the effectiveness of factory-based production and prefabricated construction still require further evaluation and practical verification.

(b) Advancements in the development of green building materials

The building material scene has consistently served as a focal point of energy consumption and carbon emissions, resulting in a cumulative carbon emission of 1.65 billion tons nationwide in 2020. Given that carbon emissions from cement production account for about 70% within the building material industry, the *Implementation Plan for Carbon Peaking in the Building Material Industry* mandates the reduction of energy consumption and carbon emission intensity in key products such as cement, glass and ceramics.

As China undergoes substantial transformations in its economic structure, there will be a continued reduction in the scale of construction for transportation and municipal infrastructure. Consequently, the demand for cement will also experience a substantial decline. Related studies[26] confirm that the reduction in cement production will account for 69% of the carbon abatement within the cement industry.

The primary technological paths to achieving carbon neutrality in the cement industry encompass the utilization of low-carbon cement to reduce carbon emissions, enhancing energy efficiency to minimize carbon output, adopting alternative energy sources to mitigate carbon emissions, implementing carbon sequestration techniques to reduce carbon footprint and various other methods.

According to a technical roadmap for carbon reduction in the cement industry published by a professional organization[27] the primary measures to be implemented prior to 2030 include enhancing energy efficiency and discontinuing inefficient production capacity. Additionally, complete utilization of alternative fuels is targeted to be achieved by 2040. Since the majority of current cement kilns are expected to reach the end of their operational lifespan by approximately 2050, the potential for fuel substitution through the utilization of electricity and hydrogen energy is anticipated.

[24] *People's Daily, improving energy efficiency of buildings, promoting low carbon development,* https://www.gov.cn/xinwen/2022-01/11/content_5667577.htm

[25] *A list of experience promotion for prefabricated buildings (Batch 1)*

[26] China Building Materials Academy, *Pilot Demonstration Study on Carbon Neutralization Path and Collaborative Disposal in China's Cement Industry*

[27] Ibid

5. Green transportation and electric vehicles

(a) Low-carbon passenger transportation structure in urban areas

China's urban built-up areas have a population density of over 10,000 people/km2, facilitating public transportation and cycling. Rail transit in big cities has thrived in the past decade, with electric bicycles replacing the more traditional versions. This has largely suppressed the trend of excessive reliance on cars for motorization and overall maintained, a transportation structure of more green transportation and relatively low-carbon development. The table 2.1 below provides a summary of the mode of travel structures in the main cities.

Table 2.1 List of the full-mode travel structures in key cities

City	Year	Travel Structures (%)							
		Walk	**Bicycle**	**Electric bicycle**	**Bus**	**Rail transit**	**Car**	**Other**	**Total**
Beijing	2020	31.2	15.5		11.7	14.7	24.3	2.6	100
	2017	29	11.9		15.9	15.4	24	3.9	100
Shanghai	2021	24.2	17.3		9.2	21.4	22.4	5.5	100
	2015	24.6	15.9		14.8	18	19.7	7	100
Changsha	2018	34.1	2.6	8.9	18.8	4.6	25.7	5.3	100
	2009	35.8	3.2	15.7	23	0	11.2	11.1	100
Shijiazhuang	2020	25	16.5	23	5.4	2.6	23.5	4	100
	1986	33.9	57.8	0	5.1	0	0	3.2	100
Wuhan	2020	42.2	4.1	13.6	12.1	6.6	19.1	2.3	100
Hangzhou	2019	23.1	5.2	22.7	12.8	4.8	26.8	4.6	100
Xiamen	2020	26.9	2.2	19	12	3.7	22	14.3	100
Taiyuan	2022	26	11.9	21.5	9.7	1.3	18.5	11.1	100

Source: Annual reports of urban transportation development for Beijing, Shanghai, and Wuhan; Collected project data for other cities.

(b) Making great efforts to develop urban rail transportation and public buses

Giving Priority to public transportation, promoting the comprehensive development of transit metropolises, and actively fostering green travel, are crucial measures for China's transportation system to effectively implement the 30-60 strategy.

In 2021, China witnessed the operation of 709,400 buses, transportation of 48.9 billion passengers via buses and electric buses throughout the year, 290 urban rail lines with 23.7 billion passengers all the year round.[28] Since 1997, when Beijing witnessed its inaugural bus lane, more than 1,300 bus lanes had been opened in 230 cities nationwide by 2004. During the past decade, most gasoline-powered buses in cities have gone electric, thereby reducing the carbon emissions associated with public transportation and contributing to a greener development.

The urban rail transit costs as high as 500-1,000 million yuan/km, while the financial subsidy for daily operations reaches up to 10-30 million yuan/km annually. This has resulted in an augmented financial burden on local governments. To this end, the Central government has made numerous interventions over the construction of rail transit and has issued regulatory policies since the 1990s. This is particularly evident in

[28] Source: National Bureau of Statistics

densely populated cities in China, while rail transit has proven to be highly advantageous in addressing urban transportation requirements.

(c) Promotion of the use of bicycles and e-bikes

In the past decade, China has borne witness to how bicycles were replaced by electric ones. A comprehensive examination of literature reveals that the present utilization of manual and electric two-wheeled vehicles in China has the potential to reduce carbon emissions by 10,000 tons. This translates to a conservation of approximately 6.6 million litres of gasoline.[29]

China has acquired a substantial quantity of over 300 million electric bicycles,[30] which function as a prevalent mode of transportation for not only the vast Chinese population, but also extend beyond its borders. Given their competitive nature, as environmentally friendly means of transportation, electric bicycles should be regarded as the most important carriers in both urban and rural areas of China, particularly as the primary energy sources have transitioned towards sustainable alternatives.

(d) Bicycle and electric bike sharing for the last mile users

By the end of 2020, bike-sharing was in operation in more than 360 cities in China, with a total of 19.45 million vehicles deployed and an average daily order volume exceeding 45.7 million units.[31]

China's bicycle sharing system constitutes paid rental of incremental supply, rather than shared use of existing resources. It has facilitated short-distance travel and feeder services and is a preferred option for residents to travel the last mile. Defining shared bicycles as environmentally friendly and low carbon is, however, challenging due to the substantial resource investment and low utilization.[32]

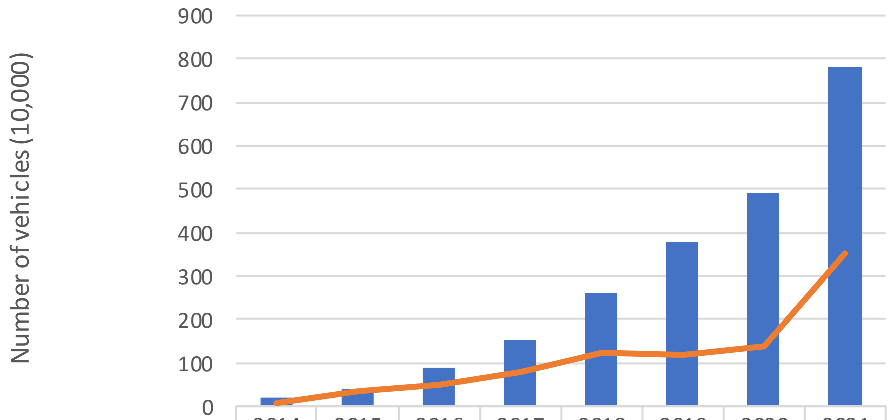
China`s possession of over 8 million shared electric bicycles, effectively reduces carbon emissions by 1.64 million tons annually.[33] Case studies have shown that each shared electric bike can effectively substitute 3-4 private motor vehicles, while remaining economically viable for operators and financially accessible to users.

(e) Development of electric vehicles

Electric vehicles, especially electric cars, have long been a pivotal industry receiving substantial support from the government. By 2021, the ownership of new energy vehicles (NEVs), dominated by electric cars, had surged to 7.8 million, accounting for about 50% of the global aggregate. Moreover, China is home to 508,900 new energy buses, accounting for 71.7% of the total number of buses, along with 2,078,000 new energy taxis.[34] As buses and taxis are frequently and extensively used electric buses play a significant role in mitigating carbon emissions.

[29] China Bicycle Association, *2022 research report on the green travel index of two-wheel bicycles*
[30] Qianzhan Industry Research Institute, 2020. Research on the development status and investment prospects of China's electric bicycle industry.
[31]Department of Transportation October 22, 2022 Press Conference, http://news.china.com.cn/txt/2020-10/22/content_76833411.htm
[32] 1-1.5 times/day on average, Source: traffic survey data from the Transportation Branch of CAUPD
[33] Aurora Industry Research Institute and Xi'an Jiaotong University, *Low Carbon Travel Makes Life Better-Social Value Report of Shared Motorcycle*
[34] The white paper *China's green development in the new era* by the State Council Information Office of the People's Republic of China, Jan. 2023.

Figure 2.7 Sales and ownership of China's new energy vehicles, 2014-2021



	2014	2015	2016	2017	2018	2019	2020	2021
NEV ownership	22	42	91.3	153.4	260.8	380.2	492	784
NEV sales	7.5	33.1	50.7	77.7	125.6	120.6	136.7	352.1

Source: The white paper China's green development in the new era.

Electric vehicles are privileged to receive municipal government support for total volume control, traffic restrictions and other urban transportation policies. However, controversies exist regarding their full lifecycle carbon reduction effect, the legitimacy of fiscal subsidies and financial support, and lax regulations. Some industry experts have raised concerns regarding China's stagnant NEV technology, excessive NEV production capacity, and the potential loss of competitiveness due to the withdrawal of supportive policies.

6. Green municipal infrastructure and solid waste management

(a) Promotion of water environment governance in urban areas

Over the last decade, China has focused on mitigating urban water pollution by treating black and odorous water, resulting in significant reduction of greenhouse gas emissions from untreated sewage. Such treatment encompasses a range of comprehensive measures, including sewage collection, river closure, construction of sewage treatment plants, reduction of wastewater volume and organic matter content and utilization of wetlands and ground ecosystems for purification, among other strategies. Moreover, the Central government provides annual financial subsidies of over 1 billion yuan to treat black and odorous water bodies, motivating urban management.

China`s issuance of the *Three-year Action Plan for Improving the Quality and Efficiency of Urban Sewage Treatment* in 2019 resulted in a 10% increase in centralized collection rate of domestic sewage in urban areas by 2022, as compared to 2018. In 2022, the country introduced the *Implementation Plan for Harmless Treatment and Resource-oriented Utilization of Sludge*, mandating all cities to establish a sludge treatment system that is both harmless and resource-oriented by 2025. So far, China has achieved a sludge treatment rate exceeding 90% with a focus on resource-oriented utilization, resulting in a harmless outcome.

(b) The development of sponge city

In 2015 China experienced a significant surge in the construction of sponge cities. These cities, functioning as an ecological concept and green infrastructure, serve to safeguard water resources, restore ecosystem, replenish over-exploited groundwater, and alleviate the burden of drainage and flood prevention works.

The Central government has allocated approximately 100 billion yuan in financial resources to construct sponge cities. This initiative commenced in 2015 and involved conducting pilot demonstrations in 100 cities across the country. Additionally, the government-imposed regulations on rainwater runoff control in these pilot cities. These efforts can better leverage the synergistic effects of water safety, ecology and environment in the construction of sponge cities.

(c) Garbage classification and resource-oriented utilization

Since 2015, the Central government has prioritized garbage disposal by advocating garbage classification. Pilot demonstrations of domestic waste classification have been conducted in 46 cities, resulting in the establishment of a comprehensive system for classification, collection, transportation, and treatment. Pilot demonstrations of domestic waste classification have been conducted in 46 cities, resulting in the establishment of a comprehensive system for classification, collection, transportation, and treatment.

Furthermore, the Central government calls for improvement of waste treatment capacity in urban areas. From 2016 to 2020, the domestic waste treatment capacity in urban China increased by 510,000 tons, while the harmless treatment rate of domestic waste reached 99.2%. Consequently, the waste treatment structure should be optimized by replacing the landfill treatment of an emission rate of about three times higher with domestic waste incineration plants of low carbon emissions to achieve 45% higher waste inci neration rate.[35]

It is also imperative to address the issue of untreated waste and substandard treatment facilities. Renovation is necessary, along with the implementation of classified garbage treatment and anaerobic digestion of kitchen waste, to produce biomass energy and reduce greenhouse gas emissions.

China aims to establish a management and utilization system for urban construction waste to address the significant amount generated by its rapid urban development and demolition-construction model. The country targets a resource-oriented utilization of 250 million tons/year by 2025 for less carbon emissions.

[35] Source: *Development Plan for Domestic Waste Classification and Treatment Facilities in Urban Areas during the 14th Five-year Plan Period*

Chapter III. Energy transition in China: policy perspectives

Energy transition plays a key role in China's climate agenda, particularly in its strategy for achieving carbon neutrality, to build an ecologically sustainable society in China. Prior to establishing the 30-60 targets, China released the *Energy Revolution Strategy*, created to promote energy conservation and renewable energy development. After committing the 30-60 targets, China conceived a comprehensive policy framework to promote the energy transition. This chapter aims to take stock of the energy transition so far in China, explore the energy policy in the country, and analyze the policy directions.

A. China's energy trend and CO2 emission from 1990 to 2021

1. Energy consumption trend

In 1990, the total primary energy consumption in China was 691 million tonnes of oil equivalent (mtoe), and 1029mtoe in 2000, 2525mtoe in 2010, and 3486mtoe in 2020 (see Figure 1). The most rapid increase occurred in the period from 2000 to 2010, with the annual growth rate of 9.39%. Growth was 4.06% annually from 1990 to 2000 and 3.28% from 2010 to 2020.

The driving force for this rapid increase in primary energy consumption from 1995 to 2014 was the rapid increase in the production of energy-intensive products, including steel, cement, glass, aluminum, copper, zinc and lead, ammonia, ethylene, and other products. Figure 3.2 presents the energy use by sectors from 1995 to 2014. Energy intensive products sectors account for 69.6% of increased energy use from 1995 to 2014, including mining sectors energy demand. And they also account for around 70% of newly increase electricity demand in the same period (NSB, 2017).

From figure 3.1, we can see that the energy mix experiences few significant changes before 2010. Policy support for renewable energy from 2010, the development of renewable energy such as solar PV and wind, started to effect some change, especially after 2020 when all newly installed solar PV and wind power plants had lower cost than existing coal fired power plants.

In 1990, the energy mix is coal 76.2%, oil 16.6%, natural gas 2.1%, and others (including renewable energy and nuclear) 5.1%. By 2020, the contribution of the "other" category[36] had tripled, but coal still dominated energy use, being the largest resource at relatively low cost. Coal consumption in the energy mix has plateaued since 2013 when the Action Plan on Air Quality Control was released, as controlling coal use is one of the top measures to improve air quality (SC, 2013). After that, there were several strong policies to control coal use in China, including Energy Revolution Strategy announced in 2014.

A move towards wind and solar power (NSB, 2022) also helped drive change. With the policy support and technology progress, China's solar PV and wind power development leads the world today. Figure 3 presents the installed capacity and power generation from renewable energy (NEA, 2022). After 2013 both wind and solar started to be developed in rapid way, especially solar PV from 2016. After 2016, annual newly increased capacity for solar and wind power accounts for nearly 40%newly installed capacity worldwide and made China a global leader in developing solar and wind power (see Table 1). By 2021, power generation from solar and wind accounted for 12.1% of total power generation, while it was 3.9% in 2015, and 1.2% in 2010, with capacity of 49.5TWh in 2010, 233.8TWh in 2015, and 981.5TWh in 2021.

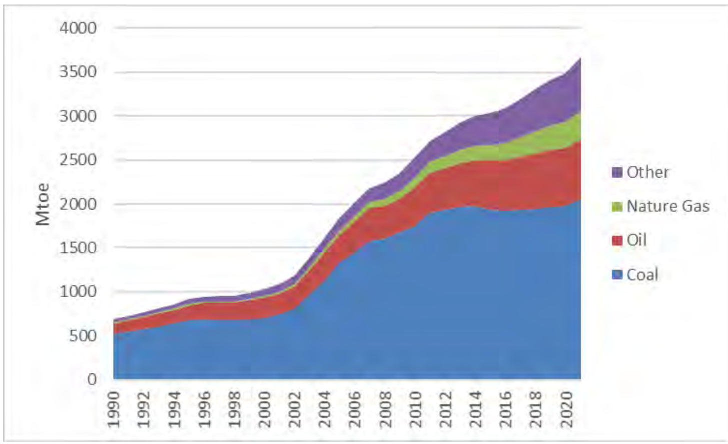
After 2018, China's newly installed capacity of solar PV accounted for more than 40% of globally installed capacity and reached 392GW. Wind power generated 370GW (NEA, 2023), or 37% of global capacity. In 2023, there has been an additional spike in solar installation; by August 2023, new capacity exceeded 100GW.

The use of nuclear power continues to rise. China has deployed third- and fourth-generation nuclear power technologies and has emphasized security to assuage potential public concerns. Installed capacity of nuclear

[36] Other energy includes renewable energy, and nuclear energy.

in 2010 reached 10.82GW, 27.17GW in 2015, and 53.26GW in 2021. After 2018, new construction brought 6 units online annually, and then reached 10 units in 2022 with a total capacity of 12GW.

Figure 3.1 Primary energy demand in China from 1990 to 2021



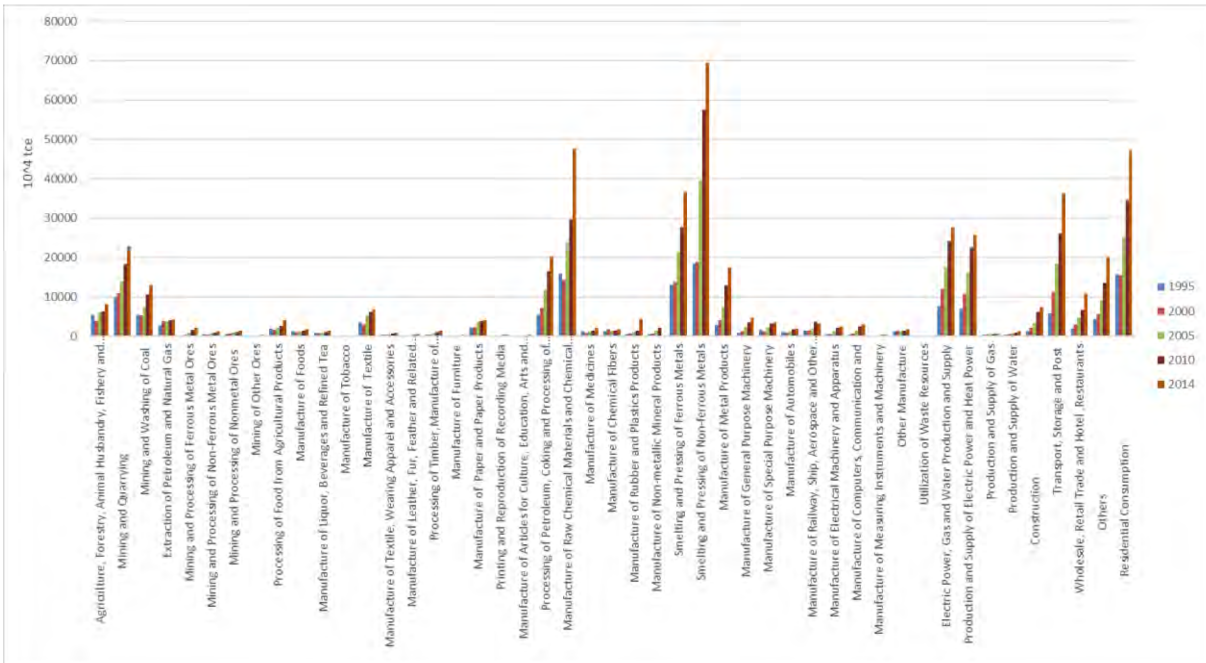
Source: NSB 2022.

Table 3.1 Newly installed capacity of solar PV and wind power in China and the world, GW

	Solar PV		Wind	
	China	world	China	world
2018	44.3	104	20.6	51
2019	30.1	110	25.7	61
2020	48.2	139	52	93
2021	53	175	55.9	102
2022	87.4	230	37.6	77.6

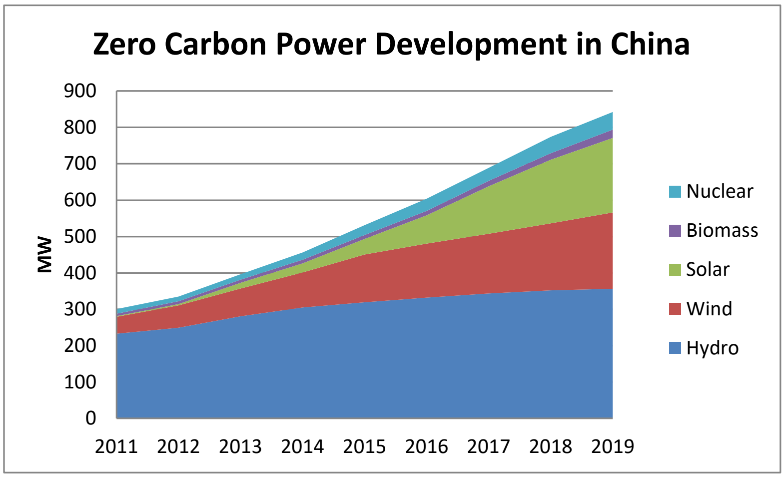
Source: REN21.

Figure 3.2 Energy use by sectors, 1995-2014



Source: NSB, 2017.

Figure 3.3 Installed capacity of renewable energy

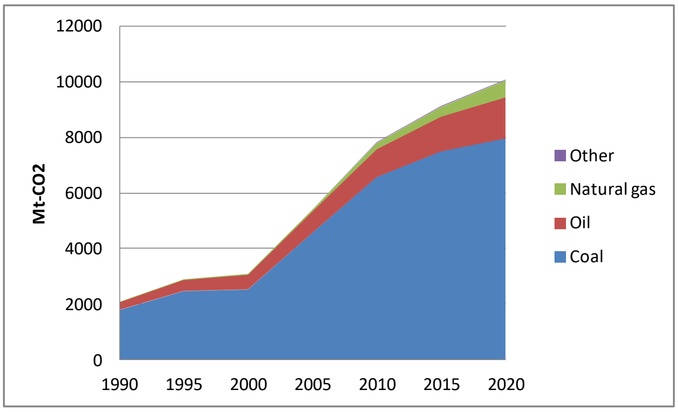


Source: NEA, 2022.

2. CO2 emission

Figure 3.4 presents the CO2 emission in China. China's CO2 emissions have increased rapidly since 2000, concurrent with fast growth of economy. After 2013, the rapid growth trend of CO2 emissions slowed as China imposed strict controls on air pollution. China's carbon intensity has decreased rapidly to 48.4%, beyond than China's commitment in the Copenhagen agreement. After China's announcement of its 30-60 targets, China's carbon intensity continued to decrease, by 4.6% from 2020 to 2022, even though China's economy development faced big challenge during the COVID19 period.

Figure 3.4 CO_2 emission in China and carbon intensity, 1990-2020



Source: IEA, 2022.

B. Energy transition for the 30-60 targets

1. Overview

China's energy usage accounts for around 85% of total CO2 emission, therefore the transition pathway of energy in China is crucial for the 30-60 targets implementation.

According to some available domestic studies (Zhang et al, 2022; Qin et al, 2021; Wang et al, 2022; Jiang et al, 2018;), meeting the carbon neutrality target before 2060 will require a significant increase of renewable energy as part of the country's primary energy consumption. Most the studies show the share of non-fossil fuel energy could account for more than 75% in total primary energy demand in China by 2050. And renewable energy dominates this category of energy in the transition, with the share between 43 and 81% by 2050, depending on a study's assumptions.

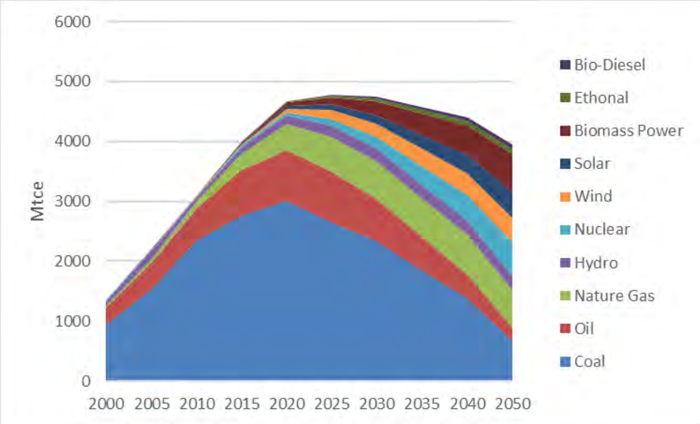
2. Energy transitions scenario in China under the 30-60 targets

By shifting from fossil to non-fossil fuels, China's energy supply could play an important role in cutting CO2 emissions deeply in the future. Recent IPCC reports outline a rapid transition in energy systems around the world and in China. By 2050, renewable energy and nuclear will dominate energy supply (IPCC, 2022). This story will be the same in China (Zhang et al, 2022; Wang et l, 2022; Jiang et al, 2021; Xiao and Jiang, 2018).

Figure 6 shows the primary energy demand in China based on IPAC results (Jiang et al, 2021; Jiang et al, 2020). The IPAC model is an integrated assessment model to analyze energy transition in the world and in China, starting in the early 1990s, with many publications (Jiang et al, 1999; Jiang et al, 2006; Jiang et al, 2013; Jiang et al, 2016; Jiang et al, 2018).

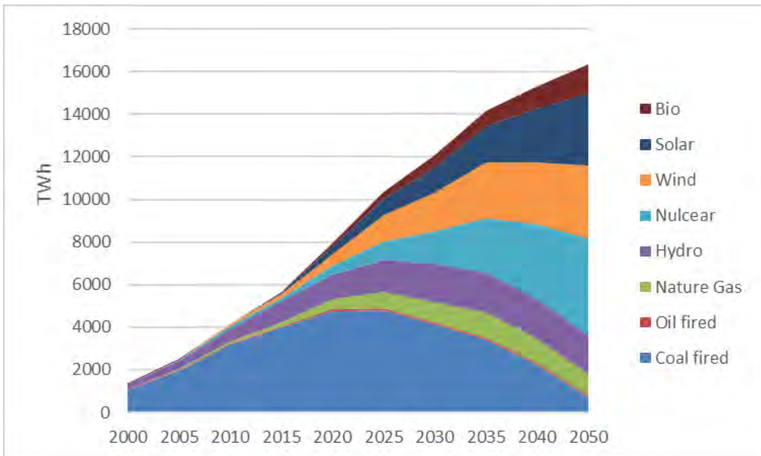
Figure 3.6. presents power generation in the energy transition scenarios that could reach the 30-60 targets. Because of the transition in power generation, which could be zero emission by 2050, other sectors will use more electricity for their own carbon neutrality transition, promoting electrification in end-use sectors. As a result, power generation would increase to more than 14000TWh by 2050, with per capita 10320kWh. The energy sector transition will have to be significant for the attainment of the climate goals.

Figure 3.5 Primary energy demand in China, energy transition scenario



Source: Jiang, 2022.

Figure 3.6 Power generation scenarios for China, energy transition scenario



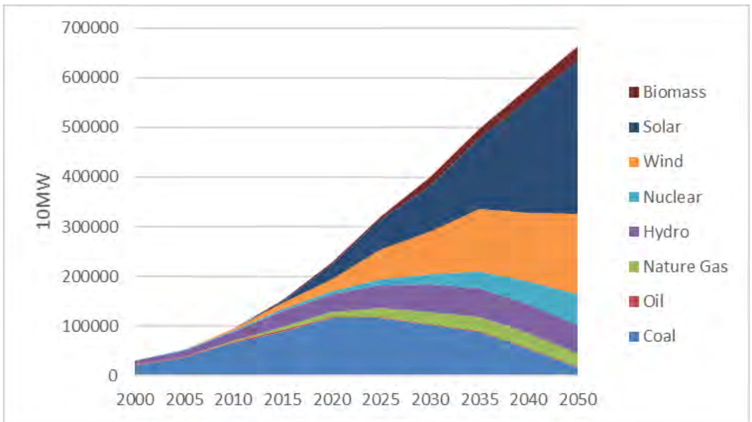
Source: Jiang et al, 2021.

Figure 3.7 show the installed capacity in power generation sector in China in an energy transition scenario. China will massively expand solar and wind power, which could enable new manufacturing sectors. In this scenario, renewable energy and nuclear would generate 87% of total power generation; wind power would account for 21%, solar 16.6%, hydro 14%, biomass 7.6%, nuclear power 28% in 2050. (These numbers are 3.3%, 0.7%, 17.7%, 0.3% and 3% in 2015 respectively.) Coal fired power would account for 5.3%, and natural gas fired power for 7.1% in 2050; they were 71% and 3% in 2015 (Figure 8). This is a significant transition in 35 years. Since the life span for fossil fuel-fired power plants is normally more than 35 years, to see this transition by 2050, changes in energy and power generation need to be made right now.

Fossil fuel power generation will have to use carbon capture and storage (CCS) technologies to make their emission as low as possible. By 2050 nearly all of coal fired power and natural gas fired power would be equipped with CCS (see Figure 9). Biomass energy with CCS is a crucial option for a low (or negative) emission scenario in the power generation sector by 2050.

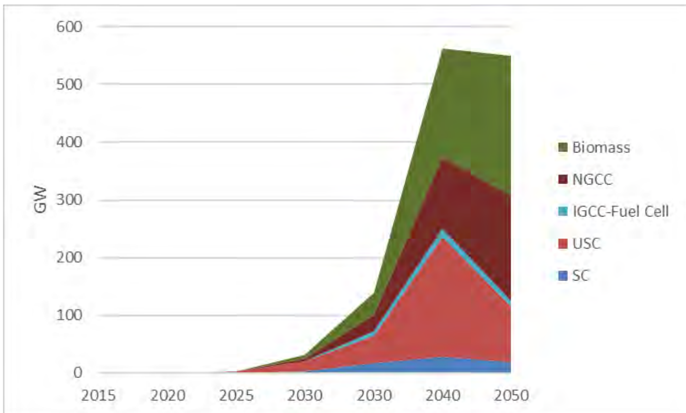
By 2050 installed capacity for biomass will be 250GW and equipped with CCS. Biomass for power generation will mainly come from firewood with planted trees. Total biomass demand will be 420 mtce (mega tonnes of coal equivalent), with power generation efficiency 32% with CCS.

Figure 3.7 Installed capacity for power generation in China



Source: Jiang et al, 2021

Figure 3.8 CCS in power generation sector



Source: Jiang et al, 2021.

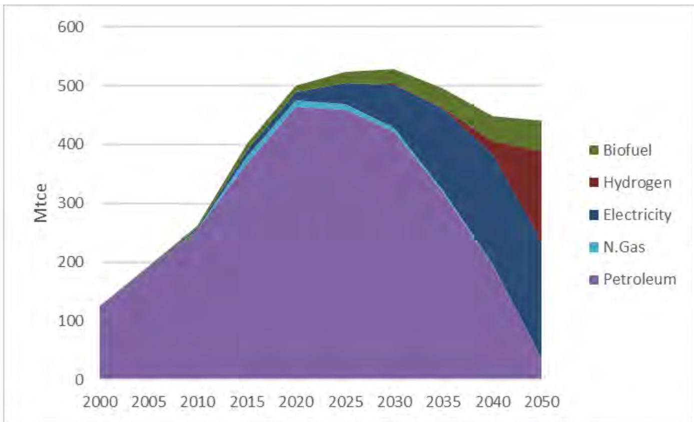
3. High share of electricity use in end-use sectors

With the transition in energy and power generation, it is possible for power sector to be net zero emission by 2050, or even achieve negative emissions from power generation after 2050. Using electricity to replace fossil fuels in end-use sectors will be a significant option for carbon neutrality in these sectors.

An energy transition in the power generation sector would promote the electrification process. In the energy transition scenario for the 30-60 targets, the share of electricity in final energy use would increase from 23.3% in 2015 to 58% in 2050. The transition to electrification could appear in transport, building and industry sectors. All three will be discussed in this section.

In the transportation sector, with the rapid development of electric vehicles, the trend toward electrification in China is clear. Electric locomotives would promote the energy transition in the railway system. Figure 10 presents the final energy use in transport in China; electricity increased its share from 2.1% in 2015 to 38.6% in 2050. Based on previous studies on the electric car industry, significant technological progress will lead to a large increase in market share in 2025. In this scenario analysis, cars will be mainly electric or fuel cell cars. Heavy duty vehicle such as buses and trucks will electric vehicles and fuel cell based. Ships or other water vessels will be green hydrogen-based or use liquid fuel from green hydrogen such as ammonia, methanol, or be fuel cell driven. Airplanes could use hydrogen as energy, but this step might not be fully realized by 2050. Bio-fuel will be used for air transport. Small electric airplanes could also play important role in future air transport. Since electric cars are much more efficient than gasoline or diesel cars, liquid fuel demand will decrease sharply after 2030.

Figure 3.9 Final energy demand in transport sector in China



Source: Jiang et al, 2021.

In China's residential sector, carbon neutrality will entail reducing fossil fuel. Cooking could be mostly from electricity by using new technologies available now, to make traditional Chinese dishes with similar quality as with gas ranges and cooking ovens. However, space heating has been very big challenge because of large demand in both urban and rural area. Key options for reducing energy from space heaters includes using heat pumps, promoting ultra-low energy use building, and other measures. Heat pumps could be installed on large scale, including air source heat pumps. But in cities it is still difficult to install heat pumps due to the high density of high-rise buildings. However, 100% electricity use in rural areas is possible because heat pumps work well in low-rise buildings, and more renewable energy could be generated on site. In all cases, highly energy efficient buildings are a must. By using all these options, share of electricity could increase from 26.3% in 2015 to 70% in 2050.

In the industry sector, the shift from heavy industry to light industry presents a favorable opportunity for promoting electrification, because more electric motor-based manufacturing processes dominate in light industry. Fossil fuel use for industrial processes such as in cement manufacture will fall due to decreased of output of energy-intensive products. Some industry process, such as steelmaking, will increase in importance. Steel output from electric arc furnaces will dominate as recycled steel becomes 68% of steel output by 2050; it was 18% in 2015. In the meantime, hydrogen-based processes could also enter widespread use in steelmaking, petrochemical production, and non-ferrous production processes, which also relies on an electricity-based hydrogen manufacturing process (Xiang et al, 2023). Share of electricity in final energy use in industry sector could increase from 24.9% in 2015 to 48.7% in 2050.

C. China's Policies strategies for energy transition

Energy security, resource conservation, and environmental protection have all been part of China's energy policies, in the context of its development strategies, since1990. Energy policy is normally driven by the central government, which also plays a key role in energy supply and consumption. Before the 30-60 targets were announced, energy policies were mainly driven by goals of energy security, resource conservation, and air quality control. After the 30-60 targets were announced, the goal of a low carbon-based energy system entered the mainstream of the energy policy-making process.

After China's 30-60 targets announced, many policies were announced by government. In October 2021, "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy" (referred to as Working Guidance) was published by Central Committee of CPC and State Council. The 30-60 target implementation is a national strategy, putting conservation as the first priority. The green economic transition will require changes in economic structures, controls on energy-intensive industry development, the development of clean, low-carbon and high-security energy system, increased energy efficiency, strictly controlled fossil fuel use, and an accelerated process to reduce coal use and develop non-fossil energy.

In September 2021, President Xi pledged that China would stop building new coal-fired power plants overseas, 2021 being the beginning year of China's 14th Five-Year Plan (FYP) (2021-2025). The year also marked the first year in the nationwide effort to curb carbon emissions since the announcement of the 30-60 goals. Throughout the year, the political will in advancing the dual-carbon agenda remained high, with important policy signals sent during national and international meetings. Also, the "1+N" series of policies steering toward directing carbon neutrality and curbing carbon emissions were also released.

1. Policies on promoting energy conservation

China has made great efforts in energy conservation and efficiency in recent decades. Energy intensity decreased by over 70%, from 3.4 tce per 10000 CNY (in year 2005 CNY) in 1980 to 0.74tce per 10000 CNY in 2020. From 2005 to 2020, the economy has grown with annual growth rate 8.8%, while in the same period the energy consumption growth rate is 5.1% (NSB, 2022). In this period, China accounted for a half the energy savings of the entire world over last twenty years. China's energy conservation record, and success in decoupling growth from energy intensity ranks among the best worldwide. However, there is still great energy-saving potential in China, and a long way to go.

Sustainable development is a long-term national strategy in China. The emphasis on building an ecologically minded society reflects the rising concern for environment issues from both the official and the public. China began enhancing its energy efficiency policies and programs in the 10th Five Year plan, and in the Eleventh Year Plan it first set hard targets for energy and environmental indicators. The Twelfth and Thirteenth FYP have seen a continuation of those policies.

In the 10th Five-Year Plan, many energy efficiency policies were included. Targets for specific energy consumption levels for key energy-intensive industries were created. In the 11th Five Year Plan, the government embraced, for the first time, a quantitative target for reducing energy intensity by 20% between 2005 and 2010. In the 12th Five Year Plan, to support the energy intensity goals, a monitoring program for the 1,000 top energy consuming enterprises was launched.

The "One Hundred Energy Efficiency Standard Promotion Program" is carried out by NDRC, Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and the Standardization Administration. As of September 2015, a total of 105 compulsory energy consumption standards and 70 mandatory energy efficiency standards have been published.

The 13th Five Year Plan (2016-2020) and The Energy Development Five-Year Plan were published in 2016. Compulsory energy intensity, renewable energy percentage, CO2 intensity and total coal consumption targets were set in the plans.

Energy-intensive sectors play key roles in energy conservation. Table 3.2 lists key sectoral policies, providing an extended view of the energy conservation policy system.

Table 3.2 Key sectoral energy conservation policies in the 12th and 13th FYP period

Sector	Policy	Policy instrument	Agencies
Industry	Ten Thousand Enterprise Energy Conservation Programme	Regulation	NDRC
	Obsolete Capacity Retirement Programme	Regulation	NDRC
	Energy Conservation Technology Fund	Incentive	NDRC
	Differential Electricity Pricing	Economic instrument	NDRC, NEA
	Small Business Closure Programme	Regulation	NDRC

Building	Promotion of Energy Efficiency Standards	Regulation	NDRC etc.
	Retrofitting Existing Residential Buildings	Investment	NDRC, MOHURD, etc.
	Retrofitting Public Buildings	Investment	NDRC, MOHURD, etc.
	Integrated Renewable Energy	Incentive	NEA, NDRC
	Promotion of Green Buildings	Incentive	MOHURD, NDRC etc.
	Energy-Efficient Product Discount Scheme	Incentive	NDRC
	Incandescent Lighting Phasing Out Programme	Regulation	NDRC
	Differential Electricity Pricing	Economic instrument	NDRC, NEA
	Ten Thousand Enterprise Energy Conservation Programme	Regulation	NDRC
	Development of the Energy Services Industry	Incentive	NDRC
	National Energy Conservation Campaign	Education	NDRC
Transport	Commercial Vehicle Fuel Standards	Regulation	MOT
	Road Passenger Transport Capacity Control	Regulation	MOT
	Thousand Enterprise Low-Carbon Programme (transport)	Voluntary agreement	MOT
	Transport Energy Conservation Fund	Incentive	MOT, NDRC
	Transport Energy Conservation Demonstration Projects	Investment	MOT
	Low-Carbon Transport System Development Programme (pilot)	Incentive	MOT
	Ten Thousand Enterprise Energy Conservation Programme	Regulation	NDRC
	Energy-efficient Product Discount Scheme	Incentive	NDRC
Public	Public Sector Key Energy Conservation Projects	Investment	NDRC, MOHURD
	City Green Lighting Project	Investment	NDRC, MOHURD
	Compulsory Government Procurement of Energy-Saving Products	Procurement	NDRC
	National Energy Conservation Campaign	Education	NDRC

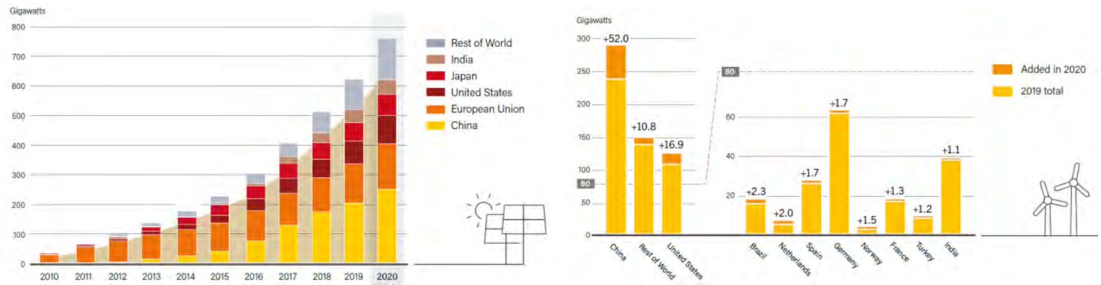
Source: 13th Five Year Plan, 2016; NSB, 2022.

In the Working Guidance announced in 2021, energy conservation received much emphasis. It directed that energy conservation should be fully implemented in all processes and area in development, continue efforts toward energy conservation in industry, building, transport, public agency, increase energy efficiency in facilities including data and communications centers. It also directed that Chinese policy aim for the highest international standards on energy efficiency.

2. Policies for developing renewable energy

China is now a leading player in renewable energy development. Annual capacity increases for renewable energy in China account for nearly half of the global total. Since 2015, China has been the world’s largest consumer of modern renewable energy (figure 3.12).

Figure 3.10 Solar PV and wind capacity in the world



(a) Installed capacity of solar PV (b) installed capacity of wind

Source: REN21, 2022.

The development of renewable energy in China is a key strategic measure for fostering emerging industries of national importance. It is also key to national action aimed at the protection of the environment, responses to climate change, and achievement of sustainable development. China worked to increase the shares of non-fossil fuels in primary energy consumption to 15% in 2020 and is aiming for installed generation capacity of 20 percent by 2025.

Against the background of a global energy crisis in 2022, local air pollution, and climate change, the development of renewable energy technology has important practical and long-term significance for replacing fossil fuels and realizing the sustainable development. China’s energy security concerns have become an increasingly prominent issue, environmental constraints have increased and the possibilities for energy savings and emission reductions are extensive. In this context, the government has prioritized adjustment of China’s energy structure and development of renewable energy sources. In recent years, governments have increased focus on renewable energy and introduced a series of policies and measures for the sector.

The basic framework of China’s renewable energy development policies includes the Renewable Energy Law, a medium and long-term development plan for renewable energy and each five-year plan as the short-term plan. Both aim to attract producers and users to participate in the development and utilization of renewable energy through the establishment of a series of effective incentive mechanisms.

The Renewable Energy Law was issued in 2005 and formally implemented on 1 January 2006. This was the first energy law in China and indicates the importance the Chinese government has placed on renewable energy. The Renewable Energy Law was revised at the end of 2009 and an amended version was implemented on 1 April 2010. The amendment established the Renewable Energy Development Fund, financed by a levy on the electricity grid, to support the development of renewable energy.

The plan for medium and long-term renewable energy development aimed to increase renewable energy’s share of total energy consumption to 10 per cent in 2010 (from 7.5% in 2005) and to 16% by 2020. The plan treated wind power generation as a key renewable energy source and set medium- and long-term wind power development goals through to 2020.

The 2005 Renewable Energy Law authorized feed-in tariffs (FITs) for wind power based on “government guided” prices, which have evolved year-by-year into competitive bidding for wind power capacity, resulting in standardized prices, generally on a province-by-province basis.

FITs were implemented in China as early as 2003 in support of the deployment of wind power. At first, the tariff amount was determined on a case-by-case basis through bidding or negotiation. However, this arrangement created intense competition among large state-owned renewable power generators, which generated speculative bids that were often insufficient to actually implement the project. This practice was considered harmful to the long-term sustainability of the wind power industry.

In response, the NDRC set baseline prices for wind tariffs in August 2009. The minimum tariff ranged from RMB0.51/kWh to RMB0.61/kWh, depending on the location of the wind farm, with four classes of wind resource ranking. In 2011, the NDRC set the national solar FIT at RMB1/kWh for projects started in 2011 or later. To support the FITs, the NDRC established a renewable electricity surcharge in 2006, of RMB0.001/kWh. The surcharge was increased to RMB0.004/kWh in 2009 and again, to RMB0.008/kWh, in 2011, to support the increasing demand for FITs following rapid growth of renewable energy.

Despite the eightfold rate hike, the surcharge remains low by international standards: with an average residential electricity price of RMB0.52/kWh, the surcharge is 1.5 per cent of the total electricity price. In comparison, Germany's renewable energy surcharge reached €0.053/kWh (RMB0.43/kWh) in 2013, or 20% of the total electricity price. China's low renewable electricity surcharge is important for the sustainable development of renewable energy because it leaves sufficient room for future expansion of FITs.

In December 2016, the NDRC released the lower FIT for new projects in 2017. For wind power, the tariffs are 15%, 10%, 9% and 5% lower for the four wind resource rankings, giving rates of RMB0.40/kWh, RMB0.45/kWh, RMB0.49/kWh andRMB0.57/kWh, respectively. For solar power, the FIT reductions are 19%, 15% and 13% for the three solar resource rankings, to rates of RMB0.65/kWh, RMB0.75/kWh and RMB0.85/kWh, respectively. The subsidy for distributed solar power remains at RMB0.42/kWh. The FITs for offshore wind and tidal zone wind power also remain unchanged, at RMB0.85/kWh and RMB0.75/kWh, respectively.

With the rapid development of wind and solar PV power generation, the curtailment of power generation was of concern. In 2018, some grid's solar PV curtailment reached higher than 40%. In order to make better use of clean power generation, NEA released regulation by "Three Year's Action Plan on Utilization of Clean Energy" to ask to control the curtailment of wind and solar power generation to be less than 5% by 2020. These targets were reached in 2020.

Due to the rapid decrease of solar PV and wind power costs, subsidies ended in 2021. In 2021, no solar PV and wind power plants required subsidies, and their product had a lower price for on the grid than existing col fired power plants. Only some distributed solar PV has some subsidies, depending on local government policies.

After the 30-60 targets were announced, many policies to further promote renewable energy came into being. These policies included starting a trading market for green energy (mainly solar PV and wind), differential pricing for peak and off-peak load. Also, additional renewable energy will not be included, due to a dual-control policy of energy intensive and energy cap, promotion of large-scale development of wind and solar PV projects in the Gobi Desert.

One of important ways for provinces, cities, and companies to reduce CO2 emission or to be carbon neutrality is to use green electricity instead of electricity from fossil fuels. But they face challenges in obtaining it in the first place. In China there is an oversupply of green electricity in Western-China, North-China, and Northeast-China, but lack of green electricity supply in eastern-China, the center of consumption. In Sep. 2021, NDRC and NEA both released the regulations structuring the green electricity market, allowing it to be traded by both supplier and user. This step provided a path for users to buy green electricity for their own purposes; 6.9TWh green electricity was traded in the first pilot trading in 2021. There was a 3 to 5 cent/kWh surcharge for green electricity compared with coal fired electricity. In 2022, more than 20TWh of green electricity was bought and sold, and traded prices were lower than coal-fired electricity due to high price of coal in 2022. This difference could encourage greater use of electricity in the near future.

To deal with load changes, peak and off-peak load price regulation was announced by NDRC in July 2021 (NDRC, 2021). Based on the regulation, the price of electricity in peak load times should be four times the cost than in off-peak periods in areas where the load changes by more than 40%; in other regions the difference will be three times.

These policies, in turn, made pumped hydropower and coal fired power at peak loads profitable. As a result, many new pumped hydro power stations started construction in 2021 and 2022. This development and the retrofitting of coal-fired power plant to be flexible power generators could further development of wind and solar PV, and reduce coal-based power generation.

Another policy places green-generated energy outside the overall regulatory cap on energy. In 2007, China allocated the sum total of both energy intensity and energy usage – that is, an overall national cap – separately to each province in order to promote energy conservation (NDRC, 2007). This so-called "dual-control" policy emerged as a central regulation in China. In 2021, nine provinces failed to reach the annual dual-control targets, and some provinces forced some energy-intensive companies to reduce production – something that was top news in China. To promote renewable energy, in September 2021, NDRC issued regulations excluding green energy from the provincial quotas under the cap (NDRC, 2021). Beginning in early 2022, this regulation was extended to newly increased renewable energy, which give much more demand on renewable energy to avoid the strict constraint for energy demand needs.

National regulations also set up rules for trading green electricity among provinces. Provinces that had a surplus of energy intensity and usage after meeting their caps could sell their green electricity quota to other provinces. This new market could help some provinces with rich renewable energy to further develop their wind and solar power.

NDRC also announced a new program to develop large wind and solar PV plants in the Gobi Desert in December 2021, which brought a surge of renewable projects. By July 2022, there was already more than 100GW of solar PV and wind power plant capacity built.

3. Policies for controlling use of fossil fuel

Rapid economic growth, the story of China since 1980, has driven fossil fuel usage and environmental degradation. By 2021, fossil energy consumption (coal, oil, natural gas) was 4.37 btce, or about 83.4% of the total; the shares of coal, oil, natural gas was 56%, 18.5%, 8.9%, respectively. In 2016, China set a cap on annual primary energy consumption of less than 5.0 btce by 2020, and established the goal of increasing the ratio of non-fossil energy from 12% to 15%.

Because coal is the lowest-cost energy in China, development of the coal-mining industry dominated the energy development with share 76.2% in 1990, 68.5% in 2000, 69.2% in 2010, and 56% in 2021. Coal is the largest fossil fuel resource, and supply of coal plays the key role in energy security in China. Before 2005, the use of coal was driven by demand, but with the increasing concern for the environment, especially air pollution control, policy makers turned to the supply side. Controlling coal usage became important in the run-up to the summer Olympic games in 2008. Also, more and more cities took actions to improve air quality by limiting coal consumption. National progress was embodied in the action plan on air quality improvement released by State Council in 2013, which established a strategy for controlling coal usage and promoting clean coal.

The Working Guidance announced in 2021 envisioned a new, sped-up process to reduce coal use by controlling the increase of coal burning through 14^{th} Five Year Plan, and start to decrease coal use in 15^{th} Five Year Plan. Oil consumption will peak, and then plateau, in the 15^{th} Five Year Plan. The capacity of coal-fired power plant will be strictly controlled, while the retrofitting of existing coal fired power plants to improve efficiency will accelerate.

Controlling fossil fuel will rely heavily on non-fossil fuel development if China is to preserve energy security is the first concerning for all countries. Well-designed renewable energy policies and nuclear energy policies can also help control fossil fuel use. Therefore, fossil fuel control policies must work closely with non-fossil energy development policies. Presently, China's is leading the development of renewable energy and nuclear in the world, with dominating the newly installed capacity for solar PV, solar thermal power, wind power, hydropower, solar heater, and nuclear energy development. Therefore, it is expected the future of fossil fuel energy use could be decreased.

D. Conclusion

With rapid economic growth, China's energy consumption increased rapidly from 1990 to 2013. A large-scale increase of energy-intensive products drove the increase, accounting for around 70% of increased energy demand and 70% increased electricity demand from 1995 to 2014. After 2014, manufacturers slowed energy-intensive output and even decreased production of some products, such as cement. CO2 emissions tracked these developments. By 2020, carbon intensity decreased by 48.7% compared with 2005, which went beyond China's commitments under the Copenhagen Agreement for a 40 to 45% reduction in carbon intensity.

China has developed many policies aimed at ensuring a secure supply through a sustainable mix of sources, mainly through energy conservation the promotion of renewable energies. From 1990 to 2005, energy conservation dominated energy policy and promoted breakthroughs in energy efficiency. After 2005, renewable energy became central to energy policy making. Through target-setting and FITs, together with significant cost reduction for solar PV and wind power through 2021, the installed capacity of solar PV and wind power increased enormously. In 2012, China ranked No.5 of installed capacity of solar PV with 8.9GW; this level reached 351GW by 2021, equal to the next 10 countries combined.

However, implementing the policies to support the 30-60 targets remains a tall order. The transition is still new for China and is likely to have major socio-economic impacts – challenge not only for China but for the world. China is moving – indeed, leading – in developing renewable energies, but the energy transition is bound to be hard for a country where coal use still dominates the energy mix. Fortunately, the Chinese government has a strategy to achieve the 30-60 targets and has moved quickly to implement it.

Based on the preceding analysis in this Chapter, the following policy actions could facilitate the transition process underway in China:

(i) The proposed new energy system by the Chinese government is an essential direction for the energy system under the 30-60 targets. China would benefit from articulating the vision for this new energy system more clearly.

(ii) Energy conservation strategies would benefit from greater specificity to achieve lower energy demand in future. Only a strong energy conservation effort can guarantee energy security and lower the cost of energy.

(iii) Mandatory, ultra-low energy use construction standards are needed as soon as possible to avoid high energy demand from buildings. The standards can also promote resilience in the face of extreme climate events.

(iv) Technological progress will promote the rapid deployment of solar PV and wind generation facilities in near future. The power grid that supports this development is crucial and will need to be well-designed.

(v) Policies to support green hydrogen-based industrial development are essential. Green hydrogen-based industry has large potential and could contribute local use of renewable energy.

(vi) A flexible pricing system for electricity use would contribute greatly to China's energy goals. It would involve the consumer side of this business, giving it a stake in ensuring high security of its power supply.

(vii) China's green energy trading system should be extended to cover the whole country. It should go beyond the province-to-province system to include all types of cross-regional trading.

(viii) The carbon pricing regime should be extended to cover more sectors, and no-free allowance for ETS in China. Carbon taxes could also be an option for pricing policies.

Chapter IV. Promoting green transition in China's industrial sector

A. Context setting

Since the reform and opening-up that began in 1978, China has made tremendous progress in industrialization. In 2022, China's total industrial added value exceeded 40 trillion yuan (about USD 6 trillion), accounting for 33.2% of the total GDP, and the added value of the manufacturing sector accounts for 27.7% of the total GDP.

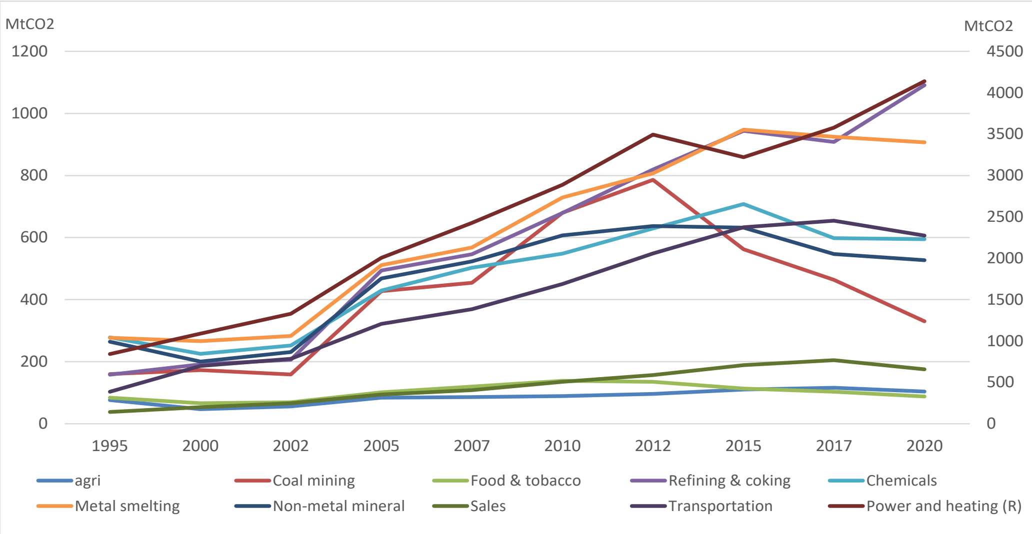
The scale of industrial output demands immense energy consumption, and a corresponding level of CO2 emissions. In 2020, total energy consumption of secondary industry was 2.6 billion ton of coal equivalent (tce), accounting for 68.7% of China's total final energy consumption. The latest official accounting show that CO2 emissions from manufacturing fuel burning and processing account for 52% of total CO2 emissions.[37] Through calculations based on officially published data[38], including the direct and indirect CO2 emission, the secondary industry has always accounted for more than 80% of China's carbon emissions from energy use from 1995 to 2005, and around 85% since 2005.

Among the whole economic sectors, the top 10 carbon-emitting sectors include power and heating, petrochemicals and coking, metal smelting, transportation, chemicals, non-metallic mineral production, coal mining, wholesale and retailing, and agriculture and food processing. As shown in Figure 4.1, among the secondary industries, the direct CO2 emissions from metal smelting, chemicals, non-metallic mineral production, coal mining, and food processing all grew continuously. The share of direct CO2 emissions of the manufacturing industry on total CO2 emission has remained relatively stable, fluctuating between 35% and 40% from 1995 to 2020. However, the CO2 emissions from power and heating and refining and coking sectors kept increasing, due to the increasing demand for electricity and heat and refinery products.

China also managed to reduce carbon intensity in the same period[39]. We selected top ten manufacturing sectors in which carbon intensity was larger than others, shown in Figure 4.2. All ten sectors showed a decline in carbon intensity for most of the period since 1995, with some declining by nearly 80% on average by 2020, compared with 1995 levels. However, during 2001-2005, when China joined the WTO, the carbon intensity in some sectors, like power and heating, refining and coking, chemicals, and coal mining, has risen, rather than continuing to decline. The reduction of carbon intensity of the power and heating sector and the petrochemicals and coking sector are relatively moderate, with carbon intensity falling by 25% and 50% respectively. By 2020, the carbon intensity of the power and heating, and petrochemicals and coking sectors remained much higher than the national average.

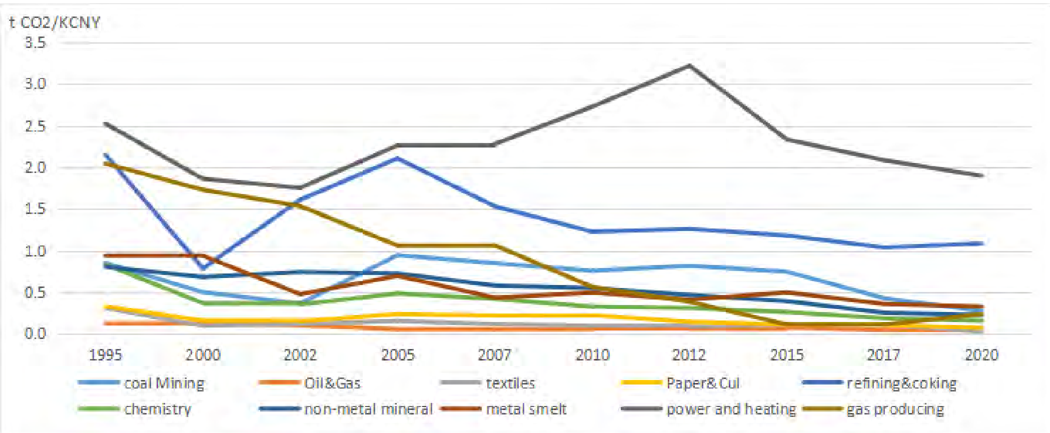
[37] Table 2-4 of the *Third National Information Communication on Climate Change by P.R.C.*, 2018.
[38] China's Energy Statistics Yearbooks and Input–Output Tables.
[39] To enable horizontal and vertical comparisons of carbon intensity in various industries, the value added of each industry needs to be calibrated using the pricing level in the reference year when using the input–output tables for each year; that is, comparable pricing is necessary. Thus, the value-added data for all industries were adjusted using 2020 as the reference year. The Industrial Producers Purchasing Price Index published in China's *National Statistical Yearbooks* was used. This is a continuous price index that has been published since 1989 for eight categories of products, including fuel power, ferrous metal materials, non-ferrous metal materials and wires, chemical raw materials, wood pulp, building materials and non-metals, agricultural products, and textile raw materials.

Figure 4.1 CO_2 emissions by sector, 1995–2020



Source: Calculated based on energy consumptions by sectors in China Energy Statistical Yearbook (2021).

Figure 4.1 CO_2 emissions intensity by industrial sector, 1995–2020



Source: Calculated by authors.

Note: We used annual data from China's Energy Statistics Yearbooks and Input–Output tables for all available years to estimate the trends in carbon emissions and carbon intensity for each industry. China's Energy Statistics Yearbooks were used to obtain data on energy consumption by industrial sector and energy type from 1995 onwards. There are 46 sectors, including 41 industrial sectors, three service sectors, a construction sector, and an agricultural sector. To avoid double counting of carbon emissions, only coal, oil products, and natural gas were included when calculating direct carbon emissions from the various industrial sectors. Emissions from power generation were only considered in the power sector, and not treated as indirect emissions in other industrial sectors.

Annual value-added data for the various sectors were not disclosed in the statistical yearbooks, and therefore we obtained value added data for each sector from the input–output tables, which were published in 1992, 1995, 1997, 2000, 2002, 2005, 2007, 2010, 2012, 2015, 2017, and 2020. Because there were differences in the division of industrial sectors in the input–output tables in various years, as well as differences in the scope of the input–output tables and the energy consumption calculations, we used 2020 as the reference year and adjusted data from other years accordingly.

Given the significance of the industrial sector in China's economy and the level of energy use and emissions, advancing the green industrial transition is a key strategy to towards the 30-60 targets. This chapter will start by reviewing China's policies in promoting energy conservation in industrial sector, then explore the policies to promote a more comprehensive green transition in secondary industries against the backdrop of the 30-60 targets.

1. Energy conservation as the main policy to limit environmental damage from industry

(a) Policies of energy conservation in industrial sector

Prior to the Paris Agreement, the main Chinese policy for addressing environment concern caused by rapid industrialization was energy conservation. As shown in Chapter 4, from 2000, China's energy consumption, driven by economic growth, rose sharply, creating large CO2 emission and air pollution.

To avoid energy consumption that tracks economic growth, China has made greater efforts at energy conservation since 2005, even before kicking off more comprehensive green industrial policies under the 30-60 targets. Giving more attention to environment protection and carbon emission mitigation, the Outline of the 11th Five-Year Plan (2005-2010)[40], proposed building a resource-saving and environment-friendly society that pursues a new industrialization. Specifically, the Five-Year Plan adopted the index of reduction of energy consumption per GDP as a target, which prompted local governments to pay more attention to energy conservation.

Since in 2012, the concept of ecological civilization was proposed and was integrated into the Five-Sphere Integrated Plan for China, together with the development of the economy, society, politics, and culture. In addition to improvements in energy efficiency in the industrial sector, more efforts went into optimizing the industrial structure, developing and utilizing green technologies, enhancing comprehensive recycling, and taking other measures.

Specifically, China took two approaches. The first an industrial structure upgrade. Since 2005, after the announcement of the Decision of the State Council on the Implementation of the Interim Provisions on Promoting Industrial Structure Adjustment, the country has continuously updated and released the Guiding Catalog for Industrial Structure Adjustment, clarifying the list of detailed industries which are encouraged, restricted, and eliminated. In 2019, the National Development and Reform Commission (NDRC) issued the Green Industry Guidance Catalogue, expanding the scope of the previous catalogues.

The second approach involves developing technical standards for industrial energy conservation, emission reduction, and green development. Since 2008, China has successively formulated energy consumption limit standards covering seven categories: steel, coal, electricity, petrochemical, non-ferrous metals, building materials, and general standards. Through 2022, China had issued and implemented 108 mandatory national standards for energy consumption quotas and 66 for performance efficiency. There are now 190 recommended national standards for energy conservation. The work provides strong support for accelerating energy conservation work in various industries. On the other hand, investment in industrial technological transformation maintained a long-term double-digit growth rate during the past decade, which boosted the industrial investment and promoted the low-carbon transition.

(b) Policy effects

Energy conservation policies have contributed to a green transition in the secondary industries:

(1) **Evolution of industrial structure.** On one hand, the energy intensive sectors started to carry out green transition. Through the regulation of reducing low-efficiency capacity and building high-efficiency capacity, the increase in production of ferrous metal, nonferrous metal, nonmetallic mineral product industries and other energy intensive sectors has slowed. The growth rate of value added of these energy intensive sectors in 2011-2020 slowed to single-digit growth from double-digit growth during 2000-2010.

On the other hand, the new green products, like equipment for solar PV, wind power, and electric cars developed quickly. Until 2022, the added value of high-tech manufacturing industry and equipment manufacturing industry accounted for the proportion of added value of large-scale industrial enterprises[41] above 15.5% and 31.8%. According to the Notice on the Establishment of Green Manufacturing System

[40] Find relevant contents in Part 6 Chapter 22 of the *Outline of the 11th Five-Year Plan*.

[41] industrial enterprises which annual main business income is above 20 million yuan.

issued by Ministry of Industry and Information Technology (MIIT) in 2016, China has built green manufacturing systems to include four aspects: factories, products, industrial parks and supply chains.

Box 4.1 Green manufacturing system establishment in China

The green manufacturing systems include four aspects: factories, products, industrial parks and supply chains

- Green factories are characterized by intensive land use, clean production, waste recycling, and low-carbon energy utilization.
- Green products are defined as the product with systematic consideration of resource and environmental impact of whole life cycle in the product design and development stage, so as to minimize the consumption of energy resources, minimize the ecological environmental impact, and maximize the renewable rate, where the whole life cycle include raw material selection, production, sales, use, recycling, treatment and others.
- Green industrial parks are characterized by layout agglomeration, green industrial and energy structure, and systematic ecological design.
- Green supply chains are like a system with resource-saving and environmentally-friendly procurement, production, marketing, recycling and logistics system.

By the end of April 2023, China had built 3,616 green factories, 267 green industrial parks, and 403 green supply chain management enterprises at the national level. Enterprises produced more than 30,000 kinds of products with a green label.[42]

To optimize the industrial layout within the whole country, some energy intensive industries have been encouraged to transfer to areas rich in renewable energy and with strong carrying capacity[43] in terms of resources and the environment. Industries with local characteristics and ecological industries will be encouraged in areas with abundant ecological and environmental resources. For instance, the Yangtze River Delta promotes the efficient agglomeration and development of green and low-carbon industries; the region is responsible for 38% of electric vehicle production in China.

(**2) Improvement of energy efficiency in secondary industries**. Based on updated benchmarks from 2012 to 2022, the comprehensive energy consumption of unit products of steel, aluminum, cement and, such as plate glass has been reduced by more than 9% compared with 2012. Coal consumption per KWh of coal fired power unit dropped to 302.5 grams of coal equivalent, a level lower than that in advanced economies.

Electrification is another important way to improve the final energy efficiency in many sectors. In key industries such as iron and steel, petrochemical industry, non-ferrous metals, and building materials, the application of mainstream electric energy replacement technologies such as electric boilers, electric kilns, and metallurgical electric furnaces continues to expand. As of the end of March 2023, a total of 118 products (technologies) and 230 demonstration enterprises in the industrial field have been released.

(3) Establishment of comprehensive circular economic system. Compared with 2012, the total comprehensive utilization of 10 important recycled resources in 2022 – like scrap steel, waste plastics, waste tires, wastepaper, and other materials – increased by about 1.4 times. Industrial solid waste has become an effective alternative raw material for cement and other important industrial products.

CO2 mitigation in industrial sectors contributed to limiting total CO2 emission mitigation in China. Responding to Climate Change: China's Policies and Actions, which was published by the Information Office of the State Council of the People's Republic of China in 2021, pointed out that in 2020, China's carbon intensity had fallen by 48.4% compared with the level in 2005, exceeding the target of 40–45% that China had promised to the international community, and basically reversing the rapid growth trend in CO2 emissions. The calculated carbon emissions from energy use by sector from 1995 to 2020 are in appendix 1 and appendix 2.

[42] Carbon Peaking and Carbon Neutrality Research Centre of Ministry of Industrial and Information Technology, 2023, White Paper on Green Development of Industry.
[43] Carrying capacity refers to the maximum number of organisms that an ecosystem can sustainably support.

2. Vision and scenario of green industrial transition under 30-60 target

The green transition will be an important aspect of China's industrialization and global sustainable development. It is not only is an important element in China's carbon neutrality strategies, but also is an important aspect of high-quality economic development and the construction of a modern industrial system. In the Outline of the 14th Five-Year Plan, it was proposed to enhance the green transition and intelligent manufacturing simultaneously. It was also suggested that, faced with the future direction of industrial change towards digital and green economies, China would build strategic and comprehensive production chains and try to cultivate the new driving forces for industrial development in these areas.

Vision of building the green manufacturing system.

In terms of industrial low-carbon transition strategy, the policy document Guiding Opinions on Accelerating the Establishment and Improvement of a Green and Low Carbon circular Development Economic System by State Council at 2021, proposed the idea of building a green, low-carbon and recycling development economic system, including six aspects: production, circulation, consumption, infrastructure, green technology, and laws/regulations/policies. These new rules outlined the requirements of "green planning, green design, Eco-investing, green construction, green production, green circulation, green life and green consumption" for all industries.

In the 14th Five Year Plan for Green Industrial Development, seven targets were identified, including "deepening the implementation of green manufacturing, accelerating industrial structure optimization and upgrading, vigorously promoting industrial energy conservation and carbon reduction, comprehensively improving resource utilization efficiency, actively promoting clean production transition, and enhancing the supply capacity of green and low-carbon technologies, green products, and services," – all with the target of achieving a carbon peak and then carbon neutrality.

The Implementation Plan for Carbon Peaking in the Industrial Field further highlights the flavor of the implementation path based on the prior polices and proposes requirements such as "breaking through with the peaking in key industries, focusing on building a green manufacturing system, improving resource and energy utilization efficiency, promoting the integration of digital, intelligent, and green technologies, and expanding the supply of green and low-carbon products."

Green factories, green manufacturing technologies, and integrated applications of different technologies across various sectors are the key areas that will be addressed in the future. Green industrial parks and green factories will be established through a process of "horizontal coupling and vertical extension." Green, low-carbon industrial chains will be used to enable enterprises to adopt a production mode involving comprehensive utilization of energy resources. Green supply chain will be established through the connection of individual green processes. The green, low-carbon concept will feed through the entire process of product design, raw material procurement, production, transportation, storage, use, and recycling to form a green supply chain management system. Eventually, an adequate supply of green products will be achieved.

3. Quantitative targets in policies and expected scenarios for green transition

In these policy documents, some quantitative targets during the 14th-Five-year period are also mentioned to provide more clear expectations on China's green industrial development, mainly covering the following five aspects.

- Carbon emissions intensity and carbon emissions reduction: CO2 emissions per unit of industrial value added need to be reduced by 18%.
- Pollutant emissions intensity: The emissions intensity of major pollutants in key industries will be reduced by 10%. The ultra-low emission retrofit of steel production capacity of 530 million tonnes will be completed, as will the clean production retrofit of coking production capacity of 460 million tonnes, and cleaner production retrofit of 4000 non-ferrous metal kilns.
- Energy and resource utilization efficiency: The energy consumption per value added of industrial enterprises above a designated size will be reduced by 13.5%, and the comprehensive energy consumption per unit of information flow will be reduced by 20%. By 2025, the proportion of new

energy-efficient motors and transformers will reach 70% and more than 80%, respectively. Water consumption per unit of industrial value added will be reduced by 16%.

- Comprehensive recycling utilization rate: The comprehensive utilization rate of bulk industrial solid waste will reach 57% of the total capacity and will rise to 62% by 2030. The comprehensive utilization rate of smelting slag (excluding red mud) and industrial by-product gypsum will reach 73% and 73%, respectively. The recycling of major recycled resources will reach 480 million tonnes. Build a relatively complete battery recycling system and nurture 50 remanufacturing companies.
- Green manufacturing system establishment: The output value of the green environmental protection industry will reach 11 trillion RMB, of which the output value of the environmental protection equipment manufacturing industry will account for 1.3 trillion RMB.

More detailed targets were also set for major sectors, including steel, building materials, petrochemicals, consumer goods, electronics, transportation, and IT.

Overall, the economy will experience significant structural change. By 2030, the proportion of tertiary production is expected to increase to about 66%, while the proportion of secondary production will gradually fall to about 30%, and then remain relatively stable.

For iron and steel sector and non-ferrous secondary, according to the Guidance on Promoting the High-Quality Development of the Steel Industry (MIIE, 2022), China will promote new steel production capacity, strengthen technological innovation in advanced materials, green and low-carbon fields, and strive to basically form a new pattern of steel industry development such as reasonable regional layout, stable resource supply, and advanced technology and equipment by 2025.

Under the Guidance on Promoting the High-Quality Development of the Petrochemical Industry, the petrochemical industry will enter a high-quality development pattern with strong independent innovation ability and reasonable structural layout. Safe, low-carbon, high-quality production capacity will be greatly improved, core competitiveness will be significantly enhanced.

Following these industrial strategies, the demand for ferrous metal and cements will peak and then gradually decline; chemical products and non-ferrous metals are expected to continue their growth, as will electric vehicles and other means of transportation, and electromechanical, electronic, and electrical products, though at a diminishing rate.[44] Meanwhile, some studies estimated that, under the scenario of the attainment of 30-60 targets, by 2030, industrial energy consumption is expected to be 2.82-3.15 billion tce, accounting for 65%–67% of total energy consumption, and will still be 2.6-3.1 billion tce in 2035[45,46,47].

4. Advancing green industrialization through policy

(a) Three pillars of green industrialization

To achieve the 30-60 targets, China formulated a set of policy framework in advancing green industrialization, which is mainly composed of 22 policy documents (table 4.1). These policies can be summarized into three following pillars.

[44] Zhang, X., etc., 2022. Research on the Pathway and Policies for China's Energy and Economy Transformation toward Carbon Neutrality[J]. Management world.2022(01):35-51. (in Chinese)
[45] Institute of Climate Change and Sustainable Development, Tsinghua University. Comprehensive report on China's long-term low-carbon development strategy and transition path[J]. China Population Resources and Environment, 2020, 30(11):25.
[46] Ji-Feng Li , Zhong-Yu MA , et al. Analysis on energy demand and CO2 emissions in China following the Energy Production and Consumption Revolution Strategy and China Dream target[J]. Advances in Climate Change Research, 2018, 9(1):11.
[47] Research Group on China's Long-term Low-carbon Development Strategy and Transition Pathway, 2021, Understanding Carbon Neutrality: China's 2020-2050 Low-Carbon Development Action Roadmap, CITIC Press (in Chinese)

Table 4.1 Major policy documents related to China's green industrial development since 2021

No.	Publication date	Title	Issued agency	Pillar mainly focused
1	2 February 2021	Guiding opinions on accelerating the establishment and improvement of a green and low-carbon circular development economic system	State Council	1, 2, 3
2	2 April 2021	Green Bond Endorsed Projects Catalogue (2021 Edition)	People's Bank of China	1
3	3 September 2021	Guiding Opinions on Strengthening Industrial and Financial Cooperation to Promote Green Industrial Development	Ministry of Industry and Information Technology (MIIT)	1
4	15 November 2021	14th Five-Year Plan industrial green development plan	MIIT	1, 2, 3
5	30 November 2021	Implement the requirements of carbon peaking and carbon neutrality targets and promote the implementation plan for the green and high-quality development of new infrastructure such as data centers and 5G	National Development and Reform Commission (NDRC)	1
6	21 December 2021	14th Five-Year Plan raw material industry development plan	MIIT	2, 3
7	31 December 2021	Smart PV Industry Innovation and Development Action Plan (2021–2025)	MIIT	1, 3
8	13 January 2022	Action Plan for High-quality Development of Environmental Protection Equipment Manufacturing Industry (2022–2025)	MIIT	1, 2
9	15 January 2022	Notice on the announcement of the 2021 Green Manufacturing List	MIIT	2, 3
10	20 January 2022	Guidance on promoting the high-quality development of the steel industry	MIIT	2, 3
11	27 January 2022	Implementation plan on accelerating the comprehensive utilization of industrial resources	MIIT	3
12	3 February 2022	Implementation Guidelines for Energy Conservation and Carbon Reduction Transformation and Upgrading in Key Areas of High Energy Consumption Industries (2022 Edition)	NDRC	1, 2
13	20 June 2022	Industrial Water Efficiency Improvement Action Plan	MIIT	2
14	23 June 2022	Industrial Energy Efficiency Improvement Action Plan	MIIT	2
15	7 July 2022	Carbon peaking implementation plan for the industrial sector	MIIT	1, 2, 3
16	22 August 2022	Action Plan for Green and Low-carbon Development of the ICT Industry (2022–2025)	MIIT	1

17	24 August 2022	Accelerate the action plan for the green and low-carbon innovation and development of power equipment	MIIT	1
18	3 January 2023	Guiding opinions on promoting the development of the energy electronics industry	MIIT	1
19	20 February 2023	Guiding Opinions on Coordinating Energy Conservation, Carbon Reduction, and Recycling to Accelerate the Updating and Renovation of Product Equipment in Key Fields	NDRC	2, 3
20	6 June 2023	Energy Efficiency Benchmark Levels in Key Industrial Fields (2023 edition)	NDRC	1, 2
21	13 July 2023	National Catalogue of Advanced and Applicable Process Technology Equipment for Comprehensive Utilization of Industrial Resources (2023 Edition)	MIIT	3
22	4 August 2023	Implementation Plan for Green and Low Carbon Advanced Technology Demonstration Project	NDRC	1

(a) Pillar One: Continuously upgrading the industrial structure

China has succeeded in promoting photovoltaic solar cells, electric vehicles and power batteries in Chinese market. To continue these successes and to explore new opportunities for green industrialization, China has put more efforts into technological innovation, acceleration of mass-production, and green financing.

At the central government level, more than 50 measures like reducing taxes and administrative charges have been applied to green industries, such as producing and utilizing energy and water-saving equipment.[48] Recently, the Implementation Plan for Green and Low Carbon Advanced Technology Demonstration Project was announced by the NDRC.[49] According to the Plan, pilot projects using advanced carbon reduction technologies will be implemented with dedicated financial and permitting support. The quality of disclosure has been improved by introducing Guidelines for Environmental Information Disclosure of Financial Institutions by the People's Bank of China (PBOC), and by mandating that listed companies controlled by state-owned enterprises publish ESG report by the State-owned Assets Supervision and Administration Commission of the State Council (SASAC).[50] In the updated Green Bond Endorsed Projects Catalog,[51] Carbon Capture, Utilization and Storage (CCUS) and clean heating facilities were added in the catalog and fossil fuel related projects were removed.

Industry categorization is introduced to keep sufficient but competitive fleet of production capacities. For energy intensive and emission intensive industries (table 4.2), the room for expanding the production capacity will be limited. In addition, stricter energy efficiency design requirements are applied to new production lines, to keep the overall efficiency improve gradually. The categorization is adjusted and updated every year by NDRC, and specific technical measures are described in the Guidance Catalogue for Industrial Structure Adjustment.

Table 4.2 Industry categories encouraged or restricted under green industrial development

Overall orientation	Industry category

[48] Guidelines on Tax and Fee Preferential Policies for Supporting Green Development, State Taxation Administration, https://www.gov.cn/xinwen/2022-06/01/content_5693350.htm.
[49] Implementation Plan for Green and Low Carbon Advanced Technology Demonstration Project, NDRC. https://www.gov.cn/zhengce/zhengceku/202308/content_6899582.htm
[50] Work Plan for Improving the Quality of Listed Companies Controlled by Central Enterprises, SASAC. http://www.sasac.gov.cn/n2588030/n2588944/c24789613/content.html
[51] Green finance helps achieve carbon peak and carbon neutrality, PBC. http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4500507/index.html

encourage	New energy, new materials, new energy vehicles, green intelligent ships, green environmental protection, advanced equipment, energy electronics, etc.
Limitation and phasing out	Control the production capacity of steel, cement, flat glass, electrolytic aluminum, petrochemical and chemical industries (e.g., urea, ammonium phosphate, calcium carbide, caustic soda, and yellow phosphorus), etc. Accelerate the implementation of green upgrading and transition of the production of steel, non-ferrous metals, petrochemicals and chemicals, building materials, textiles, light industry, machinery, etc.

Source: NDRC, Guidance Catalogue for Industrial Structure Adjustment (2023, Solicitation of comments).

(b) Pillar Two: Improving the energy efficiency at all stages of the manufacturing

Targeting 17 energy intensive and emission intensive industries, energy efficiency benchmarks were settled and updated every 2 years,[52] For those projects failing to reach the benchmarks, NDRC also provided implementation guidelines for upgrading using advanced technologies and equipment.[53] Upgrading energy consuming equipment, such as industrial kilns, boilers, motors, pumps, fans, and compressors, is the key to improve the energy efficiency of the whole industrial process. Therefore, authorities continued to update national mandatory standards on energy efficiency, some of which have reached or even exceeded international standards. NDRC formulated three-level benchmarks for key energy consuming products for equipment suppliers and customers. The government also aims to speed up and strengthen the energy-saving standards in the coming years.[54]

Energy conservation supervision is an important regulatory tool established during the 2010s. It will continue to play a significant role in controlling the overall energy usage and the level of energy efficiency.[55] Furthermore, a green manufacturing evaluation system will be constructed, including energy conservation, water efficient utilization, and the comprehensive utilization of industrial solid waste resources. It will cover not only the operation process, but also the green design, products, and supply chains. In addition, third-party evaluation will be strengthened as a to complement regulatory supervision.

Digitalization is a key enabling technology to promote the green industrialization by deeply integrating smart solutions into the industrial processes. Digital solutions could effectively optimize the production flows, improve equipment operating efficiency, enhance the accuracy of production management, and even optimizing the resource allocation among different industries. Therefore, ten regions were selected by the central government to demonstrate a collaborative digital and green transformation[56]. The demonstration starts from the beginning of 2023 and will last 2 years, with emphases on the integration of digital solutions in the traditional industrial processes, greening the digital industries, and building green and convenient city operating digital platforms.

(c) Pillar Three: Promoting energy transition and circular economy.

Apart from promoting the energy transition by speeding up the utilization of renewable energy as detailed in Chapter 4, optimizing the allocation of industries is another important way to improve the structure for iron steel, aluminum smelting and other energy-intensive industries. The green supply capacity in renewable-energy-resource-rich areas will be improved. Industries with local characteristics and ecological industries will be encouraged in areas with abundant ecological and environmental resources and in arears that are ecologically fragile.

[52] Energy efficiency benchmark levels in key industrial fields (2023 edition), NDRC. https://www.gov.cn/zhengce/zhengceku/202307/content_6890009.htm.
53 Implementation Guidelines for Energy Conservation and Carbon Reduction Transformation and Upgrading in Key Areas of High Energy Consumption Industries (2022 Edition), NDRC. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202202/t20220211_1315446.html.
54 Notice on Further Strengthening the Updating, Upgrading, and Application Implementation of Energy Conservation Standards, NDRC, 2023. https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/202303/t20230317_1351321.html
55 Notice on Further Strengthening Energy Conservation Supervision Work, NDRC. https://www.gov.cn/zhengce/zhengceku/2021-06/03/content_5615181.htm.
56 Five departments jointly carry out comprehensive pilot projects for digital and green collaborative transformation and development, MEE. https://www.mee.gov.cn/xxgk/hjyw/202211/t20221123_1005915.shtml.

Circular economies of energy and materials does not only improve overall energy efficiency but promotes a sustainable utilization of the resources. Similar to EU, China has been putting more focus on this area. China will continue to improve the recycling rate of wastewater and heat, as well as a better treatment of industrial solid waste. In addition, technological advances will promote a better utilization and reuse of a variety of resource, such as scrap steel and waste non-ferrous metals, plastics, tires, paper, electrical and electronic products, batteries, oil, and textiles.

At the beginning of 2023, NDRC together with other ministries published the Guiding Opinions on Coordinating Energy Conservation, Carbon Reduction, and Recycling to Accelerate the Updating and Renovation of Product Equipment in Key Fields.[57] This policy document suggests local government aid inn connecting supply and demand. Large sorting, processing, and trading centers of wastes are recommended to promote the circular industry to become large-scale, standardized, and clean. Within the circular utilization system, green procurement will be an important tool to provide dedicated support. By ways of trade-in, cash pledge, and green labeling, the broader customers will be attracted to participate in relevant activities. Attentions are also paid to new areas, such as wind turbines, photovoltaic solar panels, and power batteries. The recycling and reuse of these specialized equipment will be further standardized.

5. Policy measures

China's government has used multiple ways to accelerate the green industrialization. Some examples were mentioned in the previous section. A few commonly used tools are summarized as follows to provide an overview:

Reduction of taxes and fees: In the successful cases of the solar PV technology and electric vehicles, subsidies stimulated the expansion of these industries. As these industries mature, most of subsidies were gradually reduced and eventually ended. However, some were extended, such as the reduction of purchasing tax of new energy vehicles and the reduction of value-added tax from the wind generation. To stimulate the green transition in suburban regions, additional tax reductions were applied to electric vehicles and green building materials to the villages and small towns.[58] [59]

Green finance: China also promotes green finance to support the green industrialization. The standards and implementation procedures for green credit green bond were published. Financing institutions are asked to disclose environmental information following a standardized and strict rule. MEE and POB has decided to provide dedicated and accurate supports to segmented industries and fields[60].

Management through categorization: Using catalogs to implement diversified policies or to set different bars for market entrances is an effective tool to guide the development of industries. To facilitate a clear direction of green transition, China has created several catalogs together with other policy tools, such as Green Bond Endorsed Projects Catalogue, National Catalogue of Advanced and Applicable Process Technology Equipment for Comprehensive Utilization of Industrial Resources, and Green Industry Guidance Catalogue as previously mentioned.

Demonstrations and pilots: To accumulate experiences in field operation, and to promote technological and business innovations, demonstrations and pilots are carefully selected and publicly announced. Projects or enterprises are sometimes offered specially policy measures, such as reduction of taxes and promised permit of land use. On the other hand, the announcement itself may serve as an honor to the project or the company to build reputations.

Evaluation, assessment, and inspection: To force the industries to follow the standards and to guarantee a healthy market environment, assessments and inspections are necessary. The Central Environmental Projection Inspection has become the most strict and effective way to implement these changes. Actions to

[57] Guiding Opinions on Coordinating Energy Conservation, Carbon Reduction, and Recycling to Accelerate the Updating and Renovation of Product Equipment in Key Fields, NDRC. https://www.gov.cn/zhengce/zhengceku/2023-02/25/content_5743274.htm

[58] Notice on Carrying out the 2023 New Energy Vehicle Campaign to the Countryside, MEE, 2023. https://wap.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2023/art_6dbc82a29e604abb99a42cd4cf4924ca.html.

[59] Notice on Carrying out the 2023 Green Building Materials Campaign to the Countryside, MEE, 2023. https://wap.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2023/art_50a1fff89b3045abb24a9b02d367b66d.html.

[60] Guiding Opinions on Strengthening Industrial and Financial Cooperation to Promote Green Industrial Development, MEE, 2021. https://www.gov.cn/zhengce/zhengceku/2021-11/06/content_5649400.htm.

achieve 2030 targets were included in the Inspection since 2021. During the last round of inspection, some cases were disclosed and resolved, and the responsible persons were dealt with severely.[61]

6. Conclusion

China now has an established track record of promoting carbon emission mitigation, focused on energy conservation and pollutant emissions reduction. More efforts on CO2 mitigation in the secondary industry are in store. China will gradually evolve into low-carbon development, guided by efforts to reach the 30-60 targets. The green transition of industries will be a key strategy to continue industrial development and reduce CO2 emission simultaneously, to develop more green industries, promote more low-carbon transition for energy intensive companies, and finally to decouple the economic development with CO2 emission.

Appendix 1

Table 4.3 Direct CO_2 emissions by sector (1995−2020)

	1995	2000	2002	2005	2007	2010	2012	2015	2017	2020
Agriculture	76	47	56	84	86	89	96	110	116	104
Coal mining	160	173	159	427	454	680	786	562	464	330
Oil & gas	30	39	45	31	39	44	40	37	35	36
Metal mining	6	5	6	11	13	17	18	16	10	8
Non-metal mining	15	15	17	16	22	23	32	25	21	19
Food & tobacco	84	66	69	101	120	138	135	113	103	88
Textiles	52	33	36	65	69	73	60	92	71	23
Cloth	8	6	6	10	14	14	13	10	7	5
Wood & furniture	9	7	7	12	14	17	15	12	6	2
Paper & cultural Goods	45	42	46	77	89	105	107	98	98	79
Refining & coking	158	191	206	494	546	679	819	944	908	1091
Chemicals	278	225	252	429	503	548	629	708	598	595
Non-metal mineral	264	200	231	468	523	607	637	632	547	527
Metal smelting	277	266	283	511	568	729	807	948	925	907
Metal production	10	7	8	10	15	15	17	14	13	23
General equip	19	10	10	17	23	27	13	10	9	6
Special equip	14	9	9	11	15	17	12	10	7	5
Transport equip	19	19	21	20	23	26	27	21	21	15
Electric machinery	8	6	6	9	15	16	17	17	6	4
Communication & computers	4	4	5	6	8	8	7	6	6	10
Instrumentation	2	1	1	1	1	2	1	1	1	0
Other manufacturing	19	9	9	9	11	13	19	16	11	11
Power and heating (R)	842	1088	1328	2004	2427	2888	3493	3221	3579	4140
Gas production	15	22	22	28	29	26	23	13	15	47
Water production	1	1	1	1	1	2	1	1	1	1
Building construction	16	22	22	31	34	41	43	51	51	48
Sales	38	53	66	94	108	135	157	189	205	175

[61] Press Conference on the Progress and Effectiveness of Central Ecological and Environmental Protection Inspection. https://www.mee.gov.cn/ywdt/xwfb/202207/t20220706_987866.shtml.

Transportation	103	186	209	322	369	450	549	633	654	606
Other	81	79	91	120	136	147	157	171	183	196
Household	269	187	188	242	264	271	294	316	332	349
Total	2921	3017	3414	5661	6538	7845	9023	8993	8999	9450

Source: Author calculations.

Appendix 2

Table 4.4 CO_2 emissions intensity by industrial sector (1995–2020)

	1995	2000	2002	2005	2007	2010	2012	2015	2017	2020
Coal mining	8.5	5.0	3.7	9.4	8.5	7.6	8.2	7.5	4.3	2.75
Oil & gas	1.3	1.3	1.0	0.6	0.6	0.7	0.6	0.8	0.5	0.54
Metal mining	1.6	0.6	0.6	0.9	0.6	0.4	0.4	0.3	0.2	0.12
Non-metal mining	1.3	1.3	1.4	2.0	1.3	1.3	1.1	0.7	0.5	0.36
Food & tobacco	1.2	0.7	0.8	0.9	0.8	0.8	0.6	0.4	0.3	0.29
Textiles	3.1	1.0	1.2	1.6	1.2	1.0	0.9	1.2	1.1	0.32
Cloth	0.6	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.06
Wood & furniture	1.6	0.6	0.5	0.7	0.5	0.5	0.3	0.2	0.1	0.04
Paper & cultural goods	3.3	1.6	1.5	2.4	2.2	2.2	1.5	1.1	1.1	0.75
Refining & coking	21.5	7.9	16.1	21.1	15.3	12.3	12.6	11.8	10.4	10.85
Chemicals	8.3	3.7	3.5	4.9	4.2	3.3	3.1	2.6	1.9	1.61
Non-metal mineral	8.0	6.8	7.4	7.2	5.8	5.5	4.7	3.9	2.5	2.29
Metal smelting	9.4	9.4	4.8	7.0	4.3	5.0	4.1	5.0	3.6	3.29
Metal production	0.9	0.4	0.4	0.4	0.4	0.3	0.3	0.1	0.1	0.18
General equip	1.1	0.3	0.3	0.4	0.4	0.3	0.1	0.1	0.1	0.05
Special equip	1.2	0.4	0.3	0.4	0.3	0.3	0.2	0.1	0.1	0.05
Transport equip	1.4	0.7	0.5	0.5	0.3	0.2	0.2	0.1	0.1	0.08
Electric machinery	0.6	0.3	0.2	0.2	0.3	0.2	0.2	0.1	0.0	0.04
Communication & computers	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.06
Instrumentation	1.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.01
Other manufacturing	13.8	0.6	0.2	0.7	0.6	0.2	3.3	1.3	0.1	0.01
Power and heating	25.2	18.6	17.5	22.6	22.8	27.3	32.2	23.3	20.8	18.96
Gas production	20.4	17.3	15.3	10.6	10.6	5.6	3.9	1.1	1.1	2.38
Water production	0.2	0.2	0.2	0.1	0.1	0.3	0.2	0.1	0.1	0.03
Building construction	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.07

Source: Author calculations.

Chapter V. Policies and practices in advancing green agricultural development in China

A. Taking climate challenges into China's agricultural agenda

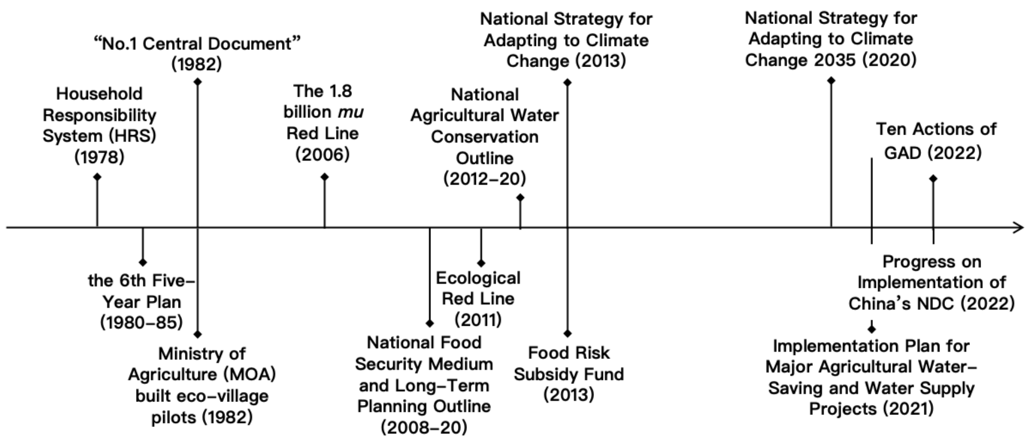
Ensuring food security has consistently been regarded as top priority of China's agricultural policy agenda. Despite having a per capita arable land of merely 1.2 *mu* (0.08 hectare),[62] China has successfully managed to provide sustenance for its vast population of 1.4 billion people, which accounts for approximately 20% of the world population. This has been accomplished with only 9% of the world's arable land and 6% of freshwater resources.

From 2008 to 2018, China`s agricultural sector incurred an economic loss of 976 billion CNY, due to droughts, floods, wind, and hail disasters, accounting for 55% of the global aggregate. It's predicted that by 2030, seasonal droughts may bring about 8% of yield drop of the three staple crops of rice, wheat, and maize.[63] Future disasters caused by extreme weather events could potentially push the formerly better-off farmers back into poverty or exacerbate their poverty conditions.

Under such circumstances, climate change has become an issue of growing concern among China's policy makers. The government has to take actions to advance high-quality green agricultural development (GAD), which balancing the goals of food security social equity and green transition, among multiple agendas of economic growth.

The below graph outlines the main policies of China in advancing GAD, which we will explore in this chapter.

Figure 5.1 GAD-Relevant Top-Level Comprehensive Policies in China (1978-2022)



Source: Drawn by the authors.

[62] The World Bank Group (2020), *Arable land (hectares per person) -China, Data*. Available at: https://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?locations=CN (accessed 29 April 2023).
[63] Yu Tian, Ding Hongyu, Zhao Haijun (2021), "Climate Resilience Agriculture to be Carried Out for Adaptation", World Resource Institute, 23 June. Available at: https://wri.org.cn/insights/agriculture-resilience-adaptation (accessed 17 June 2023).

1. Climate adaptation in agriculture - bridging food security with climate agenda

In 2013 and 2022, Chinese government jointly released *National Strategy for Adapting to Climate Change*[64] and *National Strategy for Adapting to Climate Change 2035*[65] respectively.

These strategies outline directions for agriculture to adapt to climate change in China as follows:

(a) Transforming agricultural climate adaptation for optimal health and market outcomes

The significance of personal health in relation to climate was recognized as a key factor in motivating the citizens and farmers to get involved in the GAD processes. Since 2002, the Chinese government enacted *the Clean Production Promotion Law* (No.72 Presidential Decree), in response to growing public concern about food security from safety and health concern. A comprehensive evaluation and precise zoning is conducted, based on agricultural climate resources, crop structure, and variety configuration. This ensures the precise alignment of agricultural product utilization with appropriate market channels. Subsequently, farmers started to pay attention to "pollution-free (*wu gonghai*)" agricultural products.[66]

To guard against climate change risks, high-yield, high-quality, and stress-resistant crops, livestock, poultry, aquaculture, as well as adaptive varieties of forestry, fruits, and flowers, are selected and improved. The emergence of unique local food brands distinguished by geographical, biological, cultural, and anthropological factors, has inspired local communities to develop brand-based value chains for poverty reduction and rural revitalization.

The Provincial-level competition served as a stimulus for the acceleration of policy implementation. By 2019, Sichuan province achieved a total of 1,385 varieties of "Green Food", ranking the first in Western China.[67] By 2020, pollution-free, organic, and low-carbon agricultural products – also known as the "3 High-Quality (*pin*)"- and geographical indication standardized goods - "1 Standardized (*biao*)" - of Anhui Province reached 7,262 kinds, ranking the 6th in Chinese provinces, which have increased farmers' income by 529 million CNY.[68]

Table 5.1 Main Index of GAD for "14th Five-Year Plan" (2021-2025)

Categories	Main Indicators	2020	2025
Agricultural Climate Resources	Soil Quality Grade in Cultivated Land	4.76	4.58
	Farmland Irrigation Water Effective Utilization Coefficient	0.56	0.57
Production Area Environment	Major Crops Chemical Fertilizers Utilization rate (%)	40.2	43
	Main Crop Pesticide Utilization Rate (%)	40.6	43
	Comprehensive Utilization Rate of Straw (%)	86	>86
	Comprehensive Utilization Rate of Livestock and Poultry Manure (%)	75.9	80
	Waste Mulch Recovery Rate (%)	80	85

[64] National Development and Reform Commission (NDRC) (2013), "National Strategy for Climate Adaptation". Available at: http://www.gov.cn/zwgk/2013-12/09/content_2544880.htm (accessed 11 November 2022).
[65] MEE (2022), *National Strategy for Climate Adaptation 2035*. Available at: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202206/W020220613636562919192.pdf (accessed 22 September 2023).
[66] Zemin Jiang (2002), *Presidential Decree No.72: The Clean Production Promotion Law of People's Republic of China*, The 28th Meeting of the Standing Committee of the Ninth National People's Congress, 29 June, Available at: https://www.gov.cn/gongbao/content/2002/content_61640.htm (accessed 20 June 2023).
[67] Pan Hu (2019), "Sichuan Possesses 5,375 Kinds of '3High-Quality (*pin*) 1 Standardized (*biao*)' Agricultural Products, with Geographical Indication Ranking the 2nd in China", 21 May, Available at: http://www.iprchn.com/Index_NewsContent.aspx?NewsId=116156 (accessed 2 July 2023).
[68] Yong Zhang (2020), "Anhui's '3 High-Quality and 1Standardized' Agricultural Products Totaled 7,262, Ranking the 6th in China", *Anhui Commercial Times,* 22 January. Available at: http://ah.sina.com.cn/news/2020-01-22/detail-iihnzahk5690207.shtml (accessed 10 July 2023).

Categories	Main Indicators	2020	2025
Agricultural Ecology	Newly Added Degraded Farmland Treatment Area (10,000 *mu*)	-	1400
	Newly added Northeast black soil protection and utilization area (100 million *mu*)	-	1
Green Supply	The number of certifications of green, organic, and geographically marked agricultural products (10,000)	5	6
	The overall pass rate of routine monitoring of agricultural product quality and safety (%)	97.8	98

Source: Ministry of Agriculture and Rural Affairs (MARA) of China, et al. (2021), The National GAD Plan in the 14th Five-Year Plan, August 23, p.14, Available at: http://data.mofcom.gov.cn/upload/file/07.pdf (accessed 11 September 2023).

The first national planning for GAD, *the National GAD Plan in the 14th Five-Year Plan (2021-2025)* lists targets in 11 indicators in 4 interconnected areas: integrating agricultural climate resources, production area environment, agricultural ecology, and green supply into a life cycle. The underlying logic is that: As long as the ecology (soil, water, air, etc.) is healthy and sound, there will be more crops; As long as values of local green, organic, and geographically marked agricultural products are distinguished, certifications, monitoring, and market services will be provided. Thus, the better ecology farmers have, the more prosperity the y could enjoy.

(b) Improving agricultural risk reduction system through water-saving irrigation

Agriculture is a major water consumer, accounting for 56% of the national total water usage. In some places, this proportion escalates to 62% to 90%. In 2012, the State Council of China released *the National Agricultural Water Conservation Outline (2012-2020),* which raised specific targets for the national water-saving system (table 5.2).

Table 5.2 China's Agricultural Water Conservation Targets Outline by 2020
A preliminary agricultural water-saving system will be established nationwide, characterized by a harmonized layout of agricultural production with water-soil conditions, a coordination between agricultural water consumption scale and use efficiency, and a combination between engineering and non-engineering measures.
Basic completion of large-scale and key medium-sized irrigation areas for supporting, water-saving renovations, and renewal, and transformation of large and medium-sized irrigation and drainage pumping stations will be achieved. Key counties for small-scale farmland water conservancy will be established, covering the majority of agricultural counties.
The effectively irrigated area in China will reach 1 billion *mu* (66.7 million *ha*), with an additional 300 million *mu* (20 million *ha*) of water-saving irrigation projects, of which over 150 million *mu* (10 million *ha*) will be newly added for efficient water-saving irrigation projects.
The national agricultural water consumption will be basically stable, with the effective utilization coefficient of irrigation water in farmland reaching 0.55 or above.
The promotion area of rain-fed water-saving agricultural technology nationwide will exceed 500 million *mu* (33 million *ha*), with a coverage rate of efficient water use technology at over 50%.

Source: Office of the State Council (2012), The National Agricultural Water Conservation Outline (2012-2020)

Followed the outline, China has achieved progress to those targets. Firstly, the "preliminary agricultural water-saving system" has been established. It maintains China's rural water consumption at 340 billion m^3 annually, sustaining 75% of national food production and over 90% of cash crops with 51% of lands irrigated.[69]

Secondly, there have been 7,330 large-scale and key medium-sized irrigation areas constructed, covering most of the agricultural counties, increasing grain producing capacity by about 30 billion kg. The average yield per acre in large and medium-sized irrigated areas improved by 100 kg or so.[70]

Thirdly, the effectively irrigated area of China has increased from 240 million *mu* (16.08 million *ha*) in 1949 to 1.037 billion *mu* (69.5 million *ha*) in 2021, increasing 797 million *mu* (53 million *ha*), which has become the largest in the world.[71]

Fourthly, effective utilization coefficient of irrigation of farmland reached 0.565 in 2020,[72] and was lifted to 0.568 in 2021.[73]

Fifthly, the promotion area of water-saving irrigation area was enlarged to 567 million *mu* (37.8 million *ha*), and a coverage rate of efficient water use technology water-saving technologies, such as sprinkler irrigation, micro-irrigation and pipeline irrigation, have been utilized for 350 million *mu* (23 million *ha*), which is more than 50% set in the goals.

Through the implementation of public-private partnerships (PPPs), there are advancements in has been realized in to constructions, water-saving renovations, and revitalization of large and medium-sized irrigation areas. The historical irrigation projects, such as Dujiangyan, Jinghui Canal, Hetao Irrigation District, and Qingtongxia have been rejuvenated. Furthermore, a large number of new irrigation areas like Peishi-Hang, Jingdian, Changma, and water transfer project from Datong River in Qinghai Province to Qinwangchuan district in Gansu Province (*yinda ruqin*) are being constructed. The implementation of drip irrigation technology in a 300 *mu* (20 *ha*) of vineyard in Huqiu Village, Ji'an City, Jiangxi Province, resulted in an additional income of 500 yuan/*mu* (7,463 yuan/ha) for farmers. The implementation of subsurface drip irrigation technology in the onion fields at Horsewatering Farm, Yumen City, Gansu Province, resulted in a significant reduction in water usage from 600-800 m^3/*mu* (8,955-11,940 m^3/*ha*) to 300 m^3/*mu* (4477.61 m^3/*ha*), leading to a saving over 40%. Additionally, the per-acre economic benefits increased by over 30%.[74]

While the water-saving irrigation is being consolidated, flood risk subsidies are also an important part of the central financing to prevent and control the uncertainty of natural disasters. In 2013, to control risks of food insecurity due to droughts in Southern provinces and floods in Northern ones, Chinese government allocated 31.5 billion CNY as "Food Risk Subsidy Fund".[75] Subsidies in forms of natural disaster insurance, micro-credits, microfinance services, and government bonds, have been innovated to provide more alternatives for tangible progress in agricultural production.

[69] Leilei Ji (2021). "How Much Potentiality Does Agricultural Water Conservation Have?" *Economic Daily*, 23 August, https://www.gov.cn/xinwen/2021-08/23/content_5632704.htm (accessed 27 September 2023).
[70] Fanchao Diao (2022). "Ministry of Water Resources: The Central Government of China Invests 150 billion CNY for Construction and Rebuilding of Irrigation Areas". 13 September 2022. Available at: https://m.thepaper.cn/newsDetail_forward_19881100?from=sohu (accessed 2 October 2023).
[71] Shu Yang (2022). "China Has Become A Country with the Largest Irrigated Area". *Guangming Daily*. 6 November 2021. Available at: https://www.gov.cn/xinwen/2022-11/06/content_5724969.htm (Accessed 10 October 2023).
[72] MEE (2022), *National Strategy for Climate Adaptation 2035*, p.13. Available at: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202206/W020220613636562919192.pdf (accessed 22 September 2023).
[73] Shu Yang (2022). "China Has Become A Country with the Largest Irrigated Area". *Guangming Daily*. 6 November 2021. Available at: https://www.gov.cn/xinwen/2022-11/06/content_5724969.htm (Accessed 10 October 2023).
[74] Leilei Ji (2021), "How Much Potentiality Does Agricultural Water Conservation Have?" *Economic Daily*, 23 August, https://www.gov.cn/xinwen/2021-08/23/content_5632704.htm (accessed 27 September 2023).
[75] Qu Changfu, Qiao Jinliang (2016). "Holding the Rice Bowl in Our Own Hands: A Comprehensive Review of the Implementation of National Food Security Strategy Since the 18th National Congress of the CPC", *Economic Daily*, 1 March. Available at: https://www.gov.cn/xinwen/2016-03/01/content_5047577.htm (accessed 1 May 2023).

Since the beginning of the 14th Five-Year Plan (FYP) period, China officially issued *the Implementation Plan for Major Agricultural Water-Saving and Water Supply Projects in 2021*. Through this, the construction of new large-scale irrigation areas could increase 15 million *mu* (1 million *ha*) of effective irrigated area. Similarly, another 124 areas implementing construction and renovation projects in current irrigation areas will improve irrigation to approximately 81 million *mu* (54 million *ha*). That will result in an annual increase in grain production capacity of 5.7 billion kilograms, with a total grain output of about 80 billion kilograms.[76]

(c) Increasing climate resilience of agricultural ecosystems through "Ecological Red Lines"

In light of the swift urbanization and industrialization the government has diligently safeguarded arable land as the basis for food security since the end of 1970s. At the beginning of the 21st century, China implemented measures to protect land and promote technologies advancements for food security. In 2006, as part of the 11th Five-Year Plan, the government affirmed that "Red Lines" of 1.8 billion *mu* (120 million *ha*) of arable land and 1.075 billion *mu* (72 million *ha*) of high-standard farmlands must be preserved.[77] Similarly, all stakeholders must comply with the arable land, grassland, and sown land areas, as outlined in *the National Food Security Medium and Long-Term Planning Outline (2008–2020)*, to prevent continuous decrease of arable land.

The "Red Line" was further developed into the national "Ecological Red Line" in 2011,[78] covering an area of 3.15 million km^2. This translates to over 30% of national land area, including the Qinghai-Tibet Plateau, the Yellow River, the Yangtze River, the Northeast Forest Belt, the Northern Sand Control Belt, the Southern Hilly and Mountainous Area, and the Coastal Zones. It also encompasses the vast majority of grasslands, important wetlands, coral reefs, mangrove forests, seagrass beds, and other crucial ecosystems, as well as undeveloped and uninhabited islands. Besides, the "Marine Ecological Conservation Red Line" covers an area of over 150,000 km^2. To guarantee the arable land areas and national cultivated land quality for the ecological "red lines",[79] the Ministry of Natural Resources (MNR) jointly compiled "National Land Space Planning Outline (2021-2035)" issued by Central Committee of the Communist Party of China and the State Council.[80] For sector-based work, governments and non-governmental organizations collaborate for mutual innovative solutions.

At the local level, the provinces possess the autonomy to devise distinct measures in order to attain the national objectives; for example, in Yunnan, the total area of the ecological protection red lines is 118,400 km^2, accounting for 30.9% of its total land area, and 3.76% of China's total ecological conservation red line area. To leverage the rich biological, ethnic, and cultural diversities, Yunnan administrators have strategically designed its conservation areas into 11 sub-zones, emphasizing bio-conservation, watershed conservation, soil erosion and water loss prevention.[81] This flexible central-local relationship gives freedom for local actors to innovate and pilot new approaches for improved livelihoods.

---

[76] Ministry of Water Resources (MWR) and NDRC (2021), "Implementation Plan for Major Agricultural Water-Saving and Water Supply Projects during the 14th Five-Year Plan", 16 August. Available at: https://www.gov.cn/xinwen/2021-08/16/content_5631540.htm (accessed 15 September 2023).

[77] High-standard farmland, in simple terms, refers to fields compatible with modern agricultural production and management methods. They should be well-connected, with complete facilities, supporting infrastructure, fertile soil, good ecological conditions, and strong disaster resistance, ensuring successful harvests in both droughts and floods, while maintaining high and stable yields.

[78] Li Hou (2022). "How Comes the 1.8 billion 'Red Line'?" *Study Times*, 13 June. Available at: http://www.legaldaily.com.cn/Village_ruled_by_law/content/2022-08/10/content_8734978.html (accessed 1 August 2023).

[79] MOF, MARA (2022), *Notice on the Issuance of "Measures for Subsidy for Farmland Construction"*, 12 January. Available at: http://www.gov.cn/zhengce/zhengceku/2022-02/01/content_5671563.htm (accessed 12 March 2023).

[80] Yang Shu (2022), "China Has Taken Out Measures to Strictly Observe the Red Line of Arable Lands", *Guangming Daily*, 26 June. Available at: http://www.gov.cn/xinwen/2022-06/26/content_5697791.htm (accessed 10 October 2022).

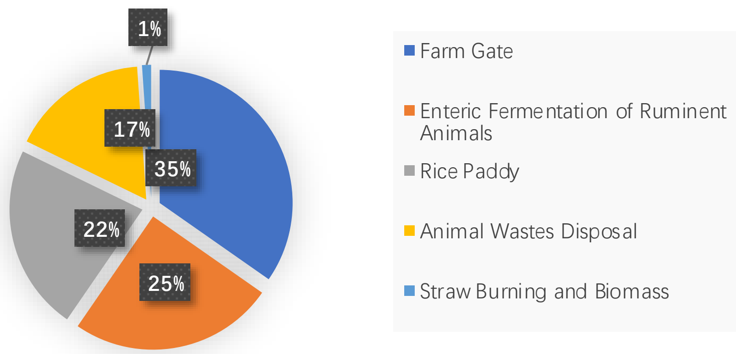
[81] "Biological and watershed conservation" are mainly the focuses of Northwest Dian Mountain Gorge, Ailao-Wuliang Mountainous Region, Southern Border Tropical Forests, Daying-Ruili River, Plateau Lakes, and Upper Reaches of Nujiang River. "Soil erosion and water loss control" is attached more importance by the Upper Reaches of Pearl River, Karst Region in Southeast Dian, Lower Reaches of Nujiang River, Central Mountain Gorge of Lancang River, Dry Valley and Plateau of Jinsha River, Lower Reaches of Jinsha River-Xiaojiang River Basin, Hot and Dry Valley and Mountain Plateau of Honghe (Yuanjiang) River. See Yunnan Government (2018), *Notice of Setting the Ecological Red Line of Yunnan Province [No.32]*, 29 June, https://www.yn.gov.cn/zwgk/zcwj/zxwj/201911/t20191101_184159.html (accessed 5 January 2023).

2. Climate mitigation in agriculture: transformation of carbon from source to sink

(a) State of play of GHG emission from China's agricultural sector

The agricultural and food system is not only greatly impacted by climate change, but also plays a crucial role in mitigating global warming. Approximately 21% to 37% of GHG emissions originate from agriculture in the world. However, it is possible to sequester these emissions by conserving energy, reducing carbon emissions in agriculture, facilities, and soil organic carbon (SOC) sink. Agricultural GHG emission (mainly composed by methane (CH_4) and nitrous oxide (N_2O) from crops and livestock) have a significant warming effect. N_2O has a warming capacity per unit of 298 times that of carbon dioxide (CO_2), while CH_4 per unit is 34 times that of CO_2. The potentiality of CH_4 and N_2O sequestration reaches 2.3 to 9.6 btCO_2e annually, making it the second-largest carbon sink capacity after new energy.[82]

Figure 5.2 Composition of China's Agricultural GHGs as Carbon Sources



Source: Ministry of Ecology and Environment of China (MEE) (2018), *The 2nd Biennial Report of China in Climate Change, p.16.*

China ranks the 5th in agricultural GHG emission which is about 600-710 mtCO_2e.[83] CH_4 and N_2O from crops and livestock accounts for 45% and 55% respectively. Among them, 34.7% is from within farm gate (such as nitrogen fertilizer), 24.9% from enteric fermentation of ruminant animals (such as beef, pork, or mutton), 22.6% from rice paddy, 16.7% from animal wastes disposal, and 1.1% from straw burning and biomass (Figure 5.2).[84]

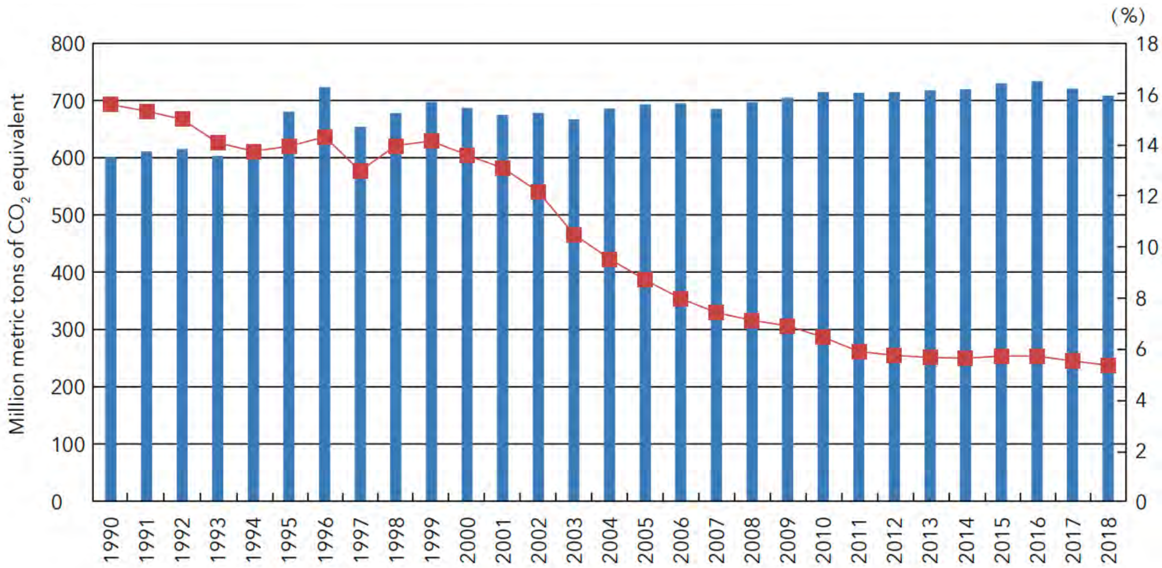
---

[82] Paola A. Arias, et al.(2021). eds. "Technical Summary", in *Climate Change 2021: The Physical Science Basis. Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)* (WMO/UNEP). New York: Cambridge University Press, p.102.

[83] The top 4 emitters of agricultural GHG are: Brazil (about 1,100 mtCO_2e), Indonesia (about 900 mtCO_2e), India (about 660 mtCO_2e), and Democratic Republic of Congo (about 655 mtCO_2e). See Giulia Conchedda, Francesco N. Tubiello (2020), "Emissions due to agriculture: Global, regional and country trends 2000–2018", *FAOSTAT Analytical Brief 18,* Rome: Environmental Team, Statistics Division, FAO, p.11. Available at: https://www.fao.org/3/cb3808en/cb3808en.pdf (accessed 11 September 2023).

[84] MEE (2018), *The 2nd Biennial Report of China in Climate Change*, Available at: https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/201907/P020190701765971866571.pdf (accessed 4 May 2023).

Figure 5.3 China's GHG Emission in Agriculture and Its National Share (1990-2018)



Sources: (1) FAO (2020), "Emissions due to agriculture: Global, regional and country trends 2000-2018", FAOSTAT (2023) Analytical Briaf 18, Rome: FAO, (2) p.11, Yumei, Zhang, et. al. (2021), "Transforming Agrifood Systems to Achieve China's 2060 Carbon Neutrality Goal", in Academy of Global Food Economics and Policy, China Agricultural University (AGFEP), China Academy for Rural Development, Zhejiang University (CARD), Centre for International Food and Agricultural Economics, Nanjing Agricultural University (CIFAE), Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences (IAED), International Food Policy Research Institute (IFPRI), 2021 China Food and Global Food Policy Report, pp.22-23, http://agfep.cau.edu.cn/module/download/downfile.jsp?classid=0&filename=2105141928327359.pdf (accessed 2 May 2023).

China's agricultural GHG emission peaked in 2016. Since the 1990s the agricultural sector`s contribution to the country`s total emissions steadily decreased from 16% to 5.5% in 2018 (Figure 5.3). The implementation of climate-smart technologies, supported by low-carbon-prone policies, help to mitigate agricultural greenhouse gas emissions.

(b) Agricultural Emission Reduction: Inputs Control and Recycling

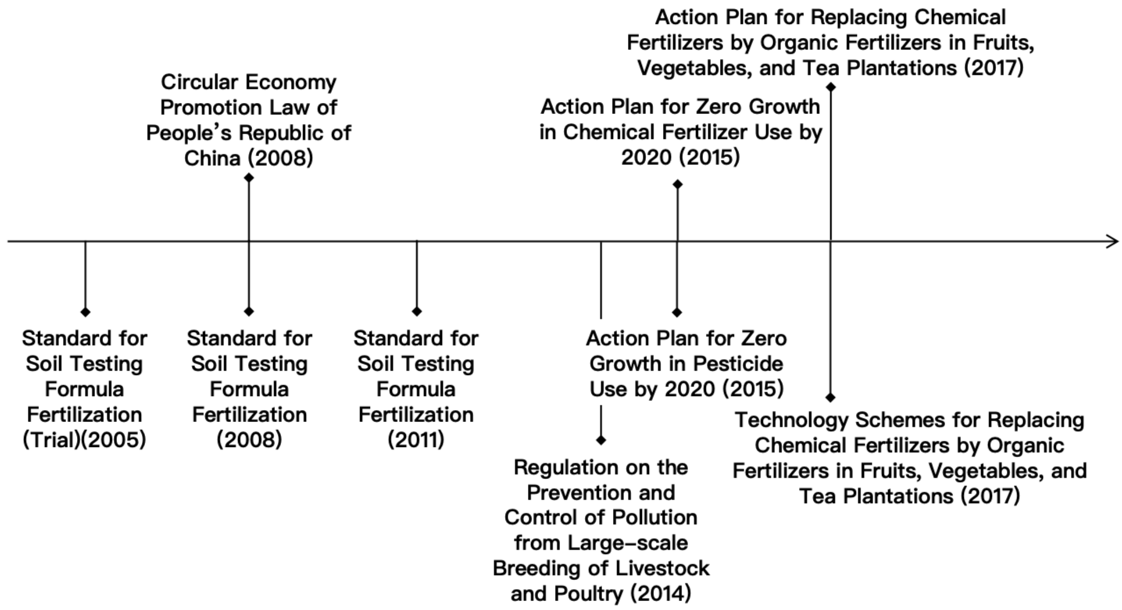
To effectively mitigate agricultural GHG emissions, it is crucial to focus on the carbon sources originating from crop plantations, livestock, and fishing breeding. To effectively mitigate agricultural GHG emission, it is crucial to focus on the carbon sources originating from crop plantations, livestock and fishing breeding. Emission reduction strategies should integrate both input management and recycling practices to optimize energy conservation and enhance overall efficiency.

From the perspective of reducing agricultural input emission and recycling for circular economy, policies have been released as shown in Figure 5.4.[85] While implementing the aforementioned policies, the Rural Biogas Tanks project, initiated in the 1970s, has been expanded since the 21st century by integrating with the "Rural Enrichment and Ecological Parks" to mitigate methane emissions.[86] Since 2005, Ministry of Agriculture (MOA) of China issued *Standard for Soil Testing Formula Fertilization (Trial)*. China invested 8 billion CNY to implement the "Soil Testing Formula Fertilization" Project for 200 million farmers and about 1.5 billion *mu* (100 million *ha*) of farmlands, increasing the utilization rate of fertilizer by 5%, reducing 10 million tons of

[85] Bin Lin, et al. (2019), "Mitigation of greenhouse gas emissions in China's agricultural sector: Current status and future perspectives", *Chinese Journal of Eco-Agriculture*, Vol.27, No.12, p.502.
[86] Targeted on clean household warming, efficient gardening, and pollution-free agricultural production, the "Rural Enrichment and Ecological Park" project, starting in 2000, with national funding of 3.4 billion CNY, had covered 2,594 counties, 26,383 villages, benefiting 3,750,000 households in China.

fertilizer and over 25 mtCO_2e of GHG emission. Consequently, this project helped achieve higher crop yield by 6%−10%.[87]

Figure 5.4 Agricultural Emission Reduction Policies in China (2005-2022)



Source: Authors.

Significant advancements have been achieved in the circular economy through decades of controlling and recycling agricultural inputs. China's national fertilizer usage, for instance, decreased by 12.8% by 2020, while soil testing and formula fertilization adoption increased by 1.93 billion *mu* sessions, a 17.7% rise from 2015. Achievements are based on non-ergotic and novel solutions for which farmers or experts might not have exact template to follow.[88] For example, it is the high-yield, low-emission rice cultivation techniques, reducing CH_4 emissions from rice paddies, that prove to be the most effective in agricultural emission reduction.

This establishes a new rice cultivation model, soil testing fertilization formula, together with straw returning and water conservation. This has consequently led to a 4.1%-8.8% increase in rice yield, 30.2%-36% increase in nitrogen fertilizer utilization efficiency, 8.3%-9.7% increase in income, and a 31.5%-71.7% reduction in CH_4 emissions. Therefore, a correlation exists between the utilization of water-conserving, drought-tolerant rice and fertilizer application. When balance is achieved, CH_4 emissions from one *mu* of rice field could be reduced by 90%-95%.

Due to this experimental finding, the provinces of Anhui, Hubei, Zhejiang and Hainan have been planting the rice varieties for over 3 million *mu*. By 2021, 96 counties in China participated in the enhancement of livestock and poultry manure resource utilization. Besides, emission reduction potentiality is also explored in fisheries and facility efficiency areas. With subsidy funds of 266 million CNY allocated by central government, 136 national-level marine ranch demonstration areas are established, and 20.93 million m^3 of artificial fish reefs are deployed, creating new areas of 2,336 km^2 for ocean carbon sequestration. Safe production and energy-

---

[87] Richard Lord, Ruben Sakrabani (2019), "Ten-year legacy of organic carbon in non-agricultural (brownfield) soils restored using green waste compost exceeds 4 per mille per annum: benefits and trade-offs of a circular economy approach". *Science of the Total Environment*. Vol.686, pp.1057-1068.
[88] Lewis Husain, Gerald Bloom (2020), "Understanding China's growing involvement in global health and managing processes of change", *Globalization and Health*, Vol.16, No.39, p.3.

saving emission reduction in agricultural machinery is promoted with over 30,000 machines scrapped, settled, renewed, or phased-out, optimizing the equipment structure.[89]

3.Agricultural Sequestration: Increasing Soil Organic Carbon Sink

China has exhibited the lowest per capita arable land among developing nations, with a historically low soil organic carbon value and limited advancements prior to the 21st century. In the 1980s, the 20cm SOC of China was only 26.6–32.5 tC/ha90, compared to the average SOC value in the US and Europe at the same period had been 43.7 tC/ha[91] and 40.2 tC/ha[92]. In 1999, after China issued *Ban on Straw Burning and Regulations on Comprehensive Straw Utilization*, the rate of straw return raised from 25% to 39.7% in 2010, and the 20cm SOC of cropland increased to 32.34–33.47 tC/ha, while the European average level was 46.8 tC/ha.[93]

SOC sequestration involves four minor policy sectors that are intricately linked to the health management of topsoil. These sectors include forestry (*senlin*), where trees in wooded areas act as carbon sinks; grassland (*caoyuan*), which holds significant potential for sustainable livestock; farmland (*nongtian)*, where soil fertility can sequester GHG emissions; and systematic management of landscape, water, forests, farmland, lakes, and grassland (*shanshui lintian hucao xitong zhili*). The SOC sequestration work is progressing steadily with gradual public disclosure of policies and regulations, as depicted in Figure 5.5.

In the *Action Plan for Conservation Tillage of Black Soil in Northeast China (2020–2025)* issued in 2020,[94] the agricultural production of corn, soybeans, and wheat is encouraged to apply non-tillage approach (in provinces of Liaoning, Jilin, Heilongjiang, and cities of Chifeng, Tongliao, Xing'an League and northeast Hulunbeier). This is aimed at achieving 140 million *mu* (9.3 million *ha*) of non-tillage land by 2025, accounting for about 70% of the total cultivated land in Northeast China.[95]

---

[89] MEE (2021). "Progress on the Implementation of China's Nationally Determined Contributions (2022)", National Determined Contribution Registry, United Nations Climate Change, 28 October. Available at: https://unfccc.int/NDCREG (accessed 20 November 2023).

[90] Guohan, Song, et al. (2005). "Topsoil organic carbon storage of China and its loss by cultivation". *Biogeochemistry*, Vol.74, pp.47-62; Zhangcai, Qin, et al. (2013), "Soil organic carbon sequestration potential of cropland in China". *Glocal Biongeochemical Cycles*. Vol.27, pp.711-722.

[91] Yinyan, Guo, et al. (2006). "Analysis of factors controlling soil carbon in the conterminous United States". *Soil Science Society of America*. Vol.70, pp.601-612.

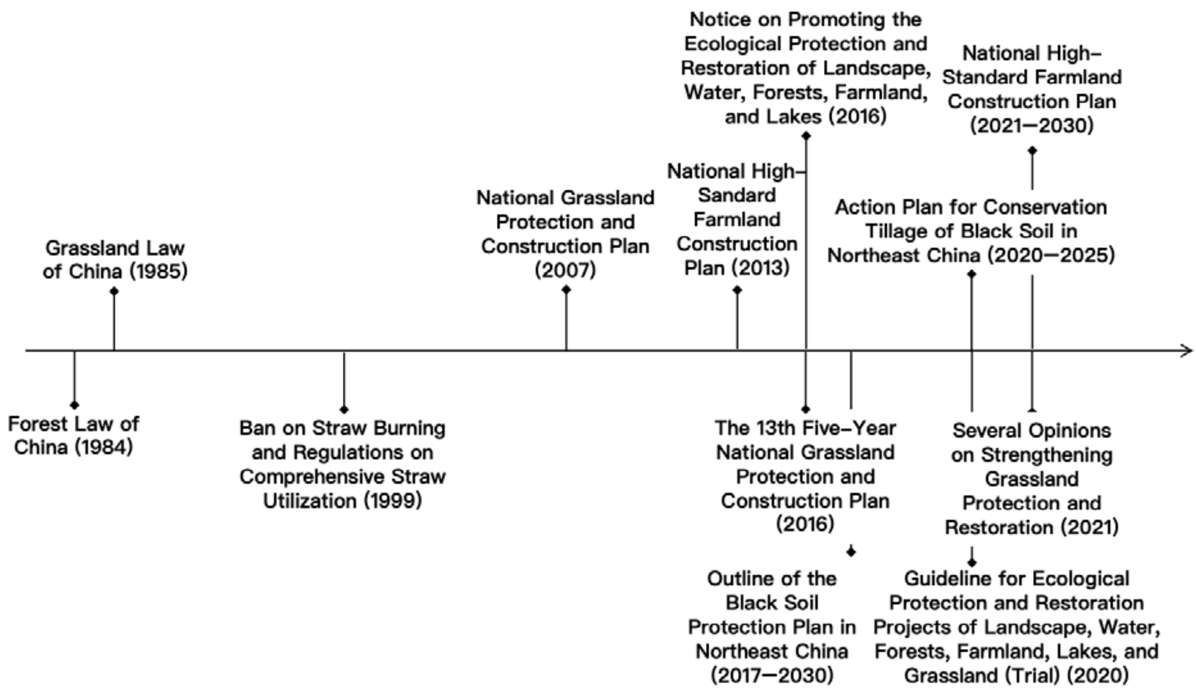
[92] Pete Smith, et al. (2000). "Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture". *Global Change Biology*. Vol.6, pp.525-539.

[93] Yongcun, Zhao, et al. (2018). "Carbon sequestration potential in Chinese cropland soils: review, challenge, and research suggestions". *Bulletin of Chinese Academy of Sciences*. Vol.33, pp.191–197.

[94] "Conservation tillage" is a modern farming technology system with straw mulching, no or less tillage and sowing as its main technological methods, which can effectively reduce soil degradation and water erosion, while increasing fertility, preserving soil moisture and drought resistance, and improving agricultural ecology and economic benefits.

[95] MARA, MOF (2020). *Action Plan of Conservation Tillage in Northeast Black Land (2020–2025) (No.2 [2020] of Agricultural Machinery)*. 18 March. http://www.gov.cn/zhengce/zhengceku/2020-03/18/content_5492795.htm (accessed 17 September 2022).

Figure 5.5 Policies Promoting Sequestration by SOC Sink in China (1984-2025)



Source: Authors.

By 2021, The central government allocated 2 billion CNY for deep plowing and land preparation nationwide, covering an area of 121 million *mu* (8.07 million *ha*) of topsoil in China. The quality of 54 million *mu* (3.6 million *ha*) of afforestation and 46 million *mu* (3.1 million *ha*) of grassland was also improved. Additionally, 21.6 million *mu* (1.44 million *ha*) of deserts and rocky deserts were reclaimed. Nine national desertified land conservation areas were further constructed, with 34.67 million *mu* (2.31 million *ha*) of new forests nurtured. Over 14 million *mu* (933,333 ha) of degraded forests were restored, and 1.09 million *mu* (72,667 *ha*) of wetlands newly added. About 105.51 million *mu* (7 million *ha*) of high-standard farmland has been established. In the well-known black soil areas of Northeast China, over 100 million *mu* (67 million *ha*) of farmland protection has been completed, including 72 million *mu* (4.8 million *ha*) of conservation tillage land. There have been 401 counties implementing "Comprehensive Straw Utilization Project", with the outcome of 400 million tons of straw returning to the fields, covering an area of nearly 1.1 billion *mu* (73.3 million *ha*).[96] Technologies of carbonizing straw and "biomass-charcoal-fertilizer" technology, SOC-oriented land management, and "Soil Testing Formula Fertilization Action", could sequestrate CH_4 or N_2O emission by 500mtCO_2e, 146.67mtCO_2e, and 18.35mtCO_2e respectively. The total of them may reach 665.02 mtCO_2e, which could offset most of the annual agricultural GHG emission in China.[97]

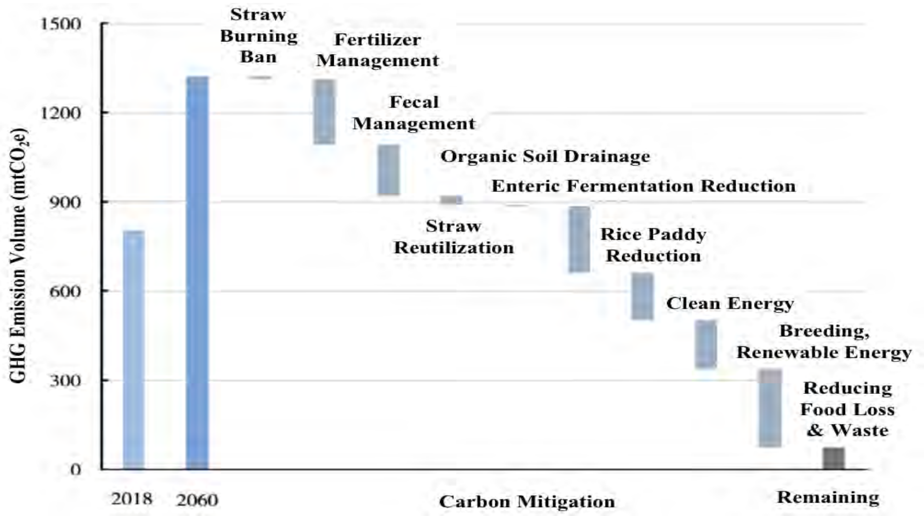
[96] MEE (2018), *The 2nd Biennial Report of China in Climate Change*, p.16. Available at: https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/201907/P020190701765971866571.pdf (accessed 4 May 2023).
[97] Kun, Cheng, Genxing, Pan (2021). "How much more carbon could China agriculture sequestrate". *China Dialog*. 12 January. Available at: https://chinadialogue.net/zh/5/69745/ (Accessed 11 January 2021).

Box 5.1 SOC Sequestration Experimental Center of Chunhua, Jiangsu, China

At the provincial level, SOC sequestration experiments are also taken up as research programs. In 2022, the first soil carbon neutrality project in China was introduced in Chunhua Community, Jiangning District, Jiangsu Province, led by China Academy of Science (CAS). Chunhua has 45,000 *mu* (3,000 *ha*) of "Tuqiao Rice" paddy, which has been certified as Nationally Distinctive Geographical Indication agricultural product, and has been operating in a fully intelligent productive way from cultivation, sowing, management to harvest. Once the paddy SOC sequestration technology could be fully applied, the speed of carbon sequestration rate will be lifted by over 50%, and over 30% of the CH_4 and N_2O could be decreased. Jiangsu provincial government funded 20 million CNY to establish a deep-soil carbon sink research platform, aiming to offset 10% of the provincial GHG emission between 2030 and 2060. It's expected that by 2026 this experimental program could form a serial of SOC sink R&D outcome, and be transferred into industrial practices. By taking this pioneering step, Jiangsu government would establish Chunhua project base into a global agricultural innovative center to tackle climate changes of China. Chunhua Community will also establish and implement talent policies to recruit 50 top-notch research teams both at home and abroad to work towards this goal.

Source: Wang, Huaiyan (2022). Jiangsu's First Soil Carbon Neutralization Project Landed in Chunhua, Jiangning.

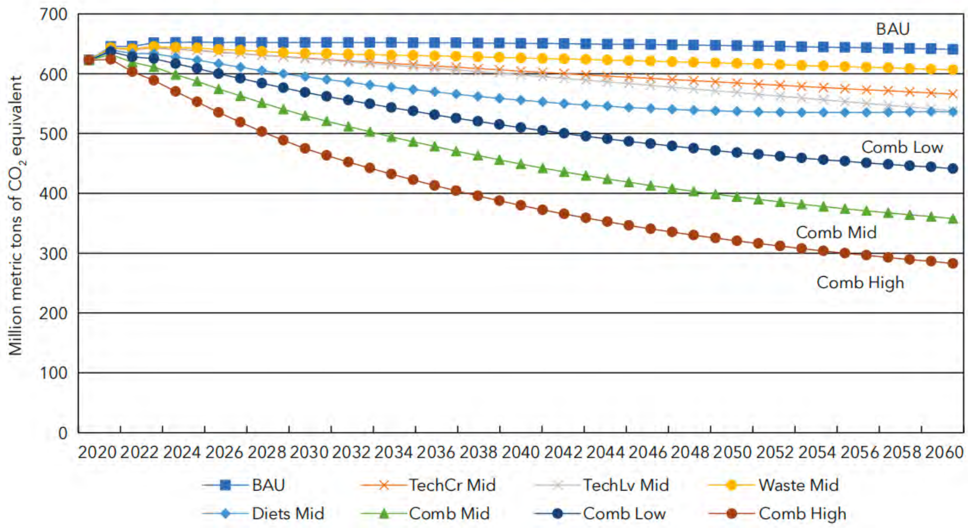
Figure 5.6 Potentiality of China's Carbon Neutral Agriculture



Source : Zhao Minjuan, et al. (2022), "*Analysis on the Goals and Paths of Carbon Neutral Agriculture in China*", Issues in Agricultural Economy, Vol.9, p.29.

It is evident that with implementation and application of appropriate technologies to tackle agricultural mitigation challenges, China could achieve agriculture carbon neutrality by 2060 (Figure 6.6). Furthermore, by comprehensively applying technologies in the "High-level" of "Comb" scenario in Figure 5.7, more carbon emission reduction targets could be reached. The optimal outcome would be a reduction of 300 $mtCO_2e$ in other sectors.

Figure 5.7 Scenarios of GHG from Agricultural Activities in China (2020-2060)



Source: Yumei, Zhang, et. al. (2021), "*Transforming Agrifood Systems to Achieve China's 2060 Carbon Neutrality Goal*", in AGFEP, et al., 2021 China Food and Global Food Policy Report: Rethinking Agrifood Systems for the Post-COVID World, p.17.

3. Conclusion

This chapter presents an overview of the policies and practices of green agricultural development (GAD) in China, including actions and policies on climate adaptation and mitigation. Given the importance of food security to China's 1.4 billion people, the government has linked climate challenges to agricultural concerns through climate adaptation.

In the context of rural development in China, climate adaptation plays a crucial role in bridging the gap between food security and climate agenda. To optimize agricultural climate resources such as soil quality in cultivated land and irrigation water utilization, farmers should assess five key aspects of their main production area using percentage rates as measurements: 1) Fertilizer utilization; 2) Pesticide utilization; 3) Comprehensive straw utilization; 4) Manure utilization; 5) Waste mulch recovery. Subsequently, the farmers should evaluate their potential contribution in rehabilitating degraded farmland, and protecting Northeast black soil.

Finally, farmers can access market opportunities as public services by certifying their agricultural products as green, organic, or geographically marked, and agreeing to quality and safety monitoring of the food supply. The convergence of such a "crop-fertilizer-soil-straw-manure-mulch-market nexus", with 7 factors in a sustainable agricultural life cycle, is a readily acceptable alignment between farmers' basic livelihood concern and the seemingly distant and indirect climate mitigation mission under the "30-60" targets.

With respect to climate adaptation three goals are identified: optimize the utilization structure of agricultural climate resources with health and market concerns; enhance agricultural risk reduction system by tapping water-saving irrigation potentiality; and increase climate resilience of agricultural ecosystems by making citizens and farmers abide by the "Red Lines". The central-local relationship allows local actors to innovate new approaches towards achieving public goals. This integration also considers individual or family private interests within the public domain.

To achieve the climate mitigation goals, or "30-60 Targets" of carbon neutrality, the agricultural sector of China could not only sequestrate all its GHG emission, but also provide extra emission credits to other sectors, given the low-carbon technologies are utilized comprehensively at a highly effective level. In 2016, China's agricultural GHG mission has peaked at approximately 600-700 CO_2e. To achieve synergies among various agricultural climate mitigation policies, science and technology (S&T) talents with know-how and expertise, local governments' branding tactics matter. Effective mobilization of unique indigenous resources, incorporating geographical, historical, biological, cultural, and anthropological features into brand-based value chains, is crucial for motivating local communities towards sustainable development. Notable examples of successful implementation include the Organic Ecological Park and Museum of Mining, Ningxia, as well as the SOC sequestration experimental center in Chunhua, Jiangsu.

Chapter VI. Facilitating green transformation through macro policies in China

A. Introduction

China has experienced remarkable fast-growing economic growth since late 1970s, which has, however, led to large-scale energy consumption, a fundamental cause of high environmental pollution and carbon emissions. China therefore needs to strike the balance between growth and green low carbon transformation.

There is a broad menu of macroeconomic policy options applicable to green transformation. In China, a holistic approach has been taken to deploy these macro policies. Strategically, China has integrated environmental and climate goals into its central economic planning system - the national five-year plan (FYP). At fiscal policy level, it has deployed various measures, such as government subsidies, procurement and budget transfers, channeling significant investments in green energy, clean transport, cleaner production as well as green infrastructure. At monetary policy level, the central bank and other financial regulators have been playing a proactive role in pushing and incentivizing financial institutions and the market to lower the capital costs and risks of addressing environmental and climate challenges. In fact, these macro policies are well coordinated with China's "1+N" climate policy system, which has been the core of the climate actions of China.

B. The role of macro policies in addressing green transition

While the objective of traditional macro policies is to keep economic growth and financial stability through economy-wide impacts, green transition requires the change of economic structure, focusing on individual markets. It is important to answer a fundamental question: What is the role of macro policies in addressing green transition?

The essence of supporting green transformation is to lower the green premium. Green premium is the difference in cost between a product that involves emitting carbon and an alternative that doesn't (Bill Gates, 2021). When high green premiums can be lowered, producers or consumers would have incentive to replace expensive fossil energy or related products with cheaper clean energy or related products. It can avoid a large majority of the activities responsible for greenhouse gas emissions.

Macroeconomic policy can help lower the green premium through either making fossil fuel more expensive, making the clean energy cheaper, or ideally both. In theory, environmental pollution or climate change has significant negative externality, accompanied by a number of market failures (Solow, 1971). Macroeconomic policies can internalize these externalities by adjusting marginal private cost or marginal private benefit. In other words, it could not only penalize negative externalities but also compensates positive externalities in the process of achieving green development.

Specifically, the key macroeconomic policies - fiscal and monetary - can be employed to influence the economy through the aggregate demand side. Fiscal policy focuses on how governments taxing and spending affects aggregate demand. All government spending and taxes affect economy, including changes in industrial structure, mode of production, lifestyle and spatial distribution. These policies can be expansionary, to reduce clean energy costs (such as government investment or fiscal subsidies to promote low-carbon technological innovation), or contractionary, to increase fossil fuel costs (such as carbon trading scheme, and environmental protection taxes aimed at phasing out fossil fuels).

Monetary policy tools are instruments that central banks use their balance sheets or guide financial institutions to add green asset allocations. An effective monetary policy that promotes green and low-carbon economic transformation would not only provide long-term financing for the energy transition, but also reduce investment uncertainty, by implementing clear and predictable measures to guide the long-term behavior of economic entities (Brunnermeier and Landau, 2020). This would effectively reduce the financing costs for green enterprises.

Although environmental policies may also contribute to achieving these objectives, it is important not to overlook potential uncertainties that they bring to the economy. The priority of environmental policies is to internalize the environmental externality and help reshape the economy toward a cleaner structure, rather than systematically reconciling these environmental objectives with the extra risks and constrains placed on the whole economy. For instance, in the short-term, environmental regulations will increase the production costs of enterprises, forcing them to adjust production scale, reallocate resources and potentially exit markets (Millimet et al., 2009; Zhou et al., 2017).

If such environmental costs are imposed on the economy at an inappropriate pace, scale, or time, it could bring negative macroeconomic consequences, such as inflation and unemployment. For example, according to the findings (WEO, 2022) of the International Monetary Fund (IMF) a package of climate policies could raise inflation in most regions from 0.1 percentage point to 0.4 percentage point between now and 2030, depending on how quickly regions move away from fossil-fuel power generation. According to another study by the IMF, a package of climate policies to achieve carbon neutrality will lead to the reallocation of about 2% of global jobs from high-carbon sectors to low-carbon sectors, (Jaumotte et al., 2021). However, it would require substantial costs in retraining the labor force to ensure an "equitable transition" (Pollin, 2019; Oei et al.,2020).

Macroeconomic policies addressing environmental concerns could therefore not only alleviate the transition risk arising from ambitious environmental policies, but also prevent environmental pollution caused by unsustainable macroeconomic policies. Historically, the traditional macroeconomic objectives have focused solely on economic development, encompassing factors such as economic growth, full employment, price stability, and international balance of payments. However, such a macro policy of blindly pursu ing economic development is often tempered by the negative effects on the economy due to environmental damage and climate issues.

In recent years, with the increasing integration of environmental objectives into government planning, macroeconomic objectives have gradually transitioned from a singular focus on economic development towards a diversified goal that also considers environmental protection. Specifically, the target of monetary policy is to keep price and financial stability and traditionally it has not been considered relevant for long-term climate change mitigation efforts. Now, major central banks around the world generally agree that appropriately accounting for climate risks in the central bank's balance sheet could be part of their first line of defense. Additional risk management measures (such as climate-related stress tests) should be implemented as necessary to protect their own balance sheets from the impacts of climate-related risks (NGFS, 2021).

Macroeconomic policies can, therefore, not only play a role in lowering the green premium through internalizing the environmental externality but also tackle the potential transition risk or uncertainty for an economy during the transition to a low-carbon economy.

C. An integrated approach to strategy development in China

1. Translating goals into step-wise actions through the Five-Year Plan

The FYP offers a comprehensive strategic blueprint to guide the social and economic development in China as it provides not only the strategic objectives but also their institutionalization and operationalization. The environmental protection objectives briefly mentioned in 1975, were expanded as a whole chapter in 1982 indicating that China became more serious in environment protection. While some progress was made in urban and industrial environmental pollution control at that time, it was not enough for achieving environmental protection goals due to the lack of concrete action plans for related industries or sectors.

Environmental concerns have been more effectively integrated in China's macro-economic policy development primarily through the adoption of quantitative targets since the 12th FYP period. The FYP adopted binding carbon-reduction and energy-transition related targets, while other economy-related targets, such as GDP growth and urbanization rate, are indicative. For example, the 12th FYP required a 17% carbon intensity reduction compared with 2005 level and 11.4% of non-fossil energy consumption in total primary energy consumption. This is in addition to other environmental targets, such as air quality, forest coverage and surface water quality improvement (table 6.1).

Table 6.1 Main binding indicators in environmental protection and green development

Indicator	12th FYP	13th FYP	14th FYP
Non-fossil fuels (% of primary energy consumption)	[3.1%]	[3%]	-
Energy consumption reduction per unit of GDP	[16%]	[15%]	[13.5%]
Carbon emission reduction per unit of GDP	[17%]	[18%]	[18%]
Aggregate major pollution emissions reduction	Chemical oxygen demand [8%]; Sulfur dioxide [8%]; Ammonia nitrogen [10%]; Nitrogen oxide [10%]	Chemical oxygen demand [10%]; Sulfur dioxide [10%]; Ammonia nitrogen [15%]; Nitrogen oxide [15%]	-
Air quality - Days of good or excellent air quality in cities at and above the prefectural level (% of the year)	-	>80% in 2020 compared with 76.7% in 2015	87.5% in 2025 compared with 87% in 2020
Forest coverage rate	-	23.04% in 2020 compared with 21.66% in 2015	24.1% in 2025 compared with 23.2% in 2019
Surface water quality with Grade Ⅲ or better in total (%)	-	>70% in 2015 compared with 66% in 2015	85% in 2025 compared with 83.4% in 2020

Source: National Development and Reform Commission.
Note: Figures in square brackets are five-year cumulative totals.

2. 1+N climate policy framework: addressing longer-term challenges

Although the FYP system can translate the green goals into actions, it only covers a duration of five years. It may therefore suit environmental challenges that have relatively smaller geographic scope of impacts and can be dealt with in a relatively shorter period of time, such as waste water, regional air pollution and heavy metal pollution. For longer-term challenges, such as climate change, however, the FYP system has reached its limitation. While it certainly is important to set up an aspirational goal for a very distant future, it can be barely functional to really guide the actions today if certain mechanisms are not put in place. In addressing the temporal mismatch between the FYP system and climate goals, China launched a 1+N climate policy framework (hereafter referred as 1+N framework), to ensure a consistent and progressive guidance on strategies and policies for achieving the carbon reduction goals throughout the next 40 years.

In the 1+N framework, the "1" refers to the overarching policy document that sets the guiding principles for all policies aimed at facilitating China's peaking and neutrality targets. The "N" stands for a collection of complementary policy documents that aim to reduce carbon emissions and facilitate the transition to a green economy. The first "N" documents, the Action Plan and covers a range of actions across major emitting sectors, such as energy, industry, infrastructure, and transport as well as other critical policy areas for abatement, including circular economy, technology, finance, economic policies, carbon trading, nature-based solutions. Meanwhile, all provinces have also had their own implementation schemes for carbon dioxide peaking within their respective jurisdictions. The policy highlights that the goals of peaking carbon emissions and subsequent carbon neutrality should balance with the medium- and long-term plans for economic and social development.

Additionally, macro policies are introduced in the 1+N framework that focus on lowering the green premium and preventing transition risks. On the one hand, lowering the green premium policies are defined both from the demand and supply sides, targeting the decreasing the use of fossil fuels as well as increasing the use of renewables. The "1" policy explicitly cites strict control the consumption of fossil fuels, through the setting of clear timetable for peaking their consumptions. For example, it requires to gradually reduce the total coal consumption during the 15th FYP period, and push the oil consumption to enter the plateau stage of peaking.

The "1" policy also spells out a comprehensive package of actions for supporting renewables, covering generation, transmission, energy storage and others. To implement this high-level principle, the latter adopted "N" policies well reflect it in the concerning fiscal and monetary measures, such as the carbon market, the environmental tax on carbon-intensive industries, government procurement for renewables and EVs, and the carbon-reduction supporting tool by the central bank.

On the other hand, on the preventing transition risks - the "1" policy document highlights the importance of transitioning toward carbon neutrality at an appropriate pace. It spells out that the transition should follow the principle of "building the new before totally removing the old" noting that the transition should be in the conditions of ensuring national energy security and economic stability, providing sufficient time for the new system to grow. This fundamental principle is then reflected in the latter adopted "N" policy documents: for example, the Ministry of Finance in its "N" document emphasizes that various fiscal measures, including tax and public procurement, needs to play their role in the distribution of the costs associated with the climate risks. The central bank has already encouraged commercial banks to do climate-risk stress tests, focusing on the impacts of carbon price increase on their capital adequacy ratio.

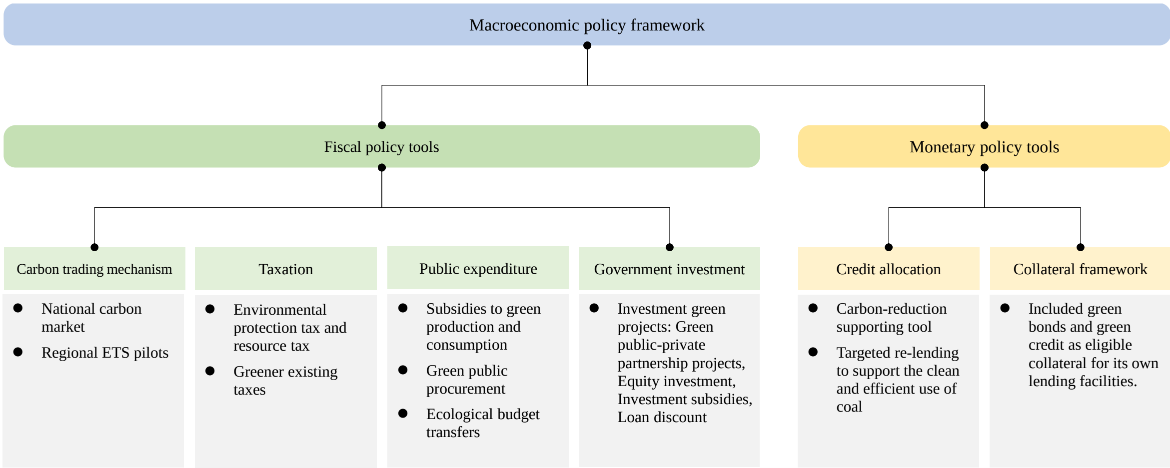
3. Aligning macro policies with specific country circumstances

High-level strategies will not guarantee the success of these macro policies without effective implementation policies being delivered. There is often a mismatch between what macro policies traditionally do - imposing economy-wide effects - and what achieving environmental and climate goals requires - namely the change of economic structure. The essence of China's experience is therefore to customize the application of appropriate macro policy tools for individual markets, taking full account of the specific country context.

For monetary policies, credit allocation and collateral framework are more relevant tools in China, since they can encourage central banks and financial institutions to own greener assets and consequently change the asset allocation. Other tools, such as adjusting interest rates and exchange rates, can only generate economy-wide impacts and are difficult to be customized for dealing with individual markets.

For fiscal policies - normally aiming at raising government revenues and increasing public expenditures - it is relatively easier to focus on individual sectors. China uses taxation and carbon trading mechanisms to raise revenue, which contribute to the deployment of public spending and investment policies for the green transition. Figure 6.1 offers a snapshot of China's macroeconomic policy framework for environmental protection and climate change.

Figure 6.1 China's macroeconomic policy framework for environmental protection and climate change



Source: Authors.

4. Fiscal policy tools

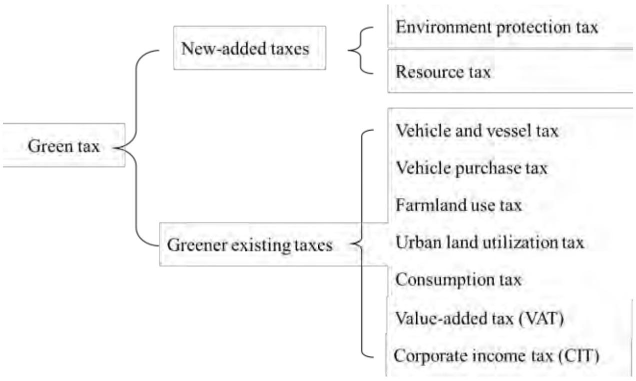
(a) Carbon trading mechanism

Carbon trading mechanism is the main instrument to internalize the cost of emitting carbon emissions, but its application in China faces at least two challenges: Firstly, as described in the previous section, China's carbon reduction goal is intensity-centered, namely targeting the decrease of carbon emissions per unit of GDP growth. While it fits the nature of China's current development stage, which is featured as continuous growth of total carbon emissions, this makes it challenging to set up the emission cap, which is the essential component of a cap-and-trade system. To address this challenge, China's emission trading scheme (ETS) is designed to allocate quotas based on the carbon-intensity benchmarks, reflecting the average emitting-performance level of regulated sectors. Secondly, carbon-intensive industries account for large portions of the country's economy and spread across the country. Integrating these industries all at once in a nation-wide ETS will have significant macroeconomic effects and disproportionally affect different provinces. To address this challenge, China piloted carbon emissions trading in seven provinces and cities, years before the launch of the national carbon market in 2021. When China started the national market, only the power generation sector was involved, with the plan to gradually expand to other industrial sectors, including petrochemicals, steel, non-ferrous metals, papermaking, chemicals, building materials, and aviation.

(b) Taxation policy

The development of the green taxation system in Chian has been aligned with the evolving progress of integrating environmental concerns into its strategic planning system. In practice, China takes two approaches to green its taxation system to reflect green transition: launching new tax items and adjusting existing tax, (see Figure 6.2 below). The launching of new tax items includes environmental protection taxes and resource taxes, while the adjustment of existing tax includes vehicle and vessel taxes, vehicle purchase taxes, farmland use taxes, urban land utilization taxes and consumption taxes.

Figure 6.2 China' green tax system



Source: Authors

The central piece of China's green taxation system is environmental protection tax (EPT). Despite its taking effect in 2018, EPT was the replacement for the Pollutant Discharge Fee (PDF), levied for the past 40 years. The evolving progress of PDF and the final adoption of EPT reflect China's continuous efforts in prioritizing environmental protection in its strategic objectives. In spite of the EPT containing the same four categories of pollutants - air and water pollutants, solid waste and noise pollution - it has a stronger legal, executive, and binding force, compared to the PDF.

Resource tax is yet another tax that is directly intended for environment and resource protection. Since its inception in 1984, the scope of resource tax has continued to expand - from coal, oil and natural gas, to all discovered fossil fuels and mineral resources - which comprise 164 tax items (STA, 2019). This progress also reflects the evolving role of the resource tax in facilitating China's industrial restructuring, energy saving and the protection of the environment (Feng et al., 2022).

For those existing taxes that integrate green consideration, some can directly influence resource consumption and pollution emissions, such as levying the consumption tax on energy-and-pollution-intensive products, and deducting the vehicle purchase tax for buying internal-combustion vehicles (ICV) with high energy efficiency and non-ICVs. On the other hand, other taxes have relatively indirect connection with resource usage, for instance the farmland occupation tax, the urban and township land use tax, which focuses on the rational utilization of land, avoiding environmental damage and decreasing pollution emissions.

Table 6.2 Practical information on the current green taxation

Items	Taxable items	Tax rate	Law (year of imposition)
Environmental Protection Tax	Air pollutants, water pollutants, solid waste, and noise pollution	Governed by the table of tax items and tax rate	Environmental Protection Tax Law (2018)
Resource Tax	Energy minerals, metal minerals, nonmetallic minerals, groundwater and gas minerals, salt)	Ad valorem tax or per unit tax for different resources, for example, 5–10% % of the sales for crude oil and natural gas	The Resource Tax Law of the People's Republic of China (2020)
Excise Tax	Tobacco, firecrackers, refined oil, batteries, motorcycles, cars etc.	Ad valorem, specific duty or combination of both	Provisional Regulations of the People's Republic of China on Consumption Tax (2009)

Items	Taxable items	Tax rate	Law (year of imposition)
Vehicle and Vessel Tax	Taxable vehicle and vessel	Differentiated fixed amount tax	Vehicle and vessel Tax Law of the People's Republic of China (2012)
Vehicle Purchase Tax	Purchase of cars, motorcycles with displacement of more than 150mL, trams and trailers	10%	Vehicle Purchase Tax Law of the People's Republic of China (2019)
Farmland Occupation Tax	Arable land to build houses or for other non-agricultural construction purposes with-in China	Differentiated tax rates for different locations	Cultivated Land Occupation Tax Law of the People's Republic of China (2019)
Urban and Township Land Use Tax	Land in cities, county towns, administrative towns and industrial and mining districts	Land use tax per square meter per year: Rmb1.5–30 for big cities; Rmb1.2–24 for medium-sized cities, Rmb0.9–18 RMB for small cities, and Rmb0.6–12 for county towns, administrative towns and industrial and mining districts	Provisional Regulations of the People's Republic of China on Urban Land Use Tax (1988)

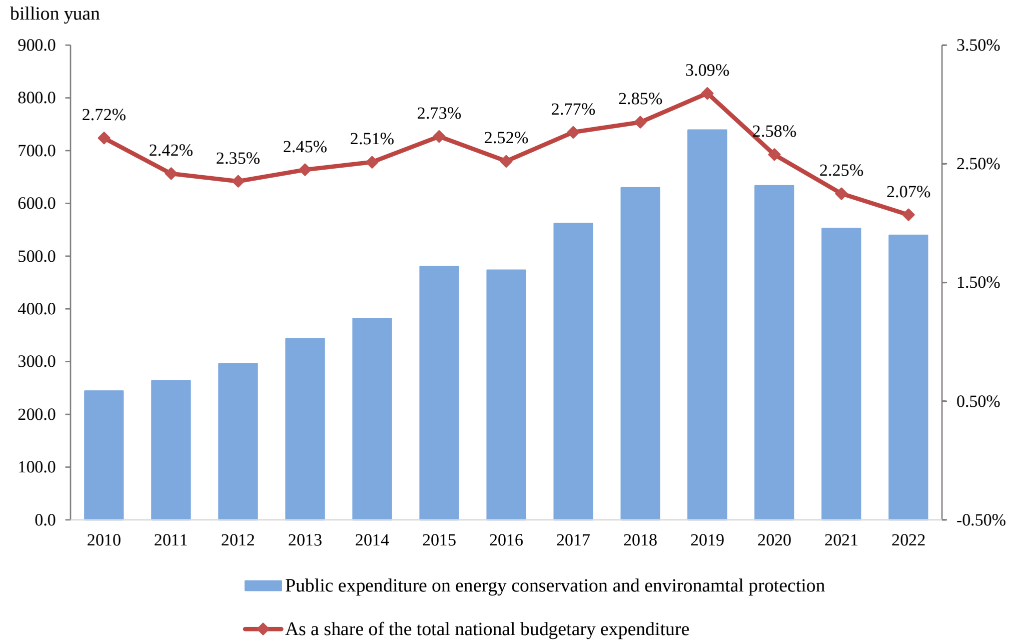
Source: State Taxation Administration of The People's Republic of China

China has not yet introduced a carbon taxation. The concern lies in the uncertainty of the impacts of such taxation on China's economy, including the huge pressure it may impose on China's energy-intensive and trade-intensive sectors. In addition, the adoption of any new tax requires consideration of the social and economic acceptance and finding the proper point of time and form, which is usually challenging in practice.

(c) Public Expenditure Policy

Public expenditure is the major force for the cultivation of the demand market for environment-friendly and green products and cost-reduction. In the past few decades, there is a marked increase in China's public expenditure on green development. For example, between 2010 and 2022, China's public expenditure on energy conservation and environmental protection increased from 244.2 billion yuan to 539.6 billion yuan (see Figure 6.3). More importantly, the share of this expenditure in total national budgetary expenditure generally increased, except for the Covid-19 period, demonstrating China's strong determination to continuously grow its green product market.

Figure 6.3 Public expenditure osn energy conservation and environmental protection (2012-2022)



Source: Ministry of Finance of the People`s Republic of China.

There are three forms of public spending - procurement, subsidy and fiscal transfer. Subsidies are usually in the form of cash grants, interest-free loans or tax exemption, which can apply to producers or consumers. Production subsidies provide financial incentives for expanding production scale. One example of production subsidies is the feed-in tariffs (FIT) for new solar and onshore wind energy with an above-market price for what they deliver to the grid. Since China implemented FIT in 2011, the solar PV as well as wind power generation market has developed rapidly and the proportion of China's renewable energy use in total primary energy consumption increased from 7% in 2007 to 14.2% in 2021. Consumer subsidies reduce the price of the product to encourage more consumption. As an example, China launches its tax deduction for electric vehicle (EV) buyers in effort to spur the demand market.

China's public expenditures on green products are also largely through green public procurement (GPP) conducted by government agencies and affiliates. In 2020, energy-saving and environmentally friendly products was 81.35-billion-yuan, accounting for over 85 percent of total products publicly procured by governments.[98] The GPP of environmental labeling products has reached 1.3 trillion yuan over the past decade. The GPP standards for priority procurement and mandatory procurement are based on many factors, including: energy intensity, environmental performance, technical level, and market maturity. More specifically, the GPP categories contain products such as computer equipment, printers, building ceramics, and architectural coatings – which are granted environmental and energy-saving certification.

The third form of public expenditure in China is ecological budget transfers (EBTs), which refers to public revenue transfer between different administrative jurisdictions at the local level. It is a common practice for China's economic planning system to categorize six development zones: ecological protection zone, nature reserving zone, maritime development zone, farmland development zones, urbanization and industrialization zone, agriculture and rural zones. As a result, ecological protection zones or nature reserving zones will, for example, have much less development opportunities than other zones, and therefore the economy in these zones need compensation from others through EBTs. The EBT payment is gradually increasing with the

[98] Ministry of Finance. Available at: https://www.gov.cn/xinwen/2021-09/04/content_5635396.htm. Accessed on 05 October 2023

annual growth of 9.6% and the central government has allocated more than 109 billion yuan in national key ecological function areas in 2023[99].

In China, EBTs can facilitate the vertical transfer of revenue from China's central government to local governments, as well as horizontal transfers between local governments (Sheng and Han, 2022). The former one is the main eco-compensation instrument including general-purpose fiscal transfer payments and specific-purpose transfer payments. The latter one is a bidirectional agreement between neighbouring provinces for governing the environmental externality of water quality. For instance, Xin'an River Basin Eco-compensation scheme, pioneered by Anhui and Zhejiang, is the demonstration case to pilot the cross-provincial ecological compensation mechanism for water-shed management and conservation.

(d) Government Investment

The Chinese government annually allocates a certain portion of public capitals from its annual budget to invest in fixed assets. Most of these investments are deployed to public services where the market cannot effectively distribute resources, such as pollution treatments and carbon reductions. These investments mostly come from two channels: - budgetary investment from central government, mostly from tax revenues, and government-managed fund at local level, primarily from local public revenues, such as the sales of land use rights. Green development has been one of the main areas that government investments allocate considerable resources to.

One of the key objectives for China to promote government investments is to maximize the catalytical effects of these public capitals to crowd in private finance. To achieve this objective, China has introduced various measures to create an enabling environment for private investors, such as public-private partnership (PPP), equity investment, investment subsidies and loan discount. In 2014, for instance, China began to undertake its PPP practice and the scale of investments for green projects continue to grow, particularly in the fields of environmental protection, afforestation, renewable energy and clean water. By the end of 2020, the accumulated investments of green PPP projects reached 5.6 trillion yuan, accounting for 36.3% of the total[100].

D. Monetary policy tools

Monetary policies are normally used to generate economy-wide effects, such as adjusting interest rate and currency rate, and do not target individual markets (or even avoid doing so), in order to prevent market distortion.

The implementation of China's monetary policies for the green transition has been taking full account of the country's circumstances including:

i) Enormous investment demands to achieve climate goals. Based on China International Capital Corporation`s (CICC) calculations (2022), China's total green investment demand to achieve carbon neutrality is approximately 139 trillion yuan, with 22 trillion yuan required between 2021 and 2030, and 117 trillion yuan between 2031 and 2060.

ii) A significantly large portion of carbon-intensive assets. As one of the largest energy consumers globally and as a coal-rich country, China's economy has been heavily dependent on coal, making most of its assets become carbon intensive, particularly in industrial sectors.

iii) Assets are more likely to be stranded, as they have a much shorter average service life. Compared with many other developed economies, most of China's carbon-intensive assets in industries and energy sectors as well as infrastructure are built. A study (Mercure, 2019) indicates that the average service life of coal power generation units in China is 12 years while for developed economies in Europe is about 52 years. Relevant assets in China will therefore have much higher possibility to be stranded when facing strengthened climate policies, such as coal-phase-out requirement.

iv) China's financial system is dominated by indirect financing. In 2022, China's total loan balance accounts for 65.3% in its total social financing[101]. Indirect financing is playing even more role in China's green finance, where green loan balance accounts for 85% of total green financing.

---

[99] Ministry of Finance. Available at: http://www.mof.gov.cn/gkml/caizhengshuju/202303/t20230316_3872867.htm. Accessed on 05 October 2023

[100] China Public Private Partnerships Center. Available at: https://www.cpppc.org/PPPsj/999982.jhtml. Accessed on 05 October 2023

[101] People's Bank of China. Available at: https://www.gov.cn/xinwen/2023-01/23/content_5738573.htm. Accessed on: 05 October 2023

v) China has already established a large green financial market. By the end of 2020, green loans and green bonds in China totaled $1.8 trillion and $125 billion respectively, ranking as the world's largest and second-largest[102].

Having aligned with the above features in carbon emissions and financial sector, China has introduced the following monetary policy tools:

Carbon-reduction supporting tool: Providing incentives to commercial banks can be very impactful in a bank-dominated financial system. China's central bank, People's Bank of China (PBoC)[103], launched carbon-reduction supporting tools in 2021, providing a concessional interest rate of 1.75% for 60% of each commercial lender's green loans for one year. It supports clean energy, energy conservation, environmental protection and carbon emission reduction. The PBoC requires financial institutions to disclose relevant information, such as the number of projects, the amount of loans, the weighted average interest rates, and carbon emission reduction data supported by the new tool. Their information disclosure will be verified by a third-party professional institution and subject to public supervision.

Targeted re-lending to support the clean and efficient use of coal: In order to lower the transition risks for coal-related assets and ensure energy security, China took a similar approach for supporting the use of clean coal, with total amount of 300 billion yuan starting from 2021. The re-lending program followed the same practice as the aforementioned carbon-reduction supporting tool in terms of interest rate and conditionalities of relending, except that 100% of commercial lenders' loans can be covered in this program.

Authorizing green bonds and loans as acceptable collaterals for Medium-term Lending Facility (MLF): In 2018, the PBoC took advantage of China's emerging green finance market, and adjusted the collateral framework and accepted green loans and green bonds as collateral in its liquidity operations. This enables holders of green loans and bonds to be more capable of requesting guarantees, which will increase the scarcity of these types of green financial assets (BIS, 2015). Furthermore, it would encourage financial institutions to be more proactive in granting green loans and issuing green bonds, including high-quality green corporate bonds, thereby making green enterprises more credible and raising the credit costs for brown enterprises (Vaze et al., 2019).

E. Conclusions

Compared to the environmental, climate and energy policies, the merit of macro policies lies in its capability to result in economy-wide impacts, rather than individual markets. The macro policies ought to strike appropriate balance between economic growth and environment/climate protections. While introducing policy interventions at a macro level is nothing new in China, establishing this appropriate balance remains challenging: China has to protect its environment and combat climate at the stage of finalizing its industrialization and urbanization. China's experiences of using macro policies in addressing green transition while keeping its economic growth are two-fold:

1. **Strategic level** - reconciling environment and climate actions with economic growth agenda in its FYP system, by inserting binding carbon/energy intensity targets, while only indicating economic development objectives; and
2. **Policy level** - applying a piloting approach to the implementation of various policy tools, such as carbon trading mechanism, environmental tax, ecology budget transfers and green finance, to achieve steady progress toward green transition while avoiding potential transition risks.

The main focus of the fiscal policies is levying and spending:

1. **Levying**: The essence of China's experience is to limit the potential financial burdens for regulated companies within a controlled scope. This is the case with environmental tax, where, for example, a piloting program was launched to initially regulate smog in the most affected areas, and then expand to other pollutants, such as sulfur dioxide and nitrogen dioxide, to other cities. In the water sector, testing water through piloting programs will help regulators identify practical issues and solutions

[102] People's Bank of China.
[103] People's Bank of China. Available at: http://www.pbc.gov.cn/zhengcehuobisi/125207/125213/4634692/4634697/4994502/index.html. Accessed on: 05 October 2023

within the constraints of limited administrative resources. This approach was tested with the carbon trading mechanism prior to its launch after several years of piloting at provincial and city level. Similarly, the national carbon market, started with coal-fired power generating units whose capacity is larger than 300 MW.

2. **Spending**: China's experience can be highlighted at two aspects: Firstly, it puts the growth of environmental/climate spending a bit ahead of fiscal income growth. This is particularly reasonable when China enters into the phase of high-quality development, where green and growth agenda are getting increasingly aligned; Secondly, China prioritizes the spending to catalyze private finance, cultivate demand market for green consumption and compensate the affected stakeholders.

The uniqueness of China's monetary policy for supporting green transition is the focus of its impacts on key sectors. The monetary policy tools are creatively used to maximize its effect of creating new value for green assets while minimizing its adverse impacts to the financial market. The carbon-reduction supporting tool and re-lending program for clean and efficient use of coal, limit the total re-lending scale for the clean coal facility to balance the needs between energy security and energy transition, but put no limitation for carbon-reduction facility based on the fact that China's commercial lenders have already accumulated large scale of green loans.

Additionally, authorizing green financial assets to be collaterals may not have wide range of impacts given the current scale of green assets, but would effectively increase the scarcity of China's green financial assets, supporting the acceleration of green financial market development.

Despite the fact that macro policies can play a significant role in addressing green transition, this alone is unable to help China achieve its carbon peaking and neutrality goals. In fact, those traditional policies in environmental, climate and energy fields, will, to some extent be the driving forces to push forward the ecological, environmental and climate agendas. Macro policies are in the better position to strike the balance between the growth and green and this is exactly what China creatively implements through various policy tools and will continue to do for a smooth green transition.

Chapter VII. Brief introduction on China's green finance and policies

With the increase in the severity of climate change and environmental problems in recent years, the notion of "green development", which emphasizes the coordination of resources, environment, economy, and society, has become a global consensus. In September 2020, China announced that it would hit peak carbon emissions by 2030 and achieve carbon neutrality by 2060.

Green finance, loosely defined as financial products and services provided to promote environmentally responsible investments, is crucial to support ambitious climate goals. As the first country to establish a national green financial system, China has been taking significant steps to improve its green finance policy framework by combining government supervision and market incentives.

This chapter provides an overview of China's green finance policy framework, including institutional arrangement and policy framework. The developments of green credit, green bonds, green insurance market, green fund market, and national carbon emission trading market are also introduced.

Concerning various sectors of China's green finance market, green credit lies at the core of China's green finance system, which relies heavily on indirect financing. In contrast, green bonds are the most critical market-based financing instruments. In addition, the green insurance market, green fund market, and national carbon emissions trading market all play non-negligible roles. Therefore, it is worthwhile to carefully examine the policies supporting these sectors of the green finance market, and their development status.

A. Definition and institutional arrangements

1. Definition

Green finance has narrow and broad definitions: The narrow definition focuses on evaluating the environmental status and pinning down the key industries and technologies green finance should support, while the general one sets the overall sustainability goal of a financial system and proposes measurements of its effectiveness. The broadly defined green finance emphasizes its connection with financial and macroeconomic stability. Specifically, financing criteria need to be set based on the goal of the overall financial system to allocate capital to address environmental risks efficiently.

Considering China's green finance at the current stage, this report adopts the definition of green finance published by the People's Bank of China (PBC),[104] China's central bank, in 2016. Green finance is defined as "using the financial tools to support environmental improvements and energy-efficient economic activities, which include but are not limited to: investment, operations, and risk management in environmentally friendly, energy-efficient, clean energy, green transportation, and green construction industries."

2. Overall framework

On August 31, 2016, The *Guidelines to Establish the Green Financial System*[105] was issued, which is the cornerstone document leading the development of China's green finance system. Additionally, the PBC would establish its policy framework of green finance based on "three functions" and "five pillars." The "three functions" refer to the three primary functions that finance can support green development, including resource allocation, risk management, and market pricing. The "five pillars" are improving the green finance standards,

[104] The Appendix presents a complete list of abbreviations used in this report.
[105] Jointly issued by the People's Bank of China (PBC), National Development and Reform Commission (NDRC), Ministry of Finance (MoF), Ministry of Ecology and Environment (MEE), the former China Banking Regulatory Commission (CBRC), and the former China Insurance Regulatory Commission (CIRC).

strengthening the supervision and information disclosure requirements on financial institutions, gradually improving the incentive mechanism, continuously promoting green financial product innovation and market development, and expanding the space for international cooperation in green finance.

3. Green finance standards

A subsequent crucial point for the standardization of China's green finance relates to the issuance of the *Green Industry Guidance Catalogue (2019 edition) in* February 2019.[106] The *Catalogue* classifies green industries into energy conservation and environmental protection, clean production, clean energy, ecological environment, green upgrading of infrastructure, and green services. In April 2021, the issuance of the *Green Bond Endorsed Projects Catalogue* (2021 Edition, which has been in effect since July 2021) critically improved the taxonomy and standardization of China's green bond market. Besides, the *Environmental Equity Financing Instruments*, issued by the PBC in August 2021, clarify the overall requirements, value assessment, risk control, and other details for environmental equity financing instruments.

4. Environmental information disclosure

Efficient and transparent disclosure of environmental information is crucial to circumvent "greenwashing" and related moral hazard risks and serves as an important institutional arrangement for green finance markets. China's disclosure policies of environmental information can be classified into those that regulate or encourage the disclosure of listed companies, green bond issuers, and financial institutions.

(a) Disclosure of listed companies

These set of policies are issued and implemented by the China Securities Regulatory Commission (CSRC) - the primary regulator of the securities industry in China, the Shenzhen Stock Exchange (SZSE) and the Shanghai Stock Exchange (SSE) - which are two major stock exchanges in mainland China directly administered by the CSRC.

Following the *Guidelines to Establish the Green Financial System*, the CSRC needs to continuously improve the annual report guidelines on environmental information disclosure by following the "three-step" principle, which would ultimately require all listed companies to disclose environmental information by 2020. As of 2018, key pollutant-discharging listed companies are required to disclose their environmental information compulsorily, while the disclosure of other listed companies has been transiting from following the "comply or explain" policy to mandatory disclosure.

In March 2019, in the *Guidelines for the Content and Format of Information Disclosure by Companies Offering Securities to the Public No. 41-Prospectus for Sci-Tech Innovation Board Companies,* the CSRC emphasized the disclosure of information on main environmental pollutants, and facilities and the ability to reduce pollutants by issuers of the Shanghai Sci-Tech Innovation Board (also called the STAR market). This also requires issuers to disclose potential environmental protection problems and measures to cope with them.

Consequently, in the listing rules of the STAR market released in March 2019 (revised in April), the SSE required listed companies to disclose their social responsibility performances mandatorily. In September 2020, the SSE issued *Guidelines No.2 on the Application of Self-Regulation Rules for Listed Companies on SSE STAR Market - Voluntary Information Disclosure,* in which Article 14 titled "Environmental, Social, and Corporate Governance" stipulates that listing companies may disclose additional information based on their industry, business characteristics and governance structure.

With regard to the policy made by the SZSE, in October and November 2019, two *Industry Information Disclosure Guidelines* were issued, which refine the disclosure requirements of environmental information for companies engaged in solid mineral resources and non-metallic building materials. Moreover, in September 2020, the SZSE revised *Measures of the Shenzhen Stock Exchange Measures for the Evaluation of Information Disclosure of Listed Companies*, which includes the social responsibility performances in the

[106] Jointly issued by the NRDC, the PBC, Ministry of Industry and Information Technology, Ministry of Natural Resources, MEE, Ministry of Housing and Urban-Rural Development, and National Energy Administration.

evaluation system, focusing on the disclosure of ESG conditions by listed companies.

(b) Disclosure of Green Bond Issuers

A relevant policy, set by the PBC in March 2018, is associated with information disclosure of green financial bond issuers. Specifically, based on the *Notice on Issues relating to Strengthening the Duration Supervision of Green Financial Bonds*, green financial bond issuers must disclose information on significant pollution liability accidents and other environmental violations occurring in companies or projects funded by the issuance of green financial bonds.

(c) Disclosure of Financial Institutions

The PBC issued the *Guidelines on Environmental Information Disclosure for Financial Institutions* in July 2021. According to the *Guidelines*, financial institutions (including commercial banks, asset management institutions, loan and trust companies, and insurance companies) are encouraged to publicly disclose their environmental information at least once a year.[107]

B. Green finance policies: Green credit

China's financial system heavily relies on bank credit. In this general context, green credit[108] policies rank among the most critical green finance policies, mainly composed of three parts: The first relates to a set of micro-prudential policies enacted by the CBIRC (formerly CBRC); the second and third involve macroprudential and monetary policies established by the PBC.

1. Micro-prudential policies

From 2012 to 2014, the CBRC successively issued the *Green Credit Guidelines* and the *Green Credit Statistics System*, establishing a whole set of green credit policies from a micro-prudential perspective. The *Green Credit Guidelines* (2012) define three pillars based on which banking financial institutions develop green credit: The first is to promote green credit from a strategic perspective and increase support for green, low-carbon, and circular economy; the second is to prevent environmental and social risks; and the third is to improve their environmental and social performances.

The *Green Credit Statistics System* (2013) divides green credit into two categories. The first pertains to the credit to support manufacturing of the three strategic emerging industries (i.e., energy conservation and environmental protection, new energy, and new energy vehicles). The second is the credit support for projects and services related to energy conservation and environmental protection.

2. Macroprudential policies

The PBC included the green credit performance of 24 deposit-taking financial institutions in the macroprudential assessment (MPA) from the third quarter of 2017 to 2019 and expanded the scope of the included institutions in August 2018. The inclusion of green credit performance in the MPA came to an end in 2019. However, based on the *Notice on Conducting Green Credit Performance Evaluation of Banking Depository Financial Institutions* (2018) and the *Notice on Conducting Green Finance Evaluation of Banking Financial Institutions* (2021),[109] green credit performance still plays an integral role in the green finance

---

[107] Disclosure contents include environmental objectives, visions, strategic plans, policies, actions and key outcomes during the year, such as their own operating activities generated by carbon emission controlling targets and achievements, resource consumption, pollution and prevention, climate change mitigation and adaptation, etc.
[108] "Green credit" and "green loans" are used interchangeably, without apparent difference in meaning, in this report.
[109] The *Green Finance Evaluation of Banking Financial Institutions* can be considered as an improved version of *Notice on Conducting Green Credit Performance Evaluation of Banking Depository Financial Institutions*. The former becomes effective on July 1, 2021, and the latter was abolished at the same date.

evaluation of banking institutions.

The green credit performance evaluation has been officially implemented nationwide since the first quarter of 2019, making China the first country to conduct extensive green credit performance evaluation. This pioneering effort has effectively boosted the green credit amount, guided financial institutions to prioritize green credit businesses and created space for monetary policy to address climate change.

3. Monetary policies

The PBC has designed several innovative monetary policy tools to incentivize the participation of financial institutions in green credit. These policies can be broadly categorized into two sets: the inclusion of qualified green credit into the collateral for the PBC's monetary policy tools and two targeted monetary policies to support carbon reduction and efficient energy use.

In compliance with the *Notice on Promoting Credit Asset Pledge and the Central Bank's Internal (Enterprise) Rating Work* (2017), the PBC has included qualified green credit into the pool of eligible collateral for MLF and the re-lending program since 2018. Specifically, on June 1, 2018, the PBC expanded the acceptable collateral of MLF to include qualified green credit. On June 27, 2018, the PBC issued the *Notice on Intensify Re-lending and Re-discounting Support to Guide Financial Institutions to Increase Credit Extended to Small and Micro Enterprises*, which incorporates qualified green credit into eligible collateral for re-lending.

In November 2021, the PBC successively released two monetary policy tools, namely *carbon emission reduction supporting tool* and *targeted re-lending for clean, efficient coal use* to support carbon reduction and clean, efficient use of coal. These two tools are an important part of the PBC's creative efforts to design targeted monetary policy. Both tools are designed in a re-lending approach. Firstly, the carbon-emission reduction supporting tool aims to motivate financial institutions to make loans targeted at carbon emission reduction. The PBC provides financial support to financial institutions based on 60% of loan principals they make, with a one-year lending rate of 1.75%.

Secondly, given China's coal-dominated energy resource endowment, a targeted re-lending program, with a quota of 200 billion yuan, is designed to support areas[110] related to clean and efficient use of coal and thus facilitate green and low-carbon development. Similar to the carbon emission reduction supporting tool, national banks make loans at their discretion to eligible projects within the supported areas, with the interest rate close to the LPR of the corresponding maturity. Accordingly, the PBC provides re-lending funds to these banks with the equivalent amount of the loan principal.

4. Green finance policies - Green bond

Green bonds have acted as the most important instrument to enhance green financing through a market-based approach. Since its launch in 2016, China's green bond market has amassed a considerable size and is currently ranked as the second-largest globally. Key policies regarding green bonds include institutional, macroprudential and monetary policy support for green bonds to lower the issuance and financing costs of these bonds, along with regulation on the use of funds raised and information disclosure of green bonds issuers. These policies are introduced in more detail as follows.

(a) Facilitate the issuance of green bonds

As detailed in the previous section, a systemic build-up of green bond standards is indispensable to reduce the frictional costs related to the issuance of green bonds. Apart from constructing green bond standards, other policies have been made to facilitate the issuance of green bonds for qualified issuers. In July 2018, the SSE issued the *Guidelines for the Supervision of Optimizing Financing* and *Guidelines for the Supervision of Continuous Financing*. The *Guidelines* implement classified supervision of corporate bond issuers, simplify

[110] These include: safe, efficient, green and smart coal mining, clean and efficient coal processing, clean and efficient use of coal-fired power, clean industrial combustion and heating, clean residential heating and comprehensive utilization of coal resources, and vigorously promote the development and utilization of coal-bed methane.

the audit processes for high-quality issuers and improve the issuance efficiency.

Most importantly, these *Guidelines* reduce the time window uncertainty generated by problems concerning the use of funds raised. A less related example is the *Notice on Supporting the Issuance of Green Debt Financing Instruments in the Green Finance Reform and Innovation Pilot Zones*, issued by the PBC in April 2019, which intended to expand enterprises' financing channels in the pilot zones.

More specifically, it facilitates the issuance of green debt financing instruments for qualified issuers [111] in the pilot zones. It also encourages enterprises in the pilot zones to register and issue private placement notes and asset-backed notes (ABN) to meet their funding needs.

(b) Provide macroprudential and monetary policy support

The most crucial macroprudential policy support for green bonds is incorporating green bond holding into the green finance evaluation imposed on banking institutions. In line with the incorporation of green credit in the collateral for monetary policy instruments, the PBC has also included green bonds in the list of eligible collateral to reduce financing costs of green projects in the bond market. Specifically, since June 1, 2018, the PBC has accepted green financial bonds with a rating no lower than AA as collateral for MLF.

The PBC has also included corporate bonds with rating AA+ and AA into the pool of eligible collateral and given corporate bonds related to SME and green economy priority over other corporate bonds (a first-among-equals status). Besides, in the *Notice on Intensify Re-lending and Re-discounting Support to Guide Financial Institutions to Increase Credit Extended to Small and Micro Enterprises*, issued on July 27, 2021, the PBC includes green financial bonds (with rating no lower than AA) and corporate bonds with rating AA+ and AA (with priority given to bonds related to SME and green economy) in the collateral pool for re-lending policy.

(c) Regulate the information disclosure for green bonds issuers

The PBC set two disclosure policies imposed on issuers of green financial bonds in March 2018. The first is the *Notice on Issues relating to Strengthening the Duration Supervision of Green Financial Bonds*, mentioned in the previous section. Aside from environmental information, the PBC put under supervision and inspection the disclosure of information on funds raised. Secondly, *Regulations on Information Disclosure throughout Duration of Green Financial Bonds*, along with a disclosure template, impose requirements on green financial bond issuers regarding disclosure of the use of funds raised, environmental benefit evaluation, green project information, and funding progress.

(d) Standardize the issuance of green corporate bonds and green asset-backed securities

In the *Guidance on Supporting the Development of Green Bonds* issued in 2017, the CSRC provided definitions of green corporate bonds, green projects, green industries and projects, and required that funds raised must be invested in green projects. Similarly, in the *QA(I) of Shanghai Stock Exchange regarding Supervision over Financing via Corporate Bonds - Green Corporate Bonds* issued in March 2018, the SSE illustrated the evaluation and certification standards for green bond issuance, as well as the use of funds raised.

Moreover, the *Green Bond Endorsed Projects Catalogue* (2021 Edition), which vastly improves the standardization of China's green bond market as mentioned above, also provides a unified standard of green corporate bonds.

Concerning green asset-backed securities (ABS), the *QA(II) of Shanghai Stock Exchange regarding the Asset-backed Securitization Business-Green Asset-Backed Securities* specified conditions that issuing companies of green ABS[112] need to satisfy. The 2021 Edition of *Catalogue* also incorporates green ABS into the definition of green bonds.

5. Other green finance policies

(a) Green insurance policies

Green insurance, when narrowly defined, typically refers to environmental pollution liability insurance (EPLI). Technically, EPLI covers claims from third parties against bodily injury and property damage caused by hazardous waste materials released during a company's business operations. Promoting a compulsory EPLI system lies at the core of China’s green insurance policy design. In addition, from September 2020, based on Article 99 of the *Law of People’s Republic of China on the Prevention and Control of Environmental Pollution by Solid Wastes,* entities that collect, store, transport, utilize and dispose of hazardous wastes, in accordance with relevant regulations of the country, are required to purchase EPLI. Aside from EPLI, China has also adopted a series of green insurance policies to support the development of other types of green insurance, including catastrophe insurance and agricultural insurance.

These policies include but are not limited to the Measures for the *Administration of Special Reserves for Earthquake Catastrophic Insurance for Urban and Rural Residents* (issued by the Ministry of Finance, or MoF in May 2017), the *Notice on Carrying out the Pilot Full Cost Insurance and Income Insurance for Three Major Grain Crops* (jointly issued by the MoF, the Ministry of Agricultural and Rural Affairs, and the CBIRC in August 2018), as well as the *Several Opinions on Prioritizing the Development of Agriculture and Rural Areas to Address the Issues Relating to Agriculture, Rural Areas and Rural People* (issued by the Central Committee of the CPC and the State Council in January 2019).

(b) Green funds

Without a unified standard in China and internationally, the concept of “green fund” can be loosely defined as a mutual fund or another related investment vehicle that invests exclusively in environmentally-friendly companies. Attempts of the Chinese government to tackle climate change by green funds can be traced back to August 2006, when the State Council approved the establishment of the China Clean Development Mechanism (CDM) Fund and its management center, which has been jointly operated by the MoF and NDRC since November 2007. It obtained the United Nations Green Climate Fund (GCF) national implementation agency qualification in October 2017, and it has precipitated the preparation of GCF projects since then.

(c) National carbon emissions trading market

China launched its national carbon emissions trading market on July 16, 2021. The launch of the national carbon market marks an important step in its efforts to tackle climate issues via market mechanism. The underlying trading mechanism in China’s national carbon market is essentially the same as its foreign counterparts (most notably, the EU Emissions Trading System or EU ETS). Specifically, the government authority sets the limit on emissions and allocates allowances to carbon-emitting companies, and companies are allowed to trade these allowances under the market price. This trading mechanism[113] internalizes the social costs of carbon through the carbon price and proves to be highly effective from both environmental and economic perspectives.

The national carbon market demonstrates China’s determination to address climate change and achieve carbon neutrality and is expected to make a significant contribution to the 30·60 Target in the future.

6. Development status of China’s green finance

(a) Green credit

Based on the statistics published by the PBC, the balance of national green credit was 11.95 trillion yuan by the end of 2020, accounting for 6.7% of the domestic and foreign currency loan balance. By 2020, the balance of green non-performing credit was 39 billion yuan, with a non-performing rate of 0.33%, 1.65% lower than that of corporate loans in the same period. According to the statistics of the CBIRC, by the end of 2020, the green credit of 21 major domestic banks is expected to reduce the coal consumption by 320 million tons and

[113] It is always referred to as “cap and trade” mechanism.

reduce the carbon emissions by 730 million tons of carbon dioxide equivalent each year, [114] which has contributed significantly to the 30·60 Target.

(b) Green bond

In 2020, domestic entities issued about 258 billion yuan of green bonds. Among them, 220 green bonds were issued by 155 issuers in the domestic market, with a total volume of 216.582 billion yuan; 17 green bonds offshore were issued by ten issuers, with a total volume of 41.42 billion yuan. By the end of 2020, 1413.4 billion yuan of domestic green bonds had been issued, and the stock volume was 813.2 billion yuan. Throughout the year, a total of 5.73 billion yuan of various bonds was issued in China's bond market, with a year-on-year increase of 26.5%. Green bonds accounted for 0.3%, half of the 0.6% in 2019.

(c) Green insurance and green fund

Green insurance has played a significant role in China's green finance system. In 2020, environmental pollution liability insurance was carried out in 31 provinces (including autonomous regions) across China, involving many high-risk industries such as metallurgy, pharmaceuticals, paper-making, and thermal power, providing risk protection of 64.661 billion yuan, a year-to-year increase of 21.75%. Various catastrophe insurance products and services are also available.

By the end of 2020, there were 80 green theme public funds in the market, with a scale of 169.411 billion yuan. Among them, there are six social responsibility investment funds with an asset under management (AUM) of 10.614 billion yuan; seven ESG investment funds with an AUM of 3.788 billion yuan; 67 funds have invested in ecology, low-carbon, environmental protection, green, environmental governance, new energy and beautiful China, with an AUM of 155.009 billion yuan.

[114] This calculation is based on the proportion of credit funds in the total investment of relevant green projects.

References

Andersson, M., Morgan, J., & Baccianti, C. (2020). Climate change and the macro economy. ECB Occasional Paper, (2020243).

Aurora Industry Research Institute and Xi'an Jiaotong University, *Low Carbon Travel Makes Life Better-Social Value Report of Shared Motorcycle.*

Beeks, J. C., & Ziko, A. (2018). Internalizing economic externalities on the macroeconomic stage. Exploring and expanding Paul Hawken's the ecology of commerce: a declaration of sustainability for globalized solutions. European Journal of Sustainable Development Research, 2(1), 03.

Bekhet, H. A., & Yasmin, T. (2012). Economic Growth and Pollutant Emission in Malaysia: An Empirical Analysis of Environmental Kuznets Curve. In 16th AFBE Conf., Putrajaya, Malaysia (pp. 370-387).

BIS, (2015). *Central bank operating frameworks and collateral markets*, Bank for International Settlements

BP Statistical Review of World Energy, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html [Accessed 2022.09.14]

Brunnermeier, M., & Landau, J. P. (2020). *Central banks and climate change*. Disponible en VoxEU. org: https://voxeu. org/article/central-banks-and-climate-change.

Camille M. and Alain N. Greening Monetary Policy: Evidence from the People's Bank of China. BIS Working papers, 2021.

CCTV, *China's new building "greening" has exceeded 90 percent*, https://www.gov.cn/xinwen/2022-07/10/content_5700331.htm [Accessed 2022.07]

Center for International Knowledge on Development (CIKD), 2021, Progress Report on China's Implementation of the 2030 Sustainable Development Agenda, 2021 Available at: https://www.fmprc.gov.cn/web/ziliao_674904/zt_674979/dnzt_674981/qtzt/2030kcxfzyc_686343/zw/202109/P020211019126076276210.pdf

Chen, J., Xu, C., Gao, M. et al. 2022 Carbon peak and its mitigation implications for China in the post-pandemic era. Sci Rep 12, 3473 (2022). https://doi.org/10.1038/s41598-022-07283-4

Cheng K, Pan G (2021). "How much more carbon could China agriculture sequestrate". *China Dialog*. 12 January. Available at: https://chinadialogue.net/zh/5/69745/ (accessed 11 January 2021).

China Bicycle Association, 2022. Research report on the green travel index of two-wheel bicycles[R].

China Building Materials Academy, 2023. Pilot Demonstration Study on Carbon Neutralization Path and Collaborative Disposal in China's Cement Industry [R].

China Emission Accounts and Datasets. Carbon Emission List of 290 Chinese Cities. Available at: https://www.ceads.net.cn/data/city/[Accessed 2023.07]

China Green Finance Policy 2021 Analysis Report. Climate Bonds Initiative and SynTao Green Finance, 2022. Published online: cn.climatebonds.net.

China Regional Green Finance Development Report (2022). International Institute of Green Finance, Central University of Finance and Economics. Beijing: Social Science Academic Press (China), 2023.

China, National Communications on Climate Change to UNFCCC, 2004, 2012, 2017 & 2018.

China's State Council Information Office (SCIO), 2021a, China's Policies and Action in Responding to Climate Change, https://www.gov.cn/zhengce/2021-10/27/content_5646697.htm

China's State Council Information Office (SCIO), White Paper on China's Practice of Alleviating Poverty of Humankind

CICC Research, CICC Global Institute (2022) Green investment: new trend, new direction. In Guidebook to carbon neutrality in China: macro and industry trends under new constraints (pp. 287–316). Singapore: Springer Singapore. Indicators 69, 758–770

City of Shanghai. *Several Opinions on the Planning and Management of Roads (Streets and Alleys) for Landscape Protection in the City of Shanghai*, 2007

City of Shenzhen. Policy opening. *Shenzhen Pilot Reform Program for Quality Industrial Space Supply*, 2021. http://www.sz.gov.cn/cn/xxgk/zfxxgj/zwdt/content/post_9640436.html [Accessed 2023.07]

Climate Bonds Initiative. 2021. China Green Finance Policy Analysis Report 2021. https://www.climatebonds.net/files/reports/policy_analysis_report_2021_en_final.pdf .

CSIO, 1996, Environmental Protection in China

Daniel Z., Jeongmin S., Jonathan W. 2021. Five consumer trends shaping the next decade of growth in China. https://www.mckinsey.com/cn/our-insights/Five-consumer-trends-shaping-the-next-decade-of-growth-in-China [Accessed 2023.07]

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). *Confronting the environmental Kuznets curve*. Journal of economic perspectives, 16(1), 147-168.

Department of Transportation, 2022. Press Conference. http://news.china.com.cn/txt/2020-10/22/content_76833411.htm [Accessed 2023.03]

Development and Research Center of the State Council (DRC) & the World Bank, 2022, Four Decades of Poverty Reduction in China: Drivers, Insights for the World, and the Way Ahead, https://thedocs.worldbank.org/en/doc/f692402b5b3b21154f103ee64c0c551d-0070012022/original/Poverty-Synthesis-Report-cn.pdf

Feng, Li & Wu, 2019 The Macroeconomic Policy Framework for Structural Transformation: Experiences and Implications from China, UNCTAD project policy paper https://unctad.org/system/files/official-document/BRI-Project_RP6_en.pdf

Gates, B. (2021). How to avoid a climate disaster: the solutions we have and the breakthroughs we need. Vintage.

General Office of the Central Committee of the Communist Party of China, and General Office of the State Council, 2021 *Opinions on Promoting Green Development of Urban and Rural Construction*

Giulia C, et al. (2020). "Emissions due to agriculture: Global, regional and country trends 2000–2018", *FAOSTAT Analytical Brief 18,* Rome: Environmental Team, Statistics Division, FAO, p.11. Available at: https://www.fao.org/3/cb3808en/cb3808en.pdf (accessed 11 September 2023).

Grossman GM, Krueger AB. Environmental impacts of a North American free trade agreement [No. w3914]. Massachusetts Avenue Cambridge: National Bureau of Economic Research; 1991

Gu Z (2022). "Five Ministries Jointly Issue the Document to Consolidate the Achievements of Converting Farmland to Forests and Grasslands", *People's Daily*, 15 November.

Guo, Y, et al. (2006). "Analysis of factors controlling soil carbon in the conterminous United States". *Soil Science Society of America*. Vol.70, pp.601-612.

Han P.D., Zou J. et al., 2021. *Global Climate Governance and China's Role*. China Council for International Cooperation on Environment and Development.

Hu P (2019). "Sichuan Possesses 5,375 Kinds of '3High-Quality (*pin*) 1 Standardized (*biao*)' Agricultural Products, with Geographical Indication Ranking the 2nd in China", 21 May, Available at: http://www.iprchn.com/Index_NewsContent.aspx?NewsId=116156 (accessed 2 July 2023).

Huaxia (2021). "Xi Focus: Walk the talk: Xi leads China in fight for carbon-neutral future", Xinhua News Agency, March 16. Available at: http://www.xinhuanet.com/english/2021-03/16/c_139814792.htm (accessed 18 March 2021).

Institute of Climate Change and Sustainable Development, Tsinghua University. Comprehensive report on China's long-term low-carbon development strategy and transition path. China Population Resources and Environment, 2020, 30(11):25. (in Chinese).

Intergovernmental Panel on Climate Change, 2022, Climate Change 2022: Mitigation of Climate Change Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York.

International Energy Agency (IEA) (2022) Global energy review: CO2 emissions in 2021. Available at https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2.

International Energy Agency, 2021. *An energy sector roadmap to carbon neutrality in China. Available at:* https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china?language=zh

International Energy Agency, 2023, Renewables 2022: Analysis and forecast to 2027, https://iea.blob.core.windows.net/assets/ada7af90-e280-46c4-a577-df2e4fb44254/Renewables2022.pdf

IPCC (2022) Sixth Assessment Report of WGIII: Mitigation, Cambridge University Press.

IPCC, 2014, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

Jaumotte, F., Liu, W., & McKibbin, W. (2021). Mitigating Climate Change: Growth-Friendly Policies to Achieve Net Zero Emissions by 2050.

Ji L (2021). "How Much Potentiality Does Agricultural Water Conservation Have?" *Economic Daily*, 23 August, https://www.gov.cn/xinwen/2021-08/23/content_5632704.htm (accessed 27 September 2023).

Jiang Kejun, He Chenmin, Xiang Pianpian (2021) Transport scenarios for China and the role of Electric Vehicles Under Global 2℃/1.5℃ Targets, Energy Economics, 103, 105172.

Jiang Kejun, He Chenmin, Zhuang Xing, Liu Jia, Gao Ji, Xu Xiangyang, Chen Sha (2016) Scenario and Feasibility Study for Peaking CO2 Emission in between 2020 and 2022 from Energy Activities in China, Advance in Climate Change Research (Chinese version), 12 (3), 167-171

Jiang Kejun, Toshihiko Masui, Tsuneyuki Morita, Yuzuru Matsuoka. 1999 Long-term emission scenarios for China. Environmental Economics and Policy Studies 2 (4):267-87.

Jiang Kejun, Xiulian Hu, Songli Zhu. 2006 multi-gas mitigation analysis by IPAC. Energy Journal Multi-Greenhouse Gas Mitigation and Climate Policy (Special Issue #3):425-40.

Jiang Kejun, Zhuang Xing, Miao Ren, He Chenmin. (2013) China's role in attaining the global 2°C target. Climate Policy, Vol. 13 No. S01, 55–69.

Jiang Z (2002). *Presidential Decree No.72: The Clean Production Promotion Law of People's Republic of China*, The 28th Meeting of the Standing Committee of the Ninth National People's Congress, 29 June, Available at: https://www.gov.cn/gongbao/content/2002/content_61640.htm (accessed 20 June 2023).

Jiang, Kejun, He Chenmin, Dai Hancheng, Liu Jia, Xu Xiangyang. (2018) Emission Scenario Analysis for China under the Global 1.5℃ Target. Carbon Management. vol. 9, No. 5, pp. 481−491.

Jiang, Kejun, Xiang Pianpian, He Chenmin, Feng Shengbo, Liu Changyi, Tan Xin, Chen Sha, Deng Liangchen (2021). Analysis of the impact of zero-carbon electricity on the layout of China's industrial sector. Journal of Global Energy Interconnection. vol.4, No.1, pp.5-8 (in Chinese).

Krogstrup, S., & Oman, W. (2019). Macroeconomic and financial policies for climate change mitigation: A review of the literature.

Levin & Rich, 2017 Turning points: trends in countries' reaching peak greenhouse gas emissions over time, World Resources Institute Working Paper, 2017. https://files.wri.org/d8/s3fs-public/turning-points-trends-countries-reaching-peak-greenhouse-gas-emissions-over-time.pdf

Lewis H, Gerald B (2020). "Understanding China's growing involvement in global health and managing processes of change", *Globalization and Health*, Vol.16, No.39.

Li H (2022). "How Comes the 1.8 billion 'Red Line'?" *Study Times*, 13 June. Available at: http://www.legaldaily.com.cn/Village_ruled_by_law/content/2022-08/10/content_8734978.html (accessed 1 August 2023).

Li X.J., Dominic W. et al., 2020 *Major Green Technology Innovation and Implementation Mechanisms.* China Council for International Cooperation on Environment and Development.

Li X.J., Dominic W. et al., 2021 *Study of Community Green Renewal under the Carbon Neutrality Goals: Major Green Technology Innovation and Implementation Mechanisms Phase II*. China Council for International Cooperation on Environment and Development.

Li, Ji-Feng, Zhong-Yu Ma, et al. Analysis on energy demand and CO2 emissions in China following the Energy Production and Consumption Revolution Strategy and China Dream target. Advances in Climate Change Research, 2018, 9(1):11. (in Chinese).

Lin B, et al. (2019). "Mitigation of greenhouse gas emissions in China's agricultural sector: Current status and future perspectives", *Chinese Journal of Eco-Agriculture*, Vol.27, No.12.

Linster M. and Yang, C. 2018. China's Progress Towards Green Growth: An International Perspective, OECD Green Growth Papers, No. 2018/05, OECD Publishing, Paris.

Liu X.H., 2023: A new answer to the green development of the mining industry under the "dual carbon" target[R], Available at: https://www.cgs.gov.cn/ddztt/jdqr/dqr54/jsdwhd/202304/t20230421_729878.html

MARA, MOF (2020). *Action Plan of Conservation Tillage in Northeast Black Land (2020–2025) (No.2 [2020] of Agricultural Machinery)*. 18 March. http://www.gov.cn/zhengce/zhengceku/2020-03/18/content_5492795.htm (accessed 17 September 2022).

MEE (2018). *The 2nd Biennial Report of China in Climate Change.* Available at: https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/201907/P020190701765971866571.pdf (accessed 4 May 2023).

MEE (2022). *National Strategy for Climate Adaptation 2035*. Available at: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202206/W020220613636562919192.pdf (accessed 22 September 2023).

Mercure, J. F. (2019). Toward risk-opportunity assessment in climate-friendly finance. One Earth, 1(4), 395-398.

Mi, Z., Meng, J., Green, F., Coffman, D. M. & Guan, D. China's "exported carbon" peak: patterns, drivers, and implications. Geophys. Res. Lett. 45, 4309–4318 (2018).

Millimet, D. L., Roy, S., & Sengupta, A. (2009). Environmental regulations and economic activity: Influence on market structure. Annu. Rev. Resour. Econ., 1(1), 99-118.

Ministry of Ecology and Environment of China (MEE) (2021). "Progress on the Implementation of China's Nationally Determined Contributions (2022)", *National Determined Contribution Registry*, United Nations Climate Change, 28 October. Available at: https://unfccc.int/NDCREG (accessed 20 November 2023).

Ministry of Housing and Urban-Rural Development, 2017: *Thirteenth Five-Year Plan for Building Energy Efficiency and Green Building Development*

Ministry of Housing and Urban-Rural Development, 2020. Statistical Yearbook of Urban-Rural Construction.

Ministry of Housing and Urban-Rural Development, 2020. Statistical Yearbook of Urban Construction.

Ministry of Housing and Urban-Rural Development, 2022. *A list of experience promotion for prefabricated buildings (Batch 1)*

Ministry of Housing and Urban-Rural Development, and National Development and Reform Commission, 2022: *"Implementation Program for Peak Carbon in Urban and Rural Construction Sector"*

Ministry of Water Resources (MWR) and NDRC (2021). "Implementation Plan for Major Agricultural Water-Saving and Water Supply Projects during the 14th Five-Year Plan", 16 August. Available at: https://www.gov.cn/xinwen/2021-08/16/content_5631540.htm (accessed 15 September 2023).

MOF, MARA (2022). *Notice on the Issuance of "Measures for Subsidy for Farmland Construction"*, 12 January. Available at: http://www.gov.cn/zhengce/zhengceku/2022-02/01/content_5671563.htm (accessed 12 March 2023).

National Bureau of Statistics (NSB) (2017) China Statistical Yearbook 2017. Beijing: China Statistic Publishing House.

National Bureau of Statistics (NSB) (2022) China Statistical Yearbook 2022. Beijing: China Statistic Publishing House.

National Bureau of Statistics*, China Statistical Yearbook, 2022*.

National Bureau of Statistics, the 7th census

National Development and Reform Commission (NDRC) (2013). "National Strategy for Climate Adaptation". Available at: http://www.gov.cn/zwgk/2013-12/09/content_2544880.htm (accessed 11 November 2022).

National Development and Reform Commission (NDRC) (2021). Improved Program for Dual-Controlling Energy Intensity and Total Energy Consumption. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202109/t20210916_1296856.html.

National Development and Reform Commission, 2018. *Review Announcement Catalogue of China Development Zones (2018 Edition).*

National Development and Reform Commission, 2021. *Development Plan for Domestic Waste Classification and Treatment Facilities in Urban Areas during the 14th Five-year Plan Period.*

National Energy Administration (NEA) (2022) Electricity Industry Information. Beijing.

Nedopil, Christoph and Song, Ziying. 2023. China Green Finance Status and Trends 2022-23, Green Finance & Development Center, FISF Fudan University, Shanghai.

NGFS, A. (2020). Adapting central bank operations to a hotter world: Reviewing some options. Network for Greening the Financial System: London, UK.

OECD. 2020. Developing Sustainable Finance Definitions and Taxonomies. https://www.oecd-ilibrary.org/finance-and-investment/developing-sustainable-finance-definitions-and-taxonomies_134a2dbe-en

Oei, P. Y., Hermann, H., Herpich, P., Holtemöller, O., Lünenbürger, B., & Schult, C. (2020). Coal phase-out in Germany–Implications and policies for affected regions. Energy, 196, 117004.

Paola A. Arias, et al. (2021). eds. "Technical Summary", in *Climate Change 2021: The Physical Science Basis. Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)* (WMO/UNEP). New York: Cambridge University Press.

Paull J (2010). "From France to the World: The International Federation of Organic Agriculture Movement (IFOAM)", *Journal of Social Research & Policy*, No.2, pp.93-102.

People's Daily, *improving energy efficiency of buildings, promoting low carbon development*, https://www.gov.cn/xinwen/2022-01/11/content_5667577.htm [Accessed 2023.03]

Peters, G. P. & Hertwich, E. G. CO2 embodied in international trade with implications for global climate policy. Env. Sci. Technol. 42, 1401–1407 (2008).

Pigou, A. C. (2013). The Economics of Welfare. New York, NY: Palgrave Macmillan

Pollin, R. (2019). Green economics and decent work: A viable unified framework. Development and Change, 51(2), 711-726.

Qianzhan Industry Research Institute, 2020. Research on the development status and investment prospects of China's electric bicycle industry[R]. https://bg.qianzhan.com/report/detail/300/200812-a2037aaa.html [Accessed 2023.03]

Qin Dahe. (2021) China's Climate Change and Eco-Environment Development 2021. Beijing, China Science Publishing House.

Qu C, Qiao J (2016). "Holding the Rice Bowl in Our Own Hands: A Comprehensive Review of the Implementation of National Food Security Strategy Since the 18th National Congress of the CPC", *Economic Daily*, 1 March. Available at: https://www.gov.cn/xinwen/2016-03/01/content_5047577.htm (accessed 1 May 2023).

Rasli, A. M., Qureshi, M. I., Isah-Chikaji, A., Zaman, K., & Ahmad, M. (2018). New toxics, race to the bottom and revised environmental Kuznets curve: The case of local and global pollutants. Renewable and Sustainable Energy Reviews, 81, 3120-3130.

Ren Y., Romson A. et al., 2021: *Opinions of the State Council of the Central Committee of the Communist Party of China on the Complete and Accurate Implementation of the New Development Concept and Doing a Good Job of Peak Carbon Achievement and Carbon Neutrality".*

Ren Y., Romson A. et al.,2019: *Special Policy Study on Green Transition and Sustainable Social Governance*. China Council for International Cooperation on Environment and Development.

REN21. 2022. Renewables 2022 Global Status Report Collection.

Research Group on China's Long-term Low-carbon Development Strategy and Transition Pathway, 2021, Understanding Carbon Neutrality: China's 2020-2050 Low-Carbon Development Action CITIC Press, Beijing, China. (in Chinese).

Research Report on The Development of China's Green Finance 2022. Zhu Xinkai, et al. Beijing: China Financial Publishing House, 2023.

Richard Lord, Ruben Sakrabani (2019), "Ten-year legacy of organic carbon in non-agricultural (brownfield) soils restored using green waste compost exceeds 4 per mille per annum: benefits and trade-offs of a circular economy approach". *Science of the Total Environment*. Vol.686, pp.1057-1068.

Shenzhen Industrial Park Association. News Center. *Implementation Program for Approval of Shenzhen "Industry to Buildings" Projects*, 2023. http://www.sipa.org.cn/news/503.html [Accessed 2023.07]

Smith P, et al. (2000). "Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture". *Global Change Biology*. Vol.6, pp.525-539.

Song G, et al. (2005). "Topsoil organic carbon storage of China and its loss by cultivation". *Biogeochemistry*, Vol.74, pp.47-62; Zhangcai, Qin, et al. (2013), "Soil organic carbon sequestration potential of cropland in China". *Glocal Biongeochemical Cycles*. Vol.27, pp.711-722.

State Council (SC) (2013) China: Air Pollution Prevention and Control Action Plan, State Council. Beijing.

State Council Information Office, 2023. *China's Green Development in the New Era*. Available at: https://www.gov.cn/zhengce/2023-01/19/content_5737923.htm

State Council Information Office. 2023. The white paper China's green development in the new era [R].

State Council, 2021. *Peak Carbon Action Program by 2030.*

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. World development, 32(8), 1419-1439.

The State Council (1982). "Minutes of National Rural Affairs Work Conference", *The State Council Bulletin*, No.8 (General No.382).

The World Bank Group (2020). *Arable land (hectares per person) -China, Data*. Available at: https://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?locations=CN (accessed 29 April 2023).

Tsinghua University, 2020, Synthesis Report, Study on China's Long-Term Low-Carbon Development and Transition Pathway, Journal of China's Population, Resources and Environment, volume 30.

UNCTAD, 2022, China's Structural Transformation: what can developing countries learn?

UNCTAD, 2023a, Trade and Development Report

UNCTAD, 2023b, Transitioning to a clean energy growth model: Challenges, opportunities and solutions, Background Note by UNCTAD secretariat for multi-year expert meeting

United Nations Environment Program. *Emissions Gap Report 2020.* Available at: https://www.unep.org/emissions-gap-report-2020

Vaze, P., Meng, A., & Giuliani, D. (2019). Greening the financial system. Climate Bonds Initiative: London, UK.

Wang Q, Xu Y (2018). "Ningxia's 'Carbon Trading Pioneer' Zhang Jisheng: The Green Development Path of a Modern 'Carbon Merchant'", *Huaxing Times*, 18 September. Available at: https://www.ideacarbon.org/news_free/46917/ (accessed 10 June 2023).

Wang Zhongying, Zheng Yanan, Zhao Yongqiang, Tao Ye, Hui Jingxuan, He Ze (2021). Development Pathway and Prospect of Renewable Energy Becoming the Dominant Energy under the Background of Carbon Neutrality. Energy of China, 9, 7-13 + 10,9-17 (in Chinese).

WEO, I. (2022). Near-Term Macroeconomic Impact of Decarbonization Policies.

William D. Nordhaus, 2021, The Spirit of Green: The Economics of Collisions and Contagions in a Crowded World. (in Chinese).

World Bank Data, https://data.worldbank.org/indicator/NY.GDP.PCAP.CD [Accessed 2021.09.14]

Xiang Pianpian, Chenmin He, Sha Chen, Weiyi Jiang, Jia Liu, Kejun Jiang. (2023) Role of hydrogen in China's energy transition towards carbon neutrality target: IPAC analysis. Advances in Climate Change Research, 14(1), 6.

Xiao, Xinjian, and Jiang Kejun (2018). China's nuclear power under the global 1.5 ℃ target: preliminary feasibility study and prospects, Advances in Climate Change Research, vol.9, No. 2, pp. 138−143.

Xie Fuzhan, Zhuang Guotai Climate Change Green Book (2021): Carbon Peak and Carbon Neutrality Album Beijing: Social Science Literature Publishing House, 2021:282-293. (in Chinese).

Xinhua News Agency (2023). "Lucid waters and lush mountains are invaluable assets", Available at: http://www.xinhuanet.com/politics/szzsyzt/lsqs2017/index.htm (accessed 10 September 2023).

Xishuangbanna National Nature Reserve Administration (2009). "The World's First Asian Elephant Public Liability Insurance Is Officially Signed in Our Prefecture". Xishuangbanna Dai Autonomous Prefecture People's Government. 17 November. Available at: https://www.xsbn.gov.cn/zrbhq/112821.news.detail.dhtml?news_id=1854496 (accessed 1 January 2023).

Yang S (2022). "China Has Taken Out Measures to Strictly Observe the Red Line of Arable Lands", *Guangming Daily*, 26 June. Available at: http://www.gov.cn/xinwen/2022-06/26/content_5697791.htm (accessed 10 October 2022).

Yu T, Ding H, and Zhao H (2021). "Climate Resilience Agriculture to be Carried Out for Adaptation", World Resource Institute, 23 June. Available at: https://wri.org.cn/insights/agriculture-resilience-adaptation (accessed 17 June 2023).

Yu, X., & Tan, C. China's process-related greenhouse gas emission dataset 1990–2020. Scientific Data.

Yunnan CPC Committee, Yunnan Government (2022). "Opinions of the CPC of Yunnan Provincial Government on Fully, Accurately, and Comprehensively Implementing the New Development Concept and Achieving Carbon Peak and Carbon Neutrality", 7 December, https://www.yn.gov.cn/zwgk/zcwj/swwj/202212/t20221214_251809.html (accessed 7 July 2023).

Yunnan Government (2018). *Notice of Setting the Ecological Red Line of Yunnan Province [No.32]*, 29 June, https://www.yn.gov.cn/zwgk/zcwj/zxwj/201911/t20191101_184159.html (accessed 5 January 2023).

Zhang Tengfei, 2023: Analysis of the energy-saving transformation situation of China's existing residential buildings [J]. *Sichuan Building Materials*, 1-3.

Zhang W (2007). "The History of the First CDM Project in China", *Economy*, Vol.7, pp.23-24.

Zhang Xiliang, Huang Xiaodan, Zhang Da, Geng Yong, Tian Lixin, Fan Ying, Chen Wenying (2022) Energy Economic Transition and Policy Study with Carbon Neutrality Target, Management World, No.1, 2022 (in Chinese).

Zhang Y (2020). "Anhui's '3 High-Quality and 1Standardized' Agricultural Products Totaled 7,262, Ranking the 6th in China", *Anhui Commercial Times,* 22 January. Available at: http://ah.sina.com.cn/news/2020-01-22/detail-iihnzahk5690207.shtml (accessed 10 July 2023).

Zhang Y, et. al. (2021), "Transforming Agrifood Systems to Achieve China's 2060 Carbon Neutrality Goal", in AGFEP, et. al., *2021 China Food and Global Food Policy Report*, pp.22-23. Available at: http://agfep.cau.edu.cn/module/download/downfile.jsp?classid=0&filename=2105141928327359.pdf (accessed 2 May 2023).

Zhao Y, et al. (2018). "Carbon sequestration potential in Chinese cropland soils: review, challenge, and research suggestions". *Bulletin of Chinese Academy of Sciences*. Vol.33, pp.191–197.

Zhou, X. Y., Lei, K., Meng, W., & Khu, S. T. (2017). Industrial structural upgrading and spatial optimization based on water environment carrying capacity. Journal of Cleaner Production, 165, 1462-1472.