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Carbon Neutrality-oriented Approach to Mid- and Long-term Low-Carbon Transition Towards the New Climate Change Goals[i]

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Abstract: Green and low-carbon transition has become an important development direction for future global economy and society. President XI Jinping pointed out that it is necessary to incorporate the goal of peaking carbon emissions and achieving carbon neutrality into the overall plan for economic and social development and ecological civilization construction. This is a major strategic decision made by the CPC Central Committee in consideration of both the international and domestic situations, and has been highly praised by the international community. It will contribute to the pursuit of the goals of high-quality development and ecological progress, inject strong impetus into the international response to climate change and the full and effective implementation of the *Paris Agreement*, and add new momentum to the post-epidemic global green recovery as well as the building of a community for all life on earth. However, the realization of the dual carbon target is very challenging, facing with multiple constraints such as technology, capital and system. At the same time, it needs to coordinate the relationships between short-term and long-term, development and emission reduction, and international and domestic. This paper organically combines the long-term low-carbon development strategy with the two phased goals of socialist modernization, and puts forward the timetable, roadmap and priorities for China's dual carbon targets. Moreover, it provides countermeasures and suggestions to promote the orderly implementation of the dual carbon strategic goals from six aspects: industrial structure, energy structure, technological innovation, regional coordination, institutional policies and international cooperation.

Key Words: Carbon neutrality, Climate change, Green and low-carbon transition, Roadmap, High-quality development

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In the general debate of the 75th United Nations General Assembly, Chinese President XI Jinping stated that "China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures, and strive to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060". Determination of this goal further demonstrates to the world the active position and strong actions taken by China to make greater contributions to the global response to climate change, and follow the new trend of achieving green and high-quality recovery and low-carbon transformation in the post-Covid era.

In order to realize the commitments made by President XI Jinping to the world and strive for a better result, China needs to make arduous efforts to integrate the short-term, medium-term and long-term goals of tackling climate change challenges with economic, social and environmental targets and establish goals-oriented mechanisms, identify the timetable, roadmap and priorities, and promote the comprehensive green transformation and green, low-carbon circulation and high-quality development in various fields in an orderly manner.

I. Background of New Climate Goals

1.1 Green and low-carbon development has become an important development trend for the global economy and society in the future

1.1.1 The urgency of global carbon neutrality

In 2019, the term "climate emergency" was selected among the "Words of the Year" in the *Oxford Dictionary*. On September 23, 2019, United Nations Secretary-General Antonio Guterres pointed out at the Climate Action Summit that the response to the climate emergency is to fight for our lives; on December 12, 2020, he called on every member country to declare a climate emergency in his speech at the Climate Ambition Summit that marked the fifth anniversary of the *Paris Agreement*. Ample evidence has shown that our current efforts cannot meet the goals and requirements set out in the *Paris Agreement*. Therefore, the Secretary-General of the United Nations also announced that the core goal of the United Nations in 2021 is to establish a global coalition for carbon neutrality by mid-century (Guterres, 2020).

In 2015, at the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21), the parties unanimously adopted the *Paris Agreement*, which identified the global response to climate change after 2020. The long-term goal is to control the global average temperature rise within 2°C compared with the pre-industrial period, and strive to limit the temperature rise within 1.5°C. However, when assessing the Nationally Determined Contributions (NDCs) targets submitted before October 1, 2015 (by 146 countries in total, accounting for approximately 90% of global emissions) the United Nations Environment Programme (UNEP) found that the NDCs submitted by the countries fell far short of meeting the 2°C target though they reflect their determination to reduce emissions (UNEP, 2015). In the 2019 Emission Gap Report, the UNEP stated that if merely the current climate commitments of the *Paris Agreement* are fulfilled, the global temperature may still rise by 3.2°C at the end of the 21st century, and now the temperature has risen by more than 1.1°C (UNEP, 2019). In order to benchmark the temperature control targets of the *Paris Agreement*, more ambitious emission reduction commitments are expected when countries update their NDCs targets in 2020.

Since the *Paris Agreement* put forward the 2°C temperature control target, growing pressure is imposed on international emission reduction. The Intergovernmental Panel on Climate Change (IPCC) special report on the impacts of global warming of 1.5°C above pre-industrial levels also mentioned that although the 1.5°C temperature increase will still have climate impact, this rise is less destructive compared with a higher global warming level (IPCC, 2018). The study shows that the world must rapidly reduce carbon emissions to 25 billion equivalent tons of CO_2 before 2030 to curb global warming within 1.5°C. The current challenge lies in the fact that the global carbon emissions by 2030 are estimated to reach 56 billion equivalent

tons of CO_2, if calculated according to the current emission reduction commitments of the *Paris Agreement*; and this will almost twice the target level (UNEP, 2019).

1.1.2 International efforts

According to the IPCC's special report on global warming of 1.5°C in 2018, only when the world achieves zero anthropogenic CO_2 emissions around 2050 can the 1.5°C temperature control target be achieved. As of December 2020, there are 126 countries that have proposed or are planning to propose carbon neutrality targets[iii] (Energy and Climate Intelligence Unit, 2020), covering 75% of global GDP, 53% of the total population, and 63% of carbon emissions. Among them, Suriname and Bhutan have achieved net zero emissions of greenhouse gases; 25 countries have clearly put forward their respective carbon neutral targets in the form of legislation (or proposed legislation) and policy announcements, including the world's top ten emitters such as China, Japan, Germany, Canada, the United Kingdom and South Korea; 99 other countries have put forward carbon neutrality targets in the form of verbal commitments, but did not give detailed information on the targets. Among the 126 countries, 28 have carbon neutral targets covering all greenhouse gases, and 29 have set clear mid-term targets.

At present, the carbon neutrality and emission reduction commitments made by European countries are more ambitious than others. All of the 27 EU member states have proposed carbon neutrality targets except Poland, and 11 of the 25 countries that have formally declared carbon neutrality targets are from the EU. On September 17, 2020, the European Commission announced that it plans to increase its greenhouse gas emission reduction targets from a 40% reduction on the basis of the 1990 levels to at least 55% in reduction (EC, 2020); on December 11, the leaders of the 27 EU countries reached a consensus on higher emission reduction targets at the summit held in Brussels. The EU is expected to cut greenhouse emissions by at least 55% compared to 1990 and realize carbon neutrality by 2050[iv]. Moreover, 10 EU member states including Germany and Spain have clarified that their targets of carbon neutrality cover all greenhouse gases (*i.e.*, the neutrality of greenhouse gases; Hungary does not have a clear stance on this). France, Sweden, Hungary and Denmark have already enacted legislation on such target. Among the European countries who have made declarations, Sweden, Austria, and Finland are more ambitious with neutrality deadlines earlier than 2050, which are 2045, 2040, and 2035, respectively. Although Iceland is not an EU country, its goal of achieving greenhouse gas neutrality by 2040 also reflects its determination to reduce emissions.

Although the United Kingdom has withdrawn from the EU, it has set carbon neutrality goal that is consistent with the organization: the United Kingdom has already made legislation about the goal of achieving greenhouse gas neutrality by 2050, and has included a medium-term goal (Energy and Climate Intelligence Unit, 2020). Japan also proposed on October 26, 2020 that it will achieve its carbon neutrality target by 2050, but it is unclear whether it will include all greenhouse gases and whether it will identify a mid-term target. Although South Korea is enacting legislation on its 2050 carbon neutrality target, still unknown are the types of greenhouse gases to be covered, nor is it known whether or not any mid-term transition goal will be given.

Among the 99 countries that have put forward their carbon neutrality goals in the form of oral commitments, all other countries plan to achieve carbon neutrality by 2050 except for Uruguay, which plans to achieve carbon neutrality by 2030. As the relevant plans of various countries are still being formulated, the greenhouse gases covered by the carbon neutrality targets and the mid-term transition targets of most countries are unclear. U.S. President Biden promised to make climate change response a major basis of governance and proposed the goal of achieving carbon neutrality by 2050. However, if the United States returns to the *Paris Agreement*, its NDC may not be disclosed until 2021, and its further policy actions remain to be seen. Although Italy, Argentina, and the Netherlands have not made official announcement, these larger economies all plan to achieve greenhouse gas neutrality by 2050 and have identified their own mid-term goals (Table 1).

[iii] Including the United States (which has verbally committed to achieving carbon neutrality).

[iv] *Leaders of EU member states have reached consensus on higher emission reduction targets.* http: //www. xinhuanet. com/2020-12/12/c_l126852794. Htm [2020-12-12].

Table 1. Countries that have clearly proposed or have achieved carbon neutrality targets and their commitment means

Number	Country or region	Target year	Commitment means	Does it cover all greenhouse gases	Does it cover mid-term goals
1	Suriname	—	Achieved	Yes	—
2	Bhutan	—	Achieved	Yes	—
3	UK	2050	Law	Yes	Yes
4	France	2050	Law	Yes	Yes
5	Sweden	2045	Law	Yes	Yes
6	Denmark	2050	Law	Yes	Yes
7	New Zealand	2050	Law	No	Yes
8	Hungary	2050	Law	Unclear	Yes
9	Spain	2050	Proposed legislation	Yes	Yes
10	Fiji	2050	Proposed legislation	Yes	Yes
11	Canada	2050	Proposed legislation	Yes	Yes
12	Chile	2050	Proposed legislation	Yes	Unclear
13	South Korea	2050	Proposed legislation	Unclear	Unclear
14	Germany	2050	Policy documents	Yes	Yes
15	Switzerland	2050	Policy documents	Yes	Yes
16	Austria	2040	Policy documents	Yes	Yes
17	Norway	2050	Policy documents	Yes	Yes
18	Ireland	2050	Policy documents	Yes	Yes
19	South Africa	2050	Policy documents	No	Yes
20	Finland	2035	Policy documents	Yes	Yes
21	Portugal	2050	Policy documents	Yes	Yes
22	Costa Rica	2050	Policy documents	Yes	Yes
23	Slovenia	2050	Policy documents	Yes	Yes
24	Iceland	2040	Policy documents	Yes	Yes
25	Marshall Islands	2050	Policy documents	Yes	No
26	China	2060	Policy documents	Unclear	Unclear
27	Japan	2050	Policy documents	Unclear	Unclear

Source: From the Net Zero Tracker released by the Energy and Climate Intelligence Unit. Data as of December 2020.

1.1.3 China's commitment

China has always been a strong advocate of global climate governance and environmental protection. Among the NDCs targets submitted by China in June 2015, four goals have been reached or even exceeded expectations for 2020, such as the CO_2 emissions per unit GDP decreased by 45.8% in 2018 compared to 2005, which exceeded the target of 40%–45% reduction set for 2020 ahead of schedule. In the face of increasing global demand for greater efforts and update of NDCs goals, China as a responsible major power has made strategic decisions with the coordination of international and domestic efforts. In his speech delivered at the general debate of the 75th United Nations General Assembly, Chinese President XI Jinping made commitment for greater emissions reduction, that is, China will strive to reach the peak of CO_2 emissions by 2030, and endeavor to achieve carbon neutrality by 2060. This embodies the determination of a major power to shoulder and make greater contributions to the goals set by the *Paris Agreement*. Meanwhile, it also boosts the global confidence in responding to climate change.

Although the announced time frame by China for carbon neutrality is about ten years later than the commitment of most developed countries who pledged to achieve carbon neutrality by 2050, it should be noted that the transition time from carbon peaking to carbon neutrality for most developed countries is 50–70 years while China only has about 30 years. This means that as a large developing country, the transformation of China's energy structure and development mode as well as the reduction of greenhouse gas emissions such as CO_2 need to be much faster and stronger than those of developed countries to meet this goal. XIE Zhenhua, special adviser for climate change affairs of the Ministry of Ecology and Environment and president of the Institute of Climate Change and Sustainable Development of Tsinghua University, believes that the current goal of achieving carbon neutrality by 2060 proposed by China far exceeds the requirement of achieving global carbon neutrality around 2065–2070 under the 2°C temperature control target of the *Paris Agreement*. This may advance the time of global carbon neutrality by 5–10 years (Xie Zhenhua, 2020). In addition, it also plays a key role in promoting global climate governance.

1.2 The goal of carbon neutrality proposed by China is the systematic continuation and deepening of ecological civilization building

1.2.1 The evolution of policies and actions related to low-carbon development

Since 2012, the CPC Central Committee with Comrade XI Jinping at its core has formed and actively promoted the overall layout of "Five-in-One", highlighting ecological civilization, new development concepts, high-quality development, ecological priority and green development. This is an important sign for the transformation of its governance principle in the new stage. Furthermore, it is also a comprehensive manifestation of the continuous improvement of the overall level of sustainable development and the ability to carry out top-level design and system promotion by China (Wang Yi, 2019).

In 2012, the Report of the 18th National Congress of the CPC proposed the building of ecological civilization, which included ecological civilization in the overall planning of "Five-in-One", and for the first time proposed the concept of "Beautiful China", prioritizing ecological civilization and integrating it into economic, political, cultural, and social endeavors[v]. Since 2013, the CPC Central Committee and the State Council have issued several important documents such as the *Decisions of the Central Committee of the CPC on Several Major Issues of Comprehensively Deepening Reform*, the *Opinions of the Central Committee of the CPC and the State Council on Accelerating the Building of Ecological Civilization*, and the *Overall Plan for the Reform of Ecological Civilization System*. More than 40 important regulations of ecological civilization have been established, and XI Jinping's Thoughts on Ecological Civilization have since been formed, and become the fundamental principle that leads the building of ecological civilization in China.

China has attached great importance to climate change over years. Active response to climate change has been taken as a major strategy for its national economic and social development. China has made green and low-carbon circular development an important part of and approach to the building of ecological civilization, and has taken a series of specific actions, making important

[v] *HU Jintao's report at the 18th National Congress of the Communist Party of China*. http: //www. xinhuanet. com//18cpcnc/2012-11/17/ c113711665_9.htm [2020-9-11].

contributions to global climate governance. In 2007, the Chinese government established the National Leading Group for Climate Change, Energy Conservation and Emission Reduction, headed by the Premier of the State Council. In the same year, it issued *China's National Climate Change Programme*. In 2008, the Climate Change Division was established under the National Development and Reform Commission. In 2009, on the eve of the United Nations Climate Change Conference in Copenhagen, the Standing Committee of the National People's Congress passed the "Resolution on Actively Addressing Climate Change"; the Chinese government announced its action targets to control greenhouse gas emissions and decided to cut the CO_2 emissions per unit GDP by 40%–45% than the level in 2005.

During the "12th Five-Year Plan" period (2011–2015), China's response to climate change entered the fast lane. *The Outline of the 12th Five-Year Plan for Economic and Social Development of the People's Republic of China* included carbon emission intensity indicators as a binding indicator for the first time, establishing a system of indicators for addressing climate change such as energy consumption intensity, carbon emission intensity, and the proportion of non-fossil energy consumption. During this period, multi-level institutional exploration was also carried out to address climate change, including dual energy control, low-carbon provinces and cities pilots, carbon trading pilots, and carbon emission intensity target accountability systems. Meanwhile, in accordance with the principles of CBDR(Common but Differentiated Responsibilities), fairness and respective capabilities, China undertakes corresponding international responsibilities and actively promotes multilateral and bilateral cooperation in addressing climate change. In November 2014 and September 2015, China and the United States issued joint statements on climate change in Beijing and Washington, which facilitated the conclusion of the *Paris Agreement* and made important contributions to the improvement of the global climate governance system. On June 30, 2015, the Chinese government submitted to the secretariat of the *United Nations Framework Convention on Climate Change the Strengthening Actions to Address Climate Change – China's Nationally Determined Contributions*, and proposed the action plans by 2030 to achieve NDCs, including: CO_2 emissions will peak around 2030 and China will strive to reach the peak as soon as possible. China also determines to reduce CO_2 emissions per unit GDP by 60%–65% compared to 2005, raise non-fossil energy to about 20% of primary energy consumption, and increase forest stocks by about 4.5 billion cubic meters compared with 2005.

During the "13th Five-Year Plan" period (2016–2020), China further clarified its goals and actions to address climate change. *The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China* continued the multi-dimensional target parameter system of energy and climate change responses during the "12th Five-Year Plan" and the dual energy control system was strengthened. Regarding the low-carbon transition of the energy sector, the National Energy Administration issued the *Energy Production and Consumption Revolution Strategy (2016–2030)* in December 2016. It put forward the long-term goal of China's energy development by 2050, highlighting the need to promote a clean and low-carbon transformation of energy and build a modern energy system. In terms of market mechanisms, the National Development and Reform Commission issued the *National Carbon Emission Trading Market Establishment Working Plan (Power Generation Industry)* in 2017, marking the official launch of the national carbon market. Furthermore, China has carried out research on systems and practices related to climate investment and financing focusing on green and low-carbon development and financial policies in response to climate change. On October 20, 2020, the Ministry of Ecology and Environment, the National Development and Reform Commission, the People's Bank of China, the China Banking and Insurance Regulatory Commission and the China Securities Regulatory Commission jointly issued the *Guidance on Promoting Investment and Financing to Address Climate Change*. This document is a milestone for guiding and promoting climate investment and financing and facilitating the new peak goal and the vision of carbon neutrality. In terms of pilots, as of October 2017, a total of 73 low-carbon pilot provinces and cities have proposed peak carbon-emission targets in different means. Areas such as Beijing, Shanghai, and Zhenjiang have also conducted preliminary explorations of carbon emission control

systems. These pilots provide experience and practical basis for formulating a total carbon emission control system and more ambitious goals at the national level. In addition, in March 2016, China and the United States also issued the third joint statement on climate change – the *U.S.-China Joint Presidential Statement on Climate Change*, which played a key role in the signing and effect of the *Paris Agreement*; the Department of Climate Change was transferred to the Ministry of Ecology and Environment in 2018, which strengthened the coordinated governance of climate change, air pollution and other ecological and environmental issues.

China has actively responded to climate change policies and taken actions, achieving remarkable results. The 2009 Copenhagen Climate Conference required all parties to put forward quantified emission reduction targets for 2020, and the NDC proposed by China for 2020 has already been exceeded. As of the end of 2019, China's carbon emission intensity has decreased by 48.1% compared with 2005, and non-fossil energy accounted for 15.3% of primary energy consumption. The average annual growth rate of energy consumption and CO_2 emissions dropped from 6.0% and 5.4% as in the 2005–2013 period to 2.2% and 0.8% in the 2013–2018 period, respectively. The gradual decoupling of economic development and carbon emissions has been achieved.

1.2.2. Public health incidents such as the Covid-19 pandemic have accelerated the response to climate change

In 2020, the Covid-19 pandemic wrecked havoc on the global political landscape, economic order, industrial chain, trade, and employment, and the impact will linger on. There are many possible scenarios and uncertainties for future development[vi]. The global spread of the corona virus has informed people for the first time the importance of public health incidents and associated safety issues. Since the beginning of the 21st century, similar non-conventional security challenges have shown some sign of gradual escalation and may cause serious damages to traditional security and economic and social order. Therefore, we must attach great significance to non-conventional security issues related to ecological environment and climate change and the response to public emergencies. China is currently in a critical period of transition to achieve high-quality economic and social development, with per capita GDP exceeding US$10,000. It has entered the ranks of middle- and high-income countries. Issues such as aging population and public health challenges have become increasingly prominent.

With the rise of a new generation of young people, more attention is drawn to environmental health issues, and the awareness of green consumption has gradually strengthened. The Chinese government has realized that green and low-carbon development will be an important opportunity for high-quality economic and social development from the perspectives of "14th Five-Year Plan" and the medium and long-term development. In this context, the 2020 Report on the Work of the Government first mentioned the concept of "Two New and One Major", namely the construction of new infrastructure, new urbanization and major projects in transportation and water conservancy. In the process of promoting economic recovery, we should focus on the integration of green and low-carbon elements, and advance the green transformation of production and consumption modes. On March 11, 2020, the National Development and Reform Commission issued the *Opinion on Accelerating the Establishment of Regulatory and Policy System for Green Production and Consumption* reviewed and approved by the Central Committee for Comprehensively Deepening Reform. The document defines the systematic framework of the legal and policy system of green production and consumption, and provides an institutional basis for the green transformation of economic and social development.

In September 2020, on the basis of systemic planning and foresighted plans, the CPC Central Committee made a major strategic decision to reach carbon peak by 2030 and achieve carbon neutrality by 2060, which boosted the confidence in global response to climate change and further emission reduction. The promise made by China prompts the world to move towards the goal of controlling the temperature rise within 1.5°C. After that, a series of policy actions were introduced or deployed in quick succession. Currently, a special plan for addressing climate change during the "14th Five-Year Plan" (2021–2025) is in formulation. A CO_2 emission control target will be put forward in line with the new carbon peak target. Furthermore, the Ministry of Ecology and Environment is formulating

[vi] *How the Covid-19 pandemic affects the world economy.* https: //home, kpmg/cn/zh/home/social/2020/03/how-coronavirus-affects-global-economy.html [2020-11-20].

the "Carbon Peaking Action Plan by 2030". It plans to clarify the roadmap, action plan and supporting measures for the peaking targets of local and key industries, which will continue during the "14th Five-Year Plan" and "15th Five-Year Plan" period. In addition, the Ministry of Ecology and Environment will promote the inclusion of Carbon Peaking Action into the range of central environmental protection inspection. On top of that, the building of the national carbon market has been further advanced. On October 28, 2020, two trial documents, the *National Measures for the Administration of Carbon Emission Trading (Trial)* (Draft for Solicitation of Comments) and the *Administrative Measures for the Registration, Trading, and Settlement of the National Carbon Emission Rights (Trial)* (Draft for Solicitation of Comments), were disclosed publicly to solicit comments. Subsequently, the official version of the documents were reviewed and approved by the Ministerial Meeting of the Ministry of Ecology and Environment on December 25, 2020, and set to be implemented on February 1, 2021; the Ministry of Ecology and Environment also issued The *2019-2020 National Carbon Emission Trading Cap Setting and Allowance Allocation Implementation Plan (Power Generation Industry)*. All these will strongly support the national carbon emission rights trading market to enter the substantive stage of operation.

1.2.3. A comprehensive green transformation under the goal of carbon neutrality is an important strategic measure for high-quality development

The report of the 19th National Congress of the Communist Party of China observed that the economy in China has shifted from a stage of rapid growth to a new one of high-quality development. High-quality development requires the implementation of the new development concept of "innovation, coordination, greenness, openness, and sharing"[vii]. Green development is not only an important yardstick for measuring the effectiveness of high-quality development, but also an effective means to promote high-quality development. The advancement of a low-carbon and even zero-carbon economy lies at the core of green development.

With the goal of carbon peak and neutrality, a comprehensive green transformation or green low-carbon development can promote high-quality development in the following aspects. One is to accelerate the transformation of the energy structure. Efforts will be made to guide the orderly withdrawal of fossil energy, establish an energy system with a high proportion of renewable energy, develop nuclear power in a safe way, actively produce and utilize green hydrogen energy, promote the hydrogen energy industry, improve the electrification of the entire economic and social process, especially end-use energy, and strengthen the combination of energy system and digital information technology to realize the intelligent and digital transformation of energy system. The second is to promote the optimization and upgrading of the industrial structure. Through green and low-carbon industries, we will gradually eliminate outdated production capacity, accelerate the withdrawal of industries with low investment efficiency and high-carbon emissions, advance the green transformation of traditional industries, support the development of green strategic emerging industries, develop the service industry and improve its level, and build a green supply chain and a circular economy and continuously tap the potential for high-quality growth. The third is to promote green and low-carbon technological transformation. The realization of low-carbon and zero-carbon technological transformation is of great strategic significance to China's technological innovation and high-quality economic development. This will not only enhance China's global leadership in new technology, but also help to obtain a new core competitiveness in building climate and environment-friendly economy in the future. China has made great contributions to the cost reduction of wind power and solar photovoltaic technologies. At present, China is a leader in the world in terms of investment and application of renewable energy, as well as the production and consumption of electric vehicles. China is also actively exploring hydrogen energy generation and its application in the industrial and transportation sectors. Attempts have also been made in the development of a flexible, safe, and stable modern smart grid system, and negative emission technologies (NETS) to remove CO_2. However, the endeavors are far from enough. In the future co-opetition between low-carbon and zero-carbon fields,

[vii] *XI Jinping: Decisive victory for building a moderately prosperous society in an all-round way and winning the great victory of socialism with Chinese characteristics in the new era – a report at the 19th National Congress of the Communist Party of China.* http: //www.gov.cn/zhuanti/2017-10/27/content_5234876.htm [2020-9-11].

China needs to double down its efforts to enhance the R&D and commercial application of low-carbon, zero-carbon technologies and NETS. China will continue to reduce the cost of green and low-carbon technology through its green market scale and policy guidance, and inject new systemic energy into China's economic growth in the near future, generating more new and high-tech employment opportunities to the society.

In short, carbon neutrality and total targets for carbon emissions are not merely constraints on economic and social development, but provide an important development opportunity, which forces the transformation of the entire economic and social development model. Therefore, we must change our mindset and development thinking, and actively seek internal growth drivers that coordinate the economy, society, energy, environment and climate to achieve a comprehensive green transformation and high-quality sustainable development.

II. Opportunities and Challenges for Achieving Carbon Peak and Neutrality

2.1 Opportunities

2.1.1 The integration of green and low-carbon development and economic transformation

On October 29, 2020, the 5th Plenary Session of the 19th Central Committee of the Communist Party of China reviewed and approved the *Proposals of the CPC Central Committee on the Formulation of the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035*. (hereinafter referred to as the *Proposals*). It is proposed to "unswervingly implement the new development concept of innovation, coordination, greenness, openness, and sharing, adhere to the key principle of seeking progress while maintaining stability, take the promotion of high-quality development as the mainstay, and deepen the supply-side structural reform, and make reform and innovation a fundamental driving force, and achieve the fundamental goal of meeting the people's growing needs for a better life"[viii].

The 19th National Congress of the Communist Party of China made a two-step strategic planning for achieving the second centenary goal, basically achieving socialist modernization by 2035, and building China into a great modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious, and beautiful by the middle of the 21st century. The 5th Plenary Session of the 19th Central Committee of the Communist Party of China has made more systematic and comprehensive explanations on green development, emphasizing "promoting green development and the harmonious coexistence between man and nature", and highlight actions such as "establish green production and lifestyles, decrease carbon emissions after peaking, fundamentally improve the ecological environment and achieve the goal of building a beautiful China". The Session also focused on the comprehensive green transformation of economic and social development, called upon to integrate development and addressing environmental and climate challenges in the new development stage, and identify the important characteristics and nature of future development[viii]. The *Proposals* also laid out a series of specific tasks, including legal and policy guarantees for strengthening green development, developing green finance, supporting green technological innovation, promoting cleaner production, environmentally friendly industries, and advancing green transformation of key industries and important fields; clean, low-carbon, safe and efficient use of energy; developing green buildings; carrying out activities to create green life; reducing carbon emission intensity, supporting areas with conditions to take the lead in reaching carbon emissions peaks, and formulating the "Action Plan for Carbon Dioxide Peaking before 2030". The *Proposals* outlined a comprehensive development blueprint for the "14th Five-Year Plan" and even medium and long-term economic and social development. It has laid a solid foundation for the building of green and low-carbon production and lifestyle, promoting carbon emissions to peak as soon as possible, stabilizing and

[viii] *Proposals of the CPC Central Committee on the Formulation of the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035*. http://www.gov.cn/zhengce/2020-11/03/content_5556991.htm [2020-12-14].

reducing carbon emissions after peaking, and achieving carbon neutrality.

2.1.2 Accelerated global green and low-carbon technological evolution lays the foundation for low-carbon transformation

At present, the world is in the midst of a fresh wave of technological and energy revolution, with the global industrial chain facing a green reconstructuring. The cost of solar energy, wind energy, and energy storage technology continues to decline rapidly. The in-depth integration of digital technology, economy and society has laid the foundation for green and low-carbon growth. Against the background of difficult recovery and in-depth adjustment of the global economy, all countries are striving to advocate and pursue green economic recovery. With the rapid development of high-tech fields such as digital technology, information technology, and artificial intelligence, energy technology systems are facing the challenge of eliminating traditional fossil fuels and transforming to cleaner, safer, and cheaper renewable energy sources. The new technology provides more economical and feasible conditions and support for this transformation so that the economic development model matched with the above transformation is bound to shift from the growth of intensive resources, energy, and pollution to sustainable development. The development of green technology and industry is conducive to improving the utilization efficiency of natural resources, providing new drivers for the economy (Jiang *et al*., 2020), and also helps to tackle the environmental pollution and ecological damage caused by the fixed industrial and energy structure (Zhu *et al.*, 2019), thereby improving public health (von der Goltz *et al*., 2020). In addition, the development of green technologies and industries will also offer employment opportunities. According to the 2018 report of the International Labour Organization, innovative emerging industries such as electric vehicles, clean energy, and green finance will create 24 million jobs worldwide by 2030, while only 6 million jobs have been lost in high-carbon industries such as coal and oil extraction the same period (ILO, 2018).

2.1.3 The development of digital technology and economy facilitates green and low-carbon transformation

In the post-pandemic economic recovery plans proposed by various countries, "green development" and "digital technology" are the common choices of all countries. The pandemic has brought a serious blow to the real economy, but it has led to new opportunities for green and low-carbon development and the "digital economy": green and low-carbon means of work and lifestyles such as remote office, videoconferencing, online shopping have become more popular. Especially during the recovery of the economy, the digital and intelligent transformation of industries such as low-carbon energy, low-carbon buildings, low-carbon transportation, energy conservation, and environmental protection has been significantly accelerated.

Digital technology can play a role in improving the utilization efficiency of resources and energy, promoting the development and utilization of renewable energy, and improving the efficiency of the production, sales, and use of products and services in the whole society, or reducing the demand for energy and raw materials by reducing physical human activities and exchanges. Studies have stated that digital technology solutions in the fields of energy, manufacturing, agriculture and land use, architecture, services, transportation and traffic management can reduce global carbon emissions by 15% (Falk *et al*., 2020). A study completed in 2020 by the Federal Association for Information Technology, Telecommunication and New Media in Germany, the Borderstep Institute and the University of Zurich also showed that digital technology can reduce global greenhouse gas emissions by as much as 20%. The use of such technologies may be particularly effective in transportation and agriculture. In Germany, the use of digital technology may reduce 29 million tons of CO_2 emissions by 2030, which accounts for about 37% of projected greenhouse gas emissions (Bitkom, 2020). Seizing the opportunity to promote the integration of green, low-carbon development and the "digital economy" will help strengthen innovation leadership and provide new momentum.

2.1.4 Unique system and market advantages provide a strong guarantee for greater emission reduction

Carbon emission is a typical economic externality. It is generally believed that the existence of externalities is one of the defects of the market mechanism in resource

allocation. In other words, when there are externalities, market mechanisms alone often cannot achieve the optimal allocation of resources and the maximization of social welfare. Therefore, on the one hand, we must give full play to the role of the government; on the other hand, we must also promote the integration of the market and the government to provide new governance tools for addressing climate challenges.

Achieving the carbon neutrality goal by 2060 will send a strong positive signal to addressing climate change, but it also faces great difficulties. It is almost impossible to achieve the goal by solely relying on the market. China's institutional advantages can play an important role in it. The outstanding performance of China in the fight against the Covid-19 pandemic has proved the remarkable advantages of our system. The advantages of this system are mainly reflected in the ability and efficiency of concentrating superior resources to finish major tasks, coping with major risks and challenges in complex situations, and the effective implementation, continuity, and stability of systems and policies.

The goal of carbon neutrality is a far-reaching plan made in the context of a complex and volatile international landscape and the deep transformation of the domestic economy and society. It not only meets the requirements of domestic high-quality development, but also conforms to the direction of global future development. However, its pathway is still uncertain. On the one hand, we need to concentrate our superior resources and provide support in industrial transformation and upgrading, technology R&D and application, and funding as well as system guarantee; on the other hand, we need to promote the consensus of all parties and release clear and stable long-term policies and price signals through policy and market means. In this way, the industrial transformation will have a clear direction, local governments will implement it meticulously, and the market will respond positively to guide the flow of funds to low-carbon projects, purchase and select appropriate technologies, tap the potential for emission reduction, and gradually form the trend of the whole society in advocating green and low-carbon production and lifestyle.

Furthermore, China has begun to operate the world's largest carbon market, and the continuous improvement of market mechanisms will also help to move toward carbon neutrality more effectively. Institutional advantages, a huge market, and the active participation of stakeholders will provide strong support and guarantee for the carbon neutrality goal.

2.2 Challenges

2.2.1 The international political and economic landscape is facing great uncertainty and China needs to be prepared to deal with green barriers

The Covid-19 pandemic has imposed great pressure on the global economy and society. The International Monetary Fund (IMF) and the World Bank respectively predict that the global economy will shrink by 4.4% and 5.2% in 2020 (IMF, 2020; World Bank, 2020). At the same time, profound changes are taking place in the international geopolitics and the strategic landscape of the response to climate change. The long-term, fundamental, and structural changes in Sino-US relations are facts. Populism and anti-globalization trends are prevailing, and international tensions have frustrated the global expectations of jointly responding to environmental and climate crises.

With the inauguration of the Biden administration in the US, he will push the United States to return to the *Paris Agreement*, exert climate leadership on multilateral platforms, and will focus on promoting the US-led global climate cooperation framework. It is expected that competition will prevail over cooperation between China and the United States in the short term, even in less divisive areas of dealing with climate change. Since the US joined the *Paris Agreement* in the form of a presidential executive order without being approved as a federal law, there is still uncertainty about the stance taken by the US in international multilateral cooperation on climate change in the future.

President Biden also proposed specific policy options regarding China, including: *1)* Punish China for the possible failure to fulfill its commitments by increasing tariffs on related products; *2)* Reach a bilateral carbon emission reduction agreement with China, requiring China to remove unreasonable export subsidies for coal and other high-emission technologies, and requiring China to reduce carbon emissions from the "Belt and Road Initiative" projects; *3)* Require G20 countries including China to commit to ending all

export financing subsidies for high-carbon projects and to eliminate coal financing from all countries except the poorest countries; *4)* Provide clean infrastructure investment alternatives to countries along the "Belt and Road Initiative" with US partners. The actions taken by the US have indicated that even though Biden has proposed to cooperate with China on climate issues, he has not shown confidence in active emission reduction actions taken by China. This means that the climate issue is not only an important area where China and the United States may reach cooperation but also a key platform for the two sides to compete with each other and strive for their respective national interests. We cannot rule out the possibility that policies on climate change might be a trigger for a new round of trade friction between the two countries.

At present, green barriers with the excuse of climate change are gaining traction, and the trend of protectionism advocating the use of carbon tariffs to increase trade barriers is expanding. The EU has made it clear that the "Carbon Border Adjustment Mechanism" will be established from 2021, and China needs to be fully prepared for it.

2.2.2 The time for achieving carbon peak and neutrality is limited, and the path to emission reduction is not smooth

Compared with Europe and the US, it takes more effort for China to achieve carbon neutrality. European countries such as the UK and France roughly reached carbon peaking in the 1980s and 1990s. After reaching the peak, their carbon emission experienced a long period of a plateau and began to slowly decline. A gap of 50–70 years between carbon peak and neutrality is promised by the EU countries. China has set a timetable for carbon peaking while its CO_2 emissions are still rising, and achieving this goal itself will take China strenuous effort. If China achieves the peak of carbon emissions as scheduled before 2030, the time from carbon peak to carbon neutrality will only be about 30 years, which means that the path to carbon neutrality after peaking will be extremely arduous; if internal and external factors lead to more fluctuations and prolongation of the plateau period, more drastic structural changes are needed to achieve the carbon neutrality vision. In any case, the annual emission in each year after 2030 is expected to be reduced by an average of 8%–10% per year compared with the previous year, which will far exceed the speed and intensity of emission reduction in developed countries. This will be the biggest challenge faced by China. In fact, both developed and developing countries have similar emission reduction routes in different sectors, but the time for China is more limited. It takes more endeavor in economic restructuring, technological innovation, and capital investment for a large country such as China to achieve its goals (Table 2).

Table 2. Comparison of the transitional period from carbon peak to carbon neutrality

Number	Country	Actual peak year	Promised year of carbon neutrality	Transition period/ year
1	UK	1973	2050	77
2	Hungary	1978	2050	72
3	Germany	1979	2050	71
4	France	1979	2050	71
5	Sweden	1976	2045	69
6	Denmark	1996	2050	54
7	Portugal	2002	2050	48
8	Ireland	2006	2050	44
9	Spain	2007	2050	43
10	Austria	2005	2040	35
11	Finland	2003	2035	32
12	China	Before 2030	Before 2060	About 30

Note: China has not reached its carbon peak yet, and the time for promised year of peak of China is shown in the table.

2.2.3 The basic R&D capabilities in China are still insufficient, and key low-carbon technologies are facing competition

Multiple issues pose challenges to China in achieving green and low-carbon development and carbon neutrality goals, such as insufficient scientific and technological achievements of original innovation in China, numerous institutional and mechanism obstacles faced by the transformation of scientific and technological achievements, inefficient allocation of innovation elements, and the gap in the number and quality of innovative talents. At present, low-carbon technologies tend to pay more attention to technical details and the improvement and promotion of existing technologies. Less attention is paid to the innovation of disruptive technologies. Furthermore, there is a lack of goal-oriented medium- and long-term emission reduction technology strategy and deployment plan that takes into account the environment, climate, economy, and society. In some key low-carbon technologies, China faces bottlenecks such as the lack of key technologies, low degree of autonomy, and lack of industrialization of hydrogen fuel cell vehicles. As for the hydrogen energy industry, although China enjoys the highest hydrogen production in the world, currently 70% of the raw materials for hydrogen production are coal and natural gas, leaving a low proportion for green hydrogen. In addition, there is no substantial breakthrough in the technology of hydrogen production, storage and transportation, and large-scale utilization. One of the core solutions for in-depth emission reduction is a technological breakthrough. Due to the influence of international economic interest competition and trade protectionism, technology transfer and cooperation are facing more obstacles. Therefore, China needs to speed up the formulation of technological innovation support plans to realize the carbon neutrality targets (Huang Jing, 2020).

2.2.4 Large gap of development between regions leads to difficulty in achieving a fair and just transition to carbon neutrality

China's inter-regional economic and social development is unbalanced, with a superior development in the eastern and southern part of China over their counterparts in the west and north. Concerning carbon emissions, the relatively developed regions in the east have seen a limited increase in carbon emissions, and some regions are already close to peaking. Although these regions have strong carbon emission reduction capabilities, there are still signs of a resurgence of traditional means and an impulse to invest in carbon-intensive projects under the pressure of economic recovery and carbon peak targets. In contrast, there is still room for growth in carbon emissions in the central and western regions. It is difficult to reach a peak in the short term, especially in provinces rich in fossil energy.

Meanwhile, the direction and long-term trend of phasing down coal in China have been determined, but the phasing-out road map needs to be carefully designed in accordance with the economic development stage and capacities. The benefits and impacts of low-carbon transformation on different industries, regions, and people should be fully considered. The traditional fossil fuel industry, especially the upstream and downstream industries of coal-including mining, transportation, coal power, coal chemical industry will undergo great shock in the zero-carbon transition. These impacts will be concentrated in areas that are heavily dependent on coal to develop the economy and offer employment opportunities. In addition, due to the development of machines, elimination of outdated production capacity, and industrial upgrading, the transformation of the coal industry has already put pressure on provinces such as Henan and Shanxi which are more reliant on the traditional coal industry. Coal will inevitably withdraw from the stage of history, and the job opportunities it carries will also disappear. Therefore, systematic solutions are required such as policy measures to properly handle coal workers or ensure their re-employment and finding new development models for these areas. These actions should be carried out as soon as possible.

On the whole, the Covid-19 pandemic has imposed a huge impact on the economic and social order, but it also presents some opportunities. In the short term, fighting the epidemic tones down the urgency of carbon emission reduction, but in the medium and long term, green and low-carbon development is still one of the strategic directions for future development. The pandemic has impaired economic growth and also brought opportunities for structural adjustment.

The pandemic has led to crises for many traditional industries, but we have also witnessed the strong vitality of emerging industries such as the information industry. These have greatly expanded the room for green economic growth and made it possible to pursue green development. The pandemic has provided us with an excellent opportunity for structural industry upgrades. The pandemic has prompted the whole society to reflect on the development model of the excessive pursuit of speed and scale. This is undoubtedly conducive to the establishment of new development concepts that place greater emphasis on green development and the harmonious coexistence between man and nature within the entire society, creating favorable conditions for pursuing green transformation under the impact of the pandemic. Besides, the economic downturn has led to a slowdown in the growth rate of energy consumption, which will become an opportunity to accelerate the energy transition to allow new energy demand to be met by renewable energy to a greater extent. China should seize the opportunity to reset the current economic and energy system, provide support for achieving carbon neutrality, and lead the creation of a greener and more resilient world.

III. General Approach to Mid-to-long-term Green and Low-carbon Transition in China

3.1 Overall strategy

The 5th Plenary Session of the 19th Central Committee of the CPC proposed that green production and lifestyles shall be extensively attained by 2035. Carbon emissions should be steadily declined after the peaking. The ecological environment shall be fundamentally improved, and the goal of a Beautiful China will be basically achieved. It intends to build China into a great modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious, and beautiful by the middle of the 21st century, ensure ecological security, and actively participate in and lead international cooperation in environmental protection such as climate change[ix].

To accelerate green and low-carbon development and achieve greater reductions in greenhouse gas emissions, it is necessary to coordinate economic, social, energy, environmental, and climate change governance, and to promote a comprehensive green transformation of economic and social development. To that end, it is vital to lead a sustainable development path towards the harmony between man and nature and a sustainable development path of the Chinese nation, and play a major role in global climate governance, protecting the ecological security of the earth and the survival and development of human beings.

The proposal of China's carbon neutrality goal has allowed the world to see the possibility of capping the global temperature rise within 2°C and striving to achieve the 1.5°C target, and it also further identifies that tackling climate change is an important goal of China as a modern socialist country. The long-term low-carbon development strategy should be consistent with the two-stage goals and strategies of socialist modernization (He Jiankun, 2018). It is necessary to include the carbon peak and the strengthening of NDCs goals by 2030 as an important part of the first-stage strategic plan of socialist modernization to promote high-quality economic development. Taking nearly zero emissions by 2050 and achieving carbon neutrality by 2060 as the leading goals and tasks of the second stage of socialist modernization, we will promote the building of a Beautiful China and establish a green, low-carbon, and circular means of production and lifestyle.

3.2 Interim goals, paths, and priorities

3.2.1 Near-term

The "14th Five-Year Plan" period will be the crucial five years for China to achieve carbon peaking and the first five years to incorporate the vision of carbon neutrality into the economic and social development plan. The difficulty and challenges are unprecedented. It is necessary to pay more attention to strengthening the balance between energy and industrial development

[ix] *Proposals of the CPC Central Committee on the Formulation of the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035*. http: //www.gov.cn/zhengce/2020-1 l/03/content_5556991. htm [2020-12-14].

planning and national climate change planning, especially to anchor the development direction and focus of energy and industry transformation during the "14th Five-year Plan" with the medium and long-term strategic goal of achieving carbon neutrality and building a beautiful China, comply with the requirements of green and low carbon development and promote the moderately advanced deployment of infrastructure and industry. Optimize the spatial deployment for the adjustment of energy structure, the green, low-carbon transformation of industry, and the urban resilient development, and facilitate the formation of a new development paradigm of "investing in green, investing in growth, investing in employment, investing in the future" and the green and low-carbon "dual circulation".

During the "14th Five-Year Plan" period, carbon emissions growth should enter a plateau period. Some developed provinces and cities in the east, provinces, and cities with a good endowment of renewable energy in the southwest, and high-carbon industries such as electricity, steel, and cement should take the lead in reaching their peaks. In terms of the primary energy consumption structure, the proportion of coal is expected to drop to about 50%, and the proportion of non-fossil energy consumption should exceed 20%. The peak is to be achieved through structural adjustment of coal power, and the development of the coal chemical industry is to be strictly controlled. In terms of policy support, it is necessary to accelerate the establishment of the "14th Five-Year Plan", "Special Plan for Addressing Climate Change", "Action Plan for Carbon Dioxide Peaking before 2030", "Comprehensive Work Plan for Energy-saving and Emission Reduction", and "Action Plan for Green Industrial System and Life" to promote the coordination and convergence of different plans and programs. Efforts shall be made to establish a total carbon emission control system, so as to replace the total energy consumption control target with a more effective greenhouse gas emission reduction binding target, expand the flexible mechanism and path to achieve the carbon emission reduction target, and adopt the combination of inter-regional quota trading, clean development and horizontal compensation in implementation. Based on scenario analysis and consensus, endeavor shall be made to update the intensity and extensity of China's NDC, including carbon peaks and mid-to-long-term near-zero or net-zero emissions targets, and integrate green recovery, Nature-based Solutions (NbS), and non-CO_2 greenhouse gas emission reduction, increasing the scope of target indicators and room for flexible adjustment. We shall strive to strengthen technology research and development for the transformation of a zero-carbon society, and prepare for industrial transformation, lifestyle shift, and possible global low-carbon technology competition[x]. We shall work hard to enhance the R&D, cooperation and promotion of global low-carbon and zero-carbon technology.

3.2.2 Mid-term

From 2025 to 2030, we must promote carbon emissions to peak as soon as possible. Studies have shown that under the premise that the target time for carbon neutrality is determined, the earlier the peak is reached, the lower the total emission reduction cost of the whole society will be (Pan *et al*., 2020). However, the steps to achieve carbon neutrality also need to keep compatible with the social and economic development conditions of China. China should seek truth from facts, and take due efforts to reach the goal ahead of schedule, achieve the phased goals in a cost-effective way, attain high-quality NDCs commitments, and strive for 25% or more share of non-fossil energy in primary energy consumption. At the same time, China should promote and lead related activities in the Global Carbon Neutrality Alliance.

From 2030 to 2035, the primary energy consumption of China is expected to enter a plateau period,where the energy structure has been continuously optimized. The overall energy structure is to present a tripartite pattern dominated by coal, oil/gas, and renewable energy, with terminal power consumption greatly increased. The carbon emissions of all provinces and cities across the country are expected to peak, and so will the carbon emissions of sectors such as transportation and construction. Measures to take in this period should focus on promoting green transformation through structural adjustment and system innovation, continued efforts should be made to deepen the reforms in the industrial structure, energy structure,

[x] *WANG Yi, member of the Standing Committee of the National People's Congress: We must be fully prepared for the global carbon neutrality competition*. https://view. inews. qq. comA/20201215 A03AKD00 [2020-12-20].

transportation structure, and land use structure, and to accelerate and adjust the layout of major infrastructure and related industries revolving around the zero-carbon goal, so as to promote the deep integration of technology with economic and social fields, and to consolidate the formation of a green and low-carbon industrial chain, supply chain, and value chain, as well as a corresponding green climate investment and financing policy system and sustainable business model.

3.2.3 Long-term

During the period from 2035 to 2050, we should establish an energy supply and consumption system based on renewable energy, accelerate to phase down fossil energy, and advance the deployment of NETs including carbon capture and storage (CCS) and bioenergy with carbon capture and storage (BECCS), in efforts striving to achieve CO_2 near-zero emissions, further improve adaptability, continuously improve the social and economic system for green, low-carbon recycling, and sustainable development, and form a sustainable consumption pattern.

From 2050 to 2060, we shall move towards the neutrality of greenhouse gas emissions by means of carbon sinks, NETs, and non-CO_2 emission control, and strive to promote carbon neutrality in the world around 2070.

3.3 Industrial structure: building a modern industrial system with green and low-carbon circulation

The modern industrial system is the biggest driver for carbon emission reduction. Studies have indicated that industrial structure adjustment can contribute up to about 60% toward achieving China's carbon intensity target (Wang Wenju and Xiang Qifeng, 2014). The establishment of a green and low-carbon circular economic system is an important part of a modern economic system. It is vital to strengthen green strategic emerging industries such as energy conservation, environmental protection, clean production, and clean energy, and make innovations to form technology, financial support systems, and policy and institutional environments that are compatible with green and low-carbon recycling industries. It is important to accelerate the building of new infrastructure characterized by green, low-carbon, and digital technologies, improve the level of green development in the service industry, and create new momentum for green and low-carbon circular development. At the same time, it is necessary to reduce the embodied carbon of export trade. In 2016, the embodied carbon of export accounted for 12.5% of China's carbon emissions (Gu Alun *et al*., 2020). This will have an important impact on carbon emissions reduction in China. It is necessary to promote China's manufacturing industry to move towards the higher end of the global value chain and to increase the share of the service industry in export.

3.4 Energy structure: building a clean, low-carbon, safe, and efficient modern energy system

Decarbonization of the energy structure is a key pathway to achieve carbon neutrality, and it is also conducive to building and improving the energy security system of China. The first is to formulate a road map for an orderly exit of coal, adopt more effective measures to control fossil energy consumption, especially to strictly control coal consumption, continuously optimize and reduce the structure and scale of coal utilization, increase the control of scattered coal, and take effective measures to curb the impulse of some local industries to launch coal-related projects, strictly control the development scale of high-carbon industries such as coal chemical industry, and avoid the resulting high-carbon lock-in effect and high costs. The second is to substantially increase the electrification level of terminal energy. The industrial sector should speed up the substitution of electricity for the direct use of fossil fuel energy in the manufacturing process. The construction sector should adopt distributed renewable energy systems and expand the application of electricity in heating. The transportation sector should promote electric vehicles, restrict and gradually phase down ICE (internal combustion engine) vehicles, promote the commercial development of hydrogen fuel cell vehicles, and facilitate the upgrading of energy consumption in various industries with a focus on electrification, high efficiency, and intelligence. The third is to build an energy supply system with a high proportion of renewable energy. It is important to establish infrastructure, smart grids, distributed energy, energy storage, multi-energy

complementarity, flexible regulation, and smart energy that adapts to such a high proportion of renewable energy. It is necessary to promote disruptive innovation and development, and advance the integration of various technologies, infrastructures, and models to form an energy system with a high proportion of renewable energy; promote the development and construction of cascade hydropower station, and build a batch of integrated watershed energy bases for hydropower, wind power, and photovoltaics; highlight the coordinated development of wind power, adhere to a combination of centralized and distributed development models, focus on both local consumption and external transmission of wind power generated both onshore and offshore; accelerate the diversification of solar energy. The central and eastern regions should adopt the innovative "PV+" model, move ahead with the complementarity between agriculture and photovoltaics, rooftop photovoltaics, and promote the development of industrial and commercial distributed household photovoltaics. In Northeast, North China, and Northwest China, it is necessary to focus on photovoltaics combined with ecological governance, promote the construction of photovoltaic bases, summarize and promote the experience, synergy model and NbS of combining renewable energy with poverty alleviation, agriculture and forestry production, ecological restoration, hydrogen production; drive the development of biomass energy based on local conditions and the development and application of geothermal energy. The fourth is to accelerate the development and application of energy storage, hydrogen energy, and smart grid technologies to provide support for the deployment of a high proportion of renewable energy. The fifth is to establish, improve and implement a guarantee mechanism for the consumption of renewable energy power, and encourage technological and institutional innovation to create favorable conditions for the high-quality development of renewable energy.

3.5 Technological innovation: formulating medium and long-term emission reduction technology development strategies for carbon neutrality

Carbon neutrality will ultimately be dependent on low emissions, zero emissions, and the extensive application of NETs in production and life. It is necessary to start the formulation of medium and long-term low-carbon technological innovation plans, and accelerate the development and application of key carbon-neutral technologies as soon as possible to meet the carbon neutrality goals. It is important to establish a world-leading low-carbon technological innovation system, and promote R&D innovation and commercial application promotion of key common technologies, cutting-edge leading technologies, and disruptive innovation technologies, including energy efficiency, large-scale integration of renewable energy into the grid, distributed renewable energy, advanced nuclear energy, hydrogen fuel cell, large-scale energy storage, smart grid, renewable resource recovery, carbon capture, utilization and storage (CCUS), BECCS, direct air capture (DAC), *etc*. It is vital to deploy a group of forward-looking, systematic, and strategic low-emission technology research and development and innovation projects to break through the technological bottlenecks in key materials, instruments and equipment, core processes, and industrial control devices in the development of carbon neutrality, and gradually build a global carbon innovation center for new technologies, products, business formats and models.

It is necessary to promote the in-depth integration of a new generation of information technology and advanced low-carbon technologies and to greatly improve energy utilization efficiency. Guided by the vision of carbon neutrality, we will cultivate new growth momentum in high-tech, high-efficiency, and low-emission areas such as digital economy, clean energy, and smart cities with great development potential and leadership, and gradually foster a number of international advanced green and low-carbon manufacturing clusters. Efforts should be made to further strengthen international technical cooperation and assistance with the vision of carbon neutrality, launch international scientific and technological plans led by China for addressing climate change and carbon neutrality, and establish relevant international organizations.

3.6 Regional coordination: formulating differentiated regional low-carbon development strategies

China boasts a vast territory with significant differences between regions in terms of economic development model, economic structure, social development level, natural resource endowment, and technological development, which poses different requirements for the design of carbon emission reduction pathways in different regions. Due to the strategic planning of the economic and social development in China and the reality of resource endowments in the central and western regions, the central and western regions bear a large number of transferred emissions from the eastern provinces while generating a large amount of energy and electricity (Lv Jiehua and Zhang Zeye, 2020). The prevention of carbon leakage between different regions not only pertains to the rationality and fairness of the break-down of carbon emission reduction targets but also pertains to the realization of low-carbon development goals as well as fair and just transition. Therefore, based on the existing division of emission responsibilities, consumption and transfer emissions should be taken into account, and differentiated regional low-carbon development goals should be established.

Specifically, during the "14th Five-Year Plan" period, the more developed areas along the east coast and the areas with abundant renewable energy resources in the southwest should plan to take the lead in achieving the peak of CO_2 during the five years, creating favorable conditions for the nationwide carbon peak during the "15th Five-Year Plan" period (2026–2030). It is important to nurture the accelerated transfer of the manufacturing industry to clean energy bases in the northwest and southwest regions, and promote the local consumption of renewable energy. We must pay special attention to fairness and justice in the transition process, especially the employment and economic development of coal-dependent areas, and the access to clean energy in impoverished areas. It must be properly addressed through capacity building, fiscal transfer payments, and ecological compensation.

3.7 Policy system: establishing the policy system for the medium and long-term low-emissions

The first is to speed up the top-level design of climate change laws to provide legal protection for the long-term low-emission strategies. It is necessary to formulate and revise relevant laws and regulations such as the Climate Change Law, Energy Law, Electricity Law, Renewable Energy Law, Energy Conservation Law to accommodate climate change response and green and low-carbon development, and give maximum priority to the demand of ensuring that there are laws to follow when achieving carbon peak, carbon neutrality and climate change response. Meanwhile, design and formulate a series of gradual and increasingly stringent standards for industries, technologies and products to establish a system of technical regulations (CAS Sustainable Development Strategy Research Group, 2009). The second is to improve the climate investment and financing policy system, step up the financial investment and tax incentives of governments at all levels for low-carbon development, promote the establishment of a policy environment conducive to climate investment and financing, encourage the development of climate investment and financing products and tool innovation, and develop an applicable, efficient and advanced climate investment and financing standard system to improve the governance structure of multiple types of funds. The third is to continue to promote and improve the supporting systems for the carbon market and formulate a roadmap for international cooperation in the carbon market. Meanwhile, it is still necessary for China to reserve a policy window for the introduction of the carbon tax while conducting carbon trading, and to promote the implementation of a carbon tax and carbon pricing policy at the right timing. The fourth is to improve and make innovations on the systems, policies, and actions to promote low-carbon consumption, including expanding the supply of low-carbon products and services, intensifying efforts for a circular economy, strengthening publicity and education, raising awareness of low-carbon consumption, and establishing and improving the governance mechanism of low-carbon consumption.

3.8 International cooperation: building a fair, just, and win-win global climate governance system

Since the Covid-19 pandemic, the international landscape has become increasingly complicated and full of uncertainties. China needs to be more active in

advancing global climate governance and international cooperation, the establishment of a global climate governance system featuring fairness, justice, and win-win cooperation. Adhering to the principles of common but differentiated, fair and respective capabilities, we should strengthen multilateral and bilateral international cooperation, and promote the response to climate change and the transition to a green and low-carbon planet to become a global consensus. Firstly, focus on maintaining the multilateral process. Facing the new reality with the US returning to the *Paris Agreement*, it is necessary to continue and maintain multilateralism, promote the relevant reform under the multilateral framework, improve the efficiency of cooperation, properly respond to the possible unreasonable unilateral actions that the United States may take, including carbon trade barriers out of its domestic interests. Secondly, strengthen bilateral cooperation, promote the establishment of a consensus, between China and Europe, and between China and the United States, on green recovery, health, climate change, and biodiversity protection. It is important to reach pragmatic cooperation agreements, and join hands with developed countries such as the US and European countries to play a leadership role as a major power. It is necessary to deepen the China-EU green cooperation partnership, facilitate high-level China-EU dialogues on climate and environment and multi-level dialogues, promote positive actions based on common interests between China and the EU, providing a good momentum for China-EU cooperation. It is necessary to restart the Sino-US dialogue on climate change, find solutions to the challenges of global governance in climate cooperation, and tap cooperation in related fields. Thirdly, cooperate with all parties to facilitate the 26th session of the Conference of the Parties (COP 26) to the *United Nations Framework Convention on Climate Change* (UNFCCC), and advance the mutual promotion between the 15th Conference of the Parties (COP15) of the *Convention on Biological Diversity* (CBD) and COP 26. Fourthly, enhance cooperation and exchanges in green and low-carbon technology and green finance, promote technology transfer and cooperative research and development, advance the development of the global green finance market, and support the green and low-carbon economic recovery and growth. Fifth, join hands with developed countries to promote cooperation in third-party countries, make full use of advanced technologies from developed countries, Chinese manufacturing prowess and capital to achieve the effect of "1+1+1>3" based on the environment protection and climate needs of the host country. Finally, China should strengthen the top-level design of the green and low-carbon "Belt and Road Initiative", and actively support the "Belt and Road" partnership countries to formulate low-carbon development layouts and action roadmaps, and transform from a single commercial project cooperation model to strategic cooperation. It is crucial to carry out climate change cooperation with the "Belt and Road" partnership countries from the perspective of development, support the "Belt and Road" partnership countries to update their NDCs goals, and formulate and implement a long-term low greenhouse gas emission development strategy by the middle of the 21st century, and garner extensive support from the international community (Tan Xianchun *et al*., 2017).

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