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Toward Carbon Neutrality: Circular Economy Approach and Policy Implications

Wendong WEI

School of International and Public Affairs, Shanghai Jiao Tong University, Shanghai 200030, China; SJTU-UNIDO Joint Institute of Inclusive and Sustainable Industrial Development, Shanghai Jiao Tong University, Shanghai 200030, China, wendongwei@sjtu.edu.cn

See next page for additional authors

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Abstract

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Keywords

circular economy; carbon neutrality; “3R” principles; resource efficiency; energy saving; emissions reduction

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Wendong WEI, Zhujun CHEN, Yong GENG, Wenqiu CAI, and Hanbin LIU

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Toward Carbon Neutrality: Circular Economy Approach and Policy Implications

WEI Wendong^{1,2}, CHEN Zhujun³, GENG Yong^{1,2,4}, CAI Wenqiu^{1,2}, LIU Hanbin⁵

1. School of International and Public Affairs, Shanghai Jiao Tong University, Shanghai 200030, China;

2. SJTU-UNIDO Joint Institute of Inclusive and Sustainable Industrial Development, Shanghai Jiao Tong University, Shanghai 200030, China;

3. Business School, University of Shanghai for Science and Technology, Shanghai 200093, China;

4. School of Environmental Science and Engineering, Shanghai Jiao Tong University, Shanghai 200240, China;

5. Shanghai Municipal Development and Reform Commission, Shanghai 200003, China

Abstract: It is challenging to promote global climate change governance under the current complicated international contexts. As a country with the largest carbon emission, China has committed to achieving carbon peak by 2030 and carbon neutrality by 2060. However, carbon neutrality is a complex system engineering and relies on the implementation of circular economy. Based upon “3R” principles of reduce, reuse, and recycle, this study investigates the internal relations between circular economy and carbon neutrality and identifies the key position of circular economy in achieving carbon neutrality targets. Several policy implications are raised to help promote the development of circular economy and achieve carbon neutrality targets. **DOI:** 10.16418/j.issn.1000-3045.20210808002-en

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There is a pressing need to mitigate global climate change. To address climate change and reduce total emissions of greenhouse gases (mainly composed of CO₂), 37 countries, including China, have formally committed to achieving carbon neutrality by developing national laws, signing agreements, or making policy declarations, and another 52 countries have made oral promises^[1]. As the country with the largest CO₂ emissions, China solemnly declared in September 2020 to strive for carbon peak by 2030 and carbon neutrality by 2060.

The concept of circular economy was formally proposed by British environmental economists David Pearce and Kerry Turner in 1990^[2]. In 1996, the *Closed Substance Cycle and Waste Management Act* was enacted in Germany. Subsequently, France, the UK, and other European countries followed Germany's example, and the development of circular economy has gradually become a global consensus^[3]. As a scientific and new model of economic development, circular economy differs from the traditional linear economic model of “exploration–production–disposal” by decoupling economic development from resource exploration and environmental impact^[4]. Less resource input can generate more

socio-economic value, which is of great significance in achieving carbon neutrality. According to research conducted by the Ellen MacArthur Foundation of the UK, circular economy is effective in reducing greenhouse gas emissions from the manufacture and use of products; furthermore, circular economy can reduce global carbon emissions by 40% from the production of key industrial materials such as cement, steel, plastics, and aluminum, and cut 49% of carbon emissions from the global food system in 2050^[5]. Studies on European countries also indicate that a shift to circular economy will reduce greenhouse gas emissions by 70%^[4].

Circular economy is of great value to carbon neutrality in China. According to the calculations performed by the China Association of Circular Economy, the comprehensive contribution of circular economy to carbon emission reduction in China was > 25% during the Thirteenth Five-Year Plan. On the one hand, circular economy changes how products and materials are produced and used through resource conservation and intensive utilization, which can effectively improve resource output, reduce carbon emission per unit product, and mitigate the carbon emissions from the value chain, supply chain, and industrial chain. On the other hand, circular

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First author: WEI Wendong: Associate Professor and Doctoral Supervisor at the School of International and Public Affairs, and the SJTU-UNIDO Joint Institute of Inclusive and Sustainable Industrial Development, Shanghai Jiao Tong University. He focuses on researches including ecological civilization, carbon peak, and carbon neutrality. He has led 5 national and provincial projects, including sponsorship by the Young Scientists Fund of the National Natural Science Foundation of China. He has also been selected for the Shanghai Sailing Program. He has published more than 60 papers in academic journals such as *Nature Sustainability*. E-mail: wendongwei@sjtu.edu.cn

economy helps the circulation of production factors and the effective recycling of wastes as resources and can reduce the dependence of economic development on primary resources, which can ensure the security of resources and alleviate the resource constraints in achieving carbon neutrality. In this context, we investigate the internal relations between circular economy and carbon neutrality, compare the current development of circular economy in China and other countries, and describe the key role of circular economy in achieving carbon neutrality. We also provide suggestions for policies to promote the development of circular economy and the achievement of carbon neutrality in China.

1 Circular economy is an important path to carbon neutrality

Circular economy follows the principles of ecology and economics. It aims to create the production and consumption mode of “resource–product–renewable resource” by implementing the “3R” principles of reduce, reuse, and recycle^[6], which is an important path to carbon neutrality.

1.1 Reduce: mitigating carbon emissions by controlling input at source

This principle reduces the input of various resources such as raw materials, energy, and water in production and consumption through eco-design and clean production, so as to achieve resource conservation and carbon emission reduction at the source of economic activities. In the automotive industry, for example, the removal of non-essential accessories, simplified vehicle structures, and the use of light materials in design can reduce the resource consumption of automobile manufacturing and cut carbon emissions by 89 million tons per year^[5,7]. In electronics manufacturing, the reduction in the use of accessories and packaging materials has also achieved remarkable emission reduction. Since 2020, iPhone no longer comes with a power adapter, which saves 800,000 tons of raw materials such as copper, zinc, and tin, improves product transportation efficiency, and effectively reduces carbon emissions^[8]. In the construction industry, green design has been used to build lighter building floors, incorporate distributed photovoltaic power generation system, and optimize the daylighting design. Those measures reduce building materials with high carbon emissions (such as cement) and the energy consumption and carbon emissions of buildings in use.

The development and application of low-carbon technologies such as new energy vehicles, renewable energy, and energy storage will increase the demand for key mineral resources^[9]. Through the innovation of manufacturing technologies, circular economy can achieve significant reductions in the consumption of key mineral resources through material reduction and substitution, thereby paving the path to carbon neutrality. In the case of ternary lithium batteries, which are widely used in electric vehicles, tracing the flows

of materials used in electric vehicle batteries in the European Union showed that circular economy increased the resilience and sustainability of the automotive supply chain, reduced the demand for primary resources such as lithium, cobalt, and nickel, and decreased the exploration of primary raw materials. A technology-driven cobalt reduction strategy can reduce the cumulative demand for cobalt in electric vehicle batteries by 54.6% from 2017 to 2050 in the European Union^[10]. This will effectively alleviate the resource constraints caused by the rapid development of electric vehicles in the context of carbon neutrality, and promote the application and popularization of low-carbon technologies.

1.2 Reuse: prolonging product cycle and improving utilization efficiency

This principle improves the utilization efficiency of products and materials in consumption and production by prolonging their life cycles, so as to realize resource conservation and carbon emission reduction. More than 50% of greenhouse gas emissions in industry originate from material production, and the emissions can be reduced by enhancing the reuse of materials^[11]. In the case of plastics, 95% of plastic packaging materials are discarded and only 14% of them are recycled^[12]. Improving the utilization of plastics based on the principle of reuse will greatly reduce carbon emissions. Studies have shown that carbon emissions from plastics will make up 15% of the global carbon budget by 2050 if the use of plastics continues to increase. Greenhouse gas emissions caused by plastics in 2050 are expected to remain at the level of 2015 through recycling, demand management, and the application of renewable energy^[13]. In addition to industrial manufacturing, food production is another important source of carbon emissions. Simple processing of fruits and vegetables with unattractive appearance into canned food or sauce and discount on food near expiration date can prolong the life cycle of food, effectively avoid food waste, and reduce carbon emissions by 1.4 billion tons per year in 2050^[5].

Improving material recycling and developing remanufacturing industry are also meaningful to resource conservation and carbon emission reduction^[14]. Studies have shown that remanufactured machinery can be used to replace new machines and effectively reduce carbon emissions. Measures for modularization, reuse, and remanufacturing can effectively improve the efficiency of remanufacturing industry^[15]. By 2050, vehicle remanufacturing alone can reduce carbon emissions by 38 million tons per year^[5]. The echelon use of products is of great value in solving the problems of low efficiency and high cost in remanufacturing. In the case of power batteries, direct disposal of retired batteries from electric vehicles results in huge waste. Retired power batteries can be inspected and reassembled, and lead-acid batteries can be replaced. While ensuring safety and controllability, the replaced batteries can be used for energy storage in communication base stations and low-speed electric vehicles^[16].

1.3 Recycle: recycling resources and reducing solid waste

This principle realizes the saving and substitution of primary resources by promoting the comprehensive utilization of waste, which can reduce the carbon emissions from the exploitation, smelting, and processing of primary resources. In the case of non-ferrous metal industry, the use of recycled non-ferrous metal resources can greatly reduce energy consumption. As compared with primary copper, aluminum, and lead production, the energy consumed in the production of recycled metals can be reduced by 1,054, 3,443, and 659 kg standard coal/ton, respectively^[17]. In 2018, the global aluminum industry emitted 1.1 billion tons of CO₂, 95% of which was from primary aluminum production (2/3 of total production) while 5% was from recycled aluminum production (1/3 of total production)^[18]. With growing demand, recycled aluminum production should be further increased to achieve the goal of 75% reduction in carbon emissions per ton of aluminum by 2050^[19]. The recovery and utilization of key mineral resources are of great value for carbon neutrality. Increasing the recovery and utilization of key mineral resources helps to reduce the dependence on primary resources and effectively supports the marketing of low-carbon technologies such as electric vehicles and renewable energy^[20]. Regenerative agriculture can reduce the inputs of carbon-intensive production factors and increase soil carbon sequestration^[5].

The principle of recycle in circular economy can effectively reduce waste generation and thus cut carbon emissions during the storage, transportation, and disposal of solid waste. Studies have shown that replacing cement with recycled concrete fine powder and using waste glass and fly ash as alternative raw materials can reduce carbon emissions from cement production^[21]. In addition, treatment of waste from water reclamation, such as the recycling of methane emitted from the incineration of sludge and the production of phosphorus fertilizer from the ash, can further reduce greenhouse gas emissions during the life cycle of reclaimed water and increase the recycling of resources in reclaimed water production^[22].

2 Challenges in the development of circular economy for carbon neutrality in China

Resource shortage and environmental pollution in China became apparent in the 1990s. For economic restructuring and development mode transformation, some researchers introduced the concept of circular economy to China from Germany and Japan^[23]. After years of development and evolution, circular economy theories, policies, and practices with Chinese characteristics have been established^[6]. In 2005, a series of documents such as the *Opinions of the State Council on Accelerating the Development of Circular*

Economy marked the official embarkation of China on the new path of circular economy. In 2008, the Fourth Session of the Standing Committee of the 11th National People's Congress passed the *Circular Economy Promotion Law*, marking a vital step toward building the law-based governance of circular economy in China. In the *Report at the 19th National Congress of the Communist Party of China*, China will establish a sound economic system that facilitates green, low-carbon, and circular development, promote the overall conservation and recycling of resources, reduce energy and material consumption, and realize the cycling and linkages between production and living systems.

The goal of carbon peak and carbon neutrality has placed new and higher demands for the development of circular economy in China. The *14th Five-Year Plan for the Development of Circular Economy* clearly states that the development of circular economy is significant to secure national resources, realize carbon peak and carbon neutrality, and promote the construction of ecological civilization. However, the *Plan* also states that the development of circular economy in China still faces many serious conflicts and problems. There are still key problems in the development of circular economy in China in order to achieve carbon peak and carbon neutrality, including incomplete circular economy governance system, immature circular industry and science/technology innovation system, and absent social co-governance system.

2.1 Incomplete circular economy governance system impedes the implementation of carbon reduction measures

Currently, what China lacks are top-level design and overall plan for the development of circular economy and the achievement of carbon peak and carbon neutrality, collaboration of circular economy legislation and environmental reform measures and policies^[24], and a circular economy governance system for carbon neutrality. (1) China has not constructed a specific path to achieving carbon neutrality based on circular economy, and has not formulated a medium- and long-term strategic plan of circular economy for carbon neutrality. The "five major projects" and "six major actions" in the *14th Five-Year Plan for the Development of Circular Economy* involve a number of departments, and the responsibilities and coordination of departments at various levels remain to be clarified. (2) There are evident differences in the development of circular economy in the eastern, central, and western regions of China^[25]. There is a pressing need to establish a roadmap and an action plan for provinces, cities, and counties to coordinate the development of circular economy for carbon peak and carbon neutrality. (3) Although enacted in China in 2009, the *Circular Economy Promotion Law* only provides principal regulations on the development of circular economy. Compared with Germany, Japan, and other developed countries, China has not yet established a complete legal and regulatory system to promote the development of circular

economy. Except for the *Energy Conservation Law*, there are incomplete laws and systems that can be used to achieve carbon neutrality in China. A series of laws and regulations on the development of circular economy and response to climate change, including the *Climate Change Response Law* and the *Resource Utilization Law*, have not been established.

2.2 Immature circular industry and science/technology innovation system fail to support carbon neutrality

In recent years, despite the great progress in the circular economy industry and science/technology innovation system in China, many problems occur in the practice of circular economy, which is insufficient to support carbon neutrality in China. (1) The circular economy industry in China is small and underdeveloped. Regulations on production and consumption throughout the industrial chain have not yet been established, and the circular economy network fails to connect various regions, industries, and fields. For example, food waste is serious in China, and the agricultural supply chain is inefficient. The proportions of recycled aluminum and copper production favored by carbon neutrality remain low, far from the target of 55% and 23% increases in output by 2025 as proposed in the *14th Five-Year Plan for the Development of Circular Economy*. The certification and promotion of remanufactured products are insufficient, and the high-end remanufacturing industry is under development^[26]. Consequently, there is a lack of support to comprehensively promote circular economy and achieve carbon neutrality. The waste recycling industry is undergoing the transformation from “offline” to “online + offline.” The digital mode of “Internet + waste recycling” has not been promoted, and the industrial chain of solid waste recycling, dismantling, and reusing is incomplete. Moreover, unregistered family- and village-based waste recycling entities compete with registered enterprises, causing a low level of resource recycling. (2) The production, distribution, and consumption systems for green, low-carbon, and circular development of enterprises have not yet been established. The construction of circular economy supporting facilities and the improvement of enterprise circular economy management system will increase production and operation costs in the initial stage. Due to the lack of financial and policy support, many enterprises have little motivation to develop and apply technologies related to circular economy. Inadequate management of product life cycle, including eco-design, green material input, green packaging, and recycling of waste materials, as well as inadequate environmental protection facilities for manufacturing, recycling, and reuse hinder the transformation of related industries to low-carbon production. (3) The innovation of circular economy and low-carbon development in China needs to be improved, and the mechanism innovation, model innovation, and product innovation of green, low-carbon, and circular industry require more attention. Recent years have witnessed slow progress of disruptive and

strategic technological innovation, including intelligent and refined disassembly of power batteries and other waste materials, in-depth sorting of rare metals, waste-to-energy (WtE) technologies, and refuse paper & plastic fuel (RPF) technologies^[27].

2.3 The slow-growing circular society impedes the popularization of low-carbon concept

At present, a circular economy governance system led by the government, dominated by enterprises, and jointly participated by social organizations and the public has not been established in China, and social forces are not active in participating in circular economy and carbon neutrality. (1) Due to the lack of guidance, a green and low-carbon lifestyle has not yet been established in the public, with widespread “throwaway” consumption behaviors of fast buying and dumping. In addition to the extensive use of disposable products, the rapid upgrading of mobile phones and other electronic products also causes significant waste of resources^[28], which aggravates the generation of solid waste. The public still lacks enthusiasm for resource conservation and garbage classification: The implementation of policies such as “Restriction on Plastic Bags” and “Green Travel” is not effective as expected; many communities have problems of loose garbage classification, dirty disposal sites, and mixed collection and transportation of different types of garbage. (2) Compared with Europe and the United States, the circulation of unwanted commodities is lower among Chinese residents. The second-hand market is not sufficiently regulated, and the standardization and regulation of pricing, trading, and after-sales service need to be improved. Despite the rapid development of the “Internet + second-hand” model relying on young consumers such as the “post-90s” and “post-00s,” the public are reluctant to participate in second-hand trading, and the centralized and standardized offline “flea markets” mainly in communities are not widely available. (3) The insufficient disclosure of information on environmental protection by enterprises in China cannot meet the information sharing needs of building a circular economy. The lack of a national information sharing platform in China has resulted in the inadequate exchange of environmental information among enterprises, making it difficult for social organizations and the public to participate in the supervision of carbon emission reduction by companies and environmental governance by the government. Scientific research groups and environmental protection organizations lack the capacity and resources of publicity and fail to lead the public to participate in environmental governance^[29].

3 Suggestions on the paths and measures to develop circular economy and achieve carbon neutrality in China

In summary, the “3R” principles of circular economy are

crucial for carbon neutrality and have been widely used in practice. Currently, the European Union and other developed economies have identified the development of circular economy as an important path to mitigating climate change and achieving carbon neutrality^[29]. After years of development, China's circular economy has made remarkable achievements, especially in industrial development and technological innovation. In the context of carbon neutrality, China should focus on solving problems and challenges in the development of circular economy. We should steadily promote the innovation of circular economy mechanisms, policies, models, technologies, and products towards carbon neutrality from the following aspects: building a circular economy governance system, establishing a circular industry and science/technology innovation system, and creating a green, low-carbon, and circular society. Those measures will support and guarantee the achievement of carbon neutrality.

3.1 Constructing a circular economy governance system for carbon neutrality

We should clarify the meaning and connection of circular economy and carbon neutrality, and the path to carbon neutrality through circular economy. The overall plan and top-level design of circular economy and carbon neutrality should be strengthened to build a circular economy governance system for carbon neutrality. (1) The coordination, supervision, and administration of circular economy, carbon peak and carbon neutrality by the National Development and Reform Commission should be strengthened for close cooperation of departments to develop circular economy and achieve carbon neutrality. (2) Plans of circular economy development for carbon neutrality need to be developed for key regions, key industries, and key enterprises to clarify the objective of each stage, roadmap, and action plans for the green, low-carbon, and circular development of relevant entities. Specific targets of carbon emission reduction are required to be identified for industries and enterprises in circular economy to ensure the synergistic promotion of circular economy development and carbon neutrality. Local governments should use fiscal/tax and industrial policies to support the industry development of circular economy, the efficient use of energy, and the recycling of resources. (3) To achieve the goal of carbon neutrality, we should timely revise and improve the existing laws and regulations such as the *Circular Economy Promotion Law*, *Energy Conservation Law*, and *Law on the Prevention and Control of Environmental Pollution by Solid Wastes*, accelerate the development of the *Comprehensive Resource Utilization Law* and the *Climate Change Response Law*, and further improve the law-based governance system of circular economy for carbon neutrality. (4) Based on the experience of circular economy industrial parks, "urban minerals" demonstration bases, "waste-free cities" pilot projects, together with the "3R" principles, pilot projects for the development of circular economy for carbon neutrality should be carried out in key

areas, key industries, and key enterprises. Mechanisms and systems can be innovated to establish a number of replicable and promoted examples and models for the development of green, low-carbon, and circular economy.

3.2 Establishing a circular industry and science/technology innovation system for carbon neutrality

A well-established industrial system and science/technology innovation system are critical to developing circular economy and achieving carbon neutrality. A green, low-carbon, and circular industrial system and a science/technology innovation system are required to improve the efficiency of resource utilization and provide strong support for the achievement of carbon neutrality. (1) A green, low-carbon, and circular development system of production, circulation, and consumption for carbon neutrality should be established. China shall give more support to circular economy industries and enterprises, coordinate and promote the transformation to green production in the whole industrial chain of relevant industries and enterprises, and encourage eco-design of products to realize a green and low-carbon life cycle and improve the green, low-carbon, and circular level of industrial chain, value chain, and supply chain. (2) We should construct a circular agricultural development model for carbon neutrality to further reduce the waste in food supply chain in China. The service cycle of agricultural products can be prolonged to improve the utilization of agricultural and forestry wastes and promote the development of circular agriculture. Food storage, transportation, and processing should be optimized by improving food storage mode, strengthening the construction of cold chain infrastructure in logistics, improving the food logistics and distribution system, and supplementing the absent food processing and packaging infrastructures^[24]. (3) China can strengthen the domestic circulation and recycling of products while expanding domestic demand, and provide raw materials and markets for the development of resource recycling enterprises. Efforts can be made to improve the waste material recycling system and strengthen the recycling and utilization of renewable resources (waste paper, waste plastics, waste tires, waste metals, and waste glass). Furthermore, we can promote the recovery and utilization of renewable resources and key mineral resources and support the development of recycling industries such as recycled metals and water. (4) We should innovate green, low-carbon, and circular technologies. Circular economy and carbon neutrality strategic technologies can be included in the National Key R&D Program of China and National Science and Technology Major Project. National key laboratories and research projects are required to be established to promote the efficient utilization of critical metals and other rare resources, the recovery and disassembly of power batteries and other new-type waste materials, and the research and application of circular and low-carbon technologies such as regenerative agriculture. (5) China should encourage the deep integration

of enterprises, universities, and scientific research institutions. Joint efforts can be made to cultivate innovative talents in circular economy and carbon neutrality. Green, low-carbon, and circular technology innovation incubators and collaborative innovation and entrepreneurial platforms should be established to promote the transfer of such technologies and the application of innovative achievements.

3.3 Creating a green, low-carbon, and circular society for carbon neutrality

Accelerating green, low-carbon, and circular development requires a pluralistic governance system led by the government, dominated by enterprises, and participated by social organizations and the public. By activating the whole society to participate in the construction of circular economy, key tasks of circular economy and carbon neutrality can be practically implemented. (1) Emphasis can be put on the media to guide public opinion towards creating a sound social atmosphere for the development of circular economy. The concept of circular economy should be consolidated to spread and popularize the “3R” principles and the knowledge of green, low-carbon, and circular economy. We should raise the awareness of green and low-carbon development, and encourage the public to reduce the consumption of plastic bags and other single-use products. Moreover, we can foster sustainable dietary habits, enhance the knowledge of garbage classification, use green transportation, and purchase green products, thereby accelerating the shift to a green and low-carbon lifestyle in terms of clothing, food, housing, and transportation. (2) We should build a shared circular transportation system in China^[24]. An urban transportation network connected by intelligent public transportation should be established based on information technology, so as to comprehensively improve the efficiency of the public transportation system. We shall support the development of bicycle-sharing enterprises, further meet the diversified transportation needs of residents, and reduce urban transportation carbon emissions. (3) Second-hand markets are required to be standardized in China. An “online + offline” platform for second-hand product circulation is preferred to establish a well-developed “Internet + second-hand” mode. We should improve the green, low-carbon, and circular operation and management of communities, build centralized and standardized “flea markets,” promote the trading and circulation of unwanted household items, and improve the level of product reuse. (4) We should construct a green, low-carbon, and circular community. Pilot green, low-carbon, and circular communities should be promoted to improve the operation and management modes. It is necessary to innovate the mode and system for the development of green, low-carbon, and circular communities. (5) Next-generation information technologies such as big data can be used to build an environmental protection information sharing and monitoring platform for circular economy and carbon neutrality. The environmental information should be

shared and exchanged among governments, enterprises, social organizations, and the public. The public’s right to know, participate, and supervise the status and key tasks of green, circular, and low-carbon development should be fully guaranteed. Those measures will stimulate the enthusiasm and initiative of social organizations and the public to participate in the governance and supervision, and help build a green, low-carbon, and circular society with the joint efforts of the government, enterprises, social organizations, and the public.

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GENG Yong, Dean of the School of Environmental Science and Engineering and the SJTU-UNIDO Joint Institute of Inclusive and Sustainable Industrial Development, Shanghai Jiao Tong University. Deputy Dean of the School of International and Public Affairs and Research Institute of Carbon Neutrality, Shanghai Jiao Tong University. He was awarded the National Science Fund for Distinguished Young Scholars of the National Natural Science Foundation of China. He focuses on the research of circular economy, industrial ecology, environmental management, climate change policy, and so on. He has undertaken several national key projects, such as the National Key Research and Development Program of China. On behalf of the Chinese government, he participated in the fifth and sixth Scientific Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC-AR5, IPCC-AR6). He also served as an expert on the United Nations Industrial Development Organization (UNIDO) Project on Resource Efficiency and Cleaner Production. He has published more than 300 papers in academic journals such as *Science*, *Nature*, *Science Advances*, *Nature Climate Change*, and *Nature Communications*. E-mail: ygeng@sjtu.edu.cn