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"Waste-free Cities" Construction and Carbon Emission Reduction in China: Based on the Perspective of Circular Economy

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ABSTRACT

Solid waste and carbon dioxide are important elements of environmental governance. Under the background of carbon peaking and carbon neutrality goals, the research on whether and how to promote the construction of "no waste cities" and carbon emission reduction is of great significance in China. The generation of solid waste and greenhouse gases such as carbon dioxide has the same origin, which can be well coordinated to promote environmental governance.

1. Introduction

According to the World Bank, the total amount of solid waste in the world shows a significant positive correlation with GDP. Compared with the rest of the world, the Asia-Pacific region generates the largest amount of solid waste, accounting for 23% of the world's total weight [1]. In addition, according to the data from the China Statistical Yearbook and the forecasts made therefrom, the amount of solid waste of China generated in 2021 will be 3.8 billion tons, which is still in a stage of slow growth compared with 3.75 billion tons in 2020. In terms of solid waste treatment, China comprehensively utilized and disposed of 3.036 billion tons or 80.96% of solid waste in 2020. In 2021, China will comprehensively utilize and dispose of 3.2 billion tons of solid waste, with a comprehensive treatment rate of 84.21%, a slight increase compared with the previous year, but there is still a big gap compared with developed countries. If these solid wastes are not properly treated and utilized, they will not only cause great waste of resources, but also cause serious pollution to the urban and rural environment of China. In recent years, Japan, the European Union, and Singapore have carried out active attempts and explorations in the comprehensive management of solid waste, which can

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provide reference experience for the pilot construction of "Waste-Free Cities". For example, Japan continues to promote the basic plan for building a circular economy society, the European Commission has successively released "Towards a Circular Economy: European Zero Waste Plan" and "Circular Economy Package", and Singapore has proposed a national vision for "zero waste".

At the same time, with the continuous increase of greenhouse gas emissions, climate issues have become the focus of the international community. The Paris Agreement provides an institutional framework for global cooperation in addressing climate change. More than 100 countries and regions around the world, including China, have pledged to achieve "carbon peaking" and "carbon neutrality" by the middle of the 21st century (referred to as the "Dual-Carbon Goals"). In December 2021, 17 government departments of China including the Ministry of Ecology and Environment jointly issued the "Work Plan for the Construction of 'Waste-Free Cities' during the '14th Five-Year Plan' period" to promote the development of waste reduction and build more "Waste-Free Cities" in China. The relevant indicators of waste reduction and carbon reduction have been adopted in the indicator system of ecological environment improvement [2].

The construction of "Waste-free City" is closely related to the Dual-Carbon Goals and has co-benefits. However, at present, the world is still in its infancy in the coordinated development of "Waste-free City" construction and carbon emission reduction including China, and how to achieve synergy between the two in this process also requires in-depth research. Therefore, this paper starts with the internal relationship between the construction of "Waste-free City" and carbon emission reduction and then uses models and tools to estimate the potential benefits of carbon emission reduction in the construction of "Waste-free City". The long-term goals, path choices and policy suggestions are also provided in the following parts of this paper for a reference of further improvements of China's urban environment construction.

2. Literature Review

The concept of zero waste (zero waste) was first proposed by the "Zero Waste International Alliance (2004)", which advocates reducing the emission of environmental pollutants such as solid waste. "Zero waste" is a solution to reduce the increasing solid waste, and there are great challenges and opportunities to transform traditional waste management into a zero waste vision. A waste-free concept promotes sustainable production, consumption and resource recycling. The United Kingdom, Canada, the United States, Japan and other countries have successively carried out the construction of waste-free cities. Regarding the concept of a zero-waste city, different scholars have expounded the concept of zero-waste from different perspectives. For example, Cole (2014) believes that "zero waste" refers to a way to minimize the impact of waste on the environment, with the goal of preventing waste generation, saving resources, and obtaining all the reuse value of materials [3]. Pietzsch (2017) examines the barriers and factors influencing the achievement of zero waste goals [4]. Lehmann (2012) examines the main principles and core drivers for the construction of "waste-free cities" [5]. Zaman (2013) proposed the Zero Waste Index (ZWI) as an alternative waste management performance evaluation tool for zero waste management systems, claiming that ZWI is a new indicator to measure and compare the substitution of raw materials by urban zero waste management systems [6]. Ozge (2020) takes universities as the research object, reduces waste from the source, and studies the quantity and characteristics of solid waste generated in one year by nature, such as classification, collection, temporary storage, recycling, transportation, disposal and control [7]. Wei Haojie (2019) researched that landfill is an important method for solid waste disposal, but solid waste landfill will have a serious impact on the surrounding environment [8]. At this stage, the comprehensive utilization rate of bulk industrial solid waste in China has been greatly improved, but there are still significant problems compared to its production.

3. The Relationship between the Construction of "Waste-free Cities" and "Dual-Carbon Goals"

(1) Both have the same goal

"Waste-free City" is an advanced urban management concept, it promotes the formation of green development mode and lifestyle, continuously promotes the source reduction and resource utilization of solid waste, minimizes the amount of landfill, and minimizes the environmental impact of solid waste. The long-term goal of the construction of "Waste-free Cities" is to achieve the minimum of solid waste production, full utilization of resources and safe disposal of the whole city, to build an environmentally friendly society. Steady development of the construction of "Waste-free Cities" is a powerful measure to further deepen the comprehensive management and utilization of urban solid waste, as well as an important method to develop a circular economy and achieve the "Dual-Carbon Goals". Therefore, the proposal of "Waste-free City" has been closely related to the goal of waste reduction and carbon reduction.

(2) The realization of the "Dual-Carbon Goals" is inseparable from the urban waste-free development

The "Dual-Carbon Goals" and the construction of "Waste-free City" are the unification of optimal utilization of energy and resources in urban construction, and the organic unification of green city, low-carbon economy and sustainable development for the ecological civilization, which will integrate material flows in social and economic systems, reduce wastes and pollutions, and improve the global environment.

(3) Practice has also proved that strengthening the management of solid waste is conducive to reducing carbon emissions

The pilot practice of "Waste-free City" that has been carried out in China has also fully demonstrated that the construction of "Waste-free City" can play a good synergistic role in promoting waste reduction and carbon reduction. After analyzing the solid waste management and carbon reduction data of 45 countries and regions around the world, the Basel Convention Asia-Pacific Regional Center concluded that by improving the scientific management level of 4 types of solid waste, the corresponding reduction in greenhouse gas emissions can reach 13.7%-45.2%. In addition, according to the calculation of China's Circular Economy Association on the management of solid waste in China, during the "13th Five-Year Plan" period, the contribution rate of reducing greenhouse gas emissions in China through the development of circular economy has reached 25% [9].

4. Estimate of Carbon Emission Reduction in the Construction of Waste-free Cities

According to the report released by the International Energy Agency in 2022, the total global greenhouse gas emissions in 2021 will reach 40.8 billion tons of CO_2 equivalent, a year-on-year increase of about 6%. In addition, according to the statistics of the World Resources Institute (WRI), the greenhouse gas generated by the global waste treatment accounts for about 3.2% of the total emissions, of which the greenhouse gas generated by the solid waste landfill accounts for 2.2%, accounts for 68.75% of the greenhouse gas generated by waste treatment.

From the above data, it seems that the total amount of carbon emissions directly caused by solid waste is not so high. However, it can directly or indirectly contribute considerable carbon emission reduction potential to the world.

Institutions and organizations "Global Waste Management Outlook" jointly published by the International Energy Agency and the International Solid Waste Association "Global Resource Outlook 2019" adopted by the United Nations General Assembly in 2019 "Research Report on Circular Economy Helping Carbon Peaking" issued by China Circular Economy Association in 2021.

There are currently four commonly used international carbon emission reduction accounting models, namely, the Waste Reduction Model (WARM model) developed by the US Environmental Protection Agency, and the Environmental Assessment Model for Solid Waste Systems and Technologies developed by the Technical University of Denmark (The Waste Reduction Model, WARM model). Environmental Assessment of Solid Waste System and Technologies, EASEWASTE model), the Solid Waste Management Green-House Gas (SWM-GHG Calculator) developed by the IFEU Institute in Germany, and the "Solid Waste Management Green-House Gas, SWM-GHG Calculator" developed by the Autonomous University of Barcelona, Spain "No Waste" Greenhouse Gas Emissions Calculator (CO_2 Zero Waste, CO_2ZW Calculator). According to the applicability and characteristics of the above

Table 1. Estimates of carbon emission reduction potential by some institutions and organizations

Institutions and organizations	*Global Waste Management Outlook*, a joint publication of the International Energy Agency and the International Solid Waste Association	*Global Resource Outlook 2019* adopted by the UN General Assembly in 2019	2021 "Research Report on Circular Economy Helping Carbon Reaching Peak" issued by China Circular Economy Association
Type of waste Municipal solid waste;	municipal solid waste; food waste	Mined and processed resources	Industrial solid waste, construction waste, biomass waste, renewable resources, some industrial parts and equipment
Treatment Approach	Landfills, energy recovery and other measures	Recycling	Recycling, Remanufacturing
potential contribution for carbon reduction	10-15%; can be increased to 15-20% if source reduction measures are included	Emission reduction contribution rate reach 25%	In 2020, China has reduced carbon dioxide emissions by about 2.6 billion tons with the contribution rate of emission reduction is 25%, this rate is expected to be 30% during the next 5 years.

four solid waste management GHG emission assessment models, combined with the specific conditions of China, the most suitable model for China's solid waste management carbon emission reduction accounting is the WARM model developed by the US Environmental Protection Agency. The model can be used for carbon emission reduction accounting for the construction of "Waste-free City" and the carbon emission reduction benefit evaluation of each city.

The WARM tool is developed by the U.S. Environmental Protection Agency (EPA) to help solid waste planning and estimate waste management measures to reduce greenhouse gas emissions. It uses emission factors to calculate the greenhouse gas emissions of solid waste under various management modes, containing different solid wastes. Treatment methods: including source reduction, recycling, composting, incineration, landfill, etc. According to the calculation method proposed by Jiang Lingling, Ding Shuang in 2022, from the perspective of the whole life cycle of the product, it can be calculated that the direct carbon emissions and carbon emission reduction benefits of solid waste disposal in China by measuring the disposal of typical solid wastes such as general industrial solid waste, domestic waste, agricultural solid waste and construction waste.

In the past five years, China's general industrial solid waste production has remained at 3 billion tons to 4 billion tons. In 2016, China's general industrial solid waste production was 3.092 billion tons, then reached 3.316 billion tons in 2017.It has grown to 3.675 billion tons in 2020, with a 3.5% compound annual growth rate. Since China's 2022 Statistical Yearbook has not yet been released, based on this growth rate, it can be predicted that China's general industrial solid waste generation will reach 3.8 billion tons in 2021,which is shown in Chart 1.

On the other hand, the comprehensive utilization of general industrial solid waste in China is 2.038 billion tons in 2020, accounting for only 55.45%. The disposal volume was 917 million tons, accounting for 24.96%. The storage capacity was 808 million tons, accounting for 21.98%. The dumping and discarding volume was 1.1349 million tons, accounting for 0.03%. So, it can be deduced that the potential benefits of carbon emission reduction for the solid waste in China is huge. Taking the solid waste utilization level in 2020 as the construction benchmark, and referring to the "14th Five-Year Plan" Period "Waste-free City Construction Work Plan" issued by the Ministry of Ecology and Environment of China and the OECD country's "Waste-free City" construction standards, we set the 2030 vision and 2050 vision for the construction of a

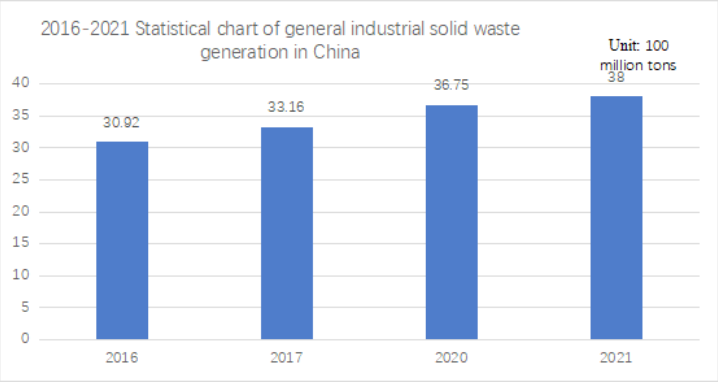

Chart 1. General Industrial Solid Waste Generation in China from 2016-2021

Table 2. Prospects for the construction of a waste-free city

Types of solid waste	Construction benchmark (2020)	Vision for 2030 "Waste-Free Cities" Construction	Vision for 2050 "Waste-Free Cities" Construction
Industrial solid waste	Recycling ratio 55.45%	The recycling ratio is 70%, and the source is reduced by 15%	The recycling ratio is 95%, and the source is reduced by 30%
Agricultural solid waste	Recycling ratio 82%	Recycling ratio 90%	Recycling ratio 100%
Household solid waste	Landfill ratio 33.1%	The landfill ratio is 15%, and the source is reduced by 15%	Landfill tends to 0, and the source is reduced by 30%
Construction waste	Recycling ratio 10%	Recycling ratio 30%	Recycling ratio 60%

"Waste-free City" (see the table below):

The overall carbon emission reduction contribution is expressed in terms of direct carbon emissions reduction from solid waste and benefits caused by the reduction. Direct carbon emission reduction refers to the emissions of greenhouse gas directly generated in the process of landfilling and incineration, and emission reduction benefits refer to the additional environmental and economic benefits (such as increased output value, by-product benefits, carbon trading benefits, etc.) compared with the construction benchmark of the base period.

According to the calculation results of the WARM model, compared with the benchmark level in 2020, the direct carbon emissions reduction of solid waste disposal in China through the construction of "Waste-free City" in 2030 will be about 130 million tons, while the emission reduction benefits from source reduction and comprehensive utilization can reach 1.68 billion tons; by 2050, China's direct carbon emissions reduction through solid waste disposal in "Waste-free City" will be reduced to 35.5 million tons, and the carbon emission reduction benefits from source reduction and comprehensive utilization will reach 5.02 billion tons. The calculation of the model shows that the carbon emission reduction benefits that China can achieve in the next 30 years through the construction of "Waste-free City" are very considerable.

5. Policy Suggestion

The calculation of carbon emission reduction based on solid waste treatment shows that in the construction of "Waste-free Cities", priority should be given as: Reduction of the source>Recycling>Terminal disposal. Further actions of governments such as circular economy supporting policies and green fiscal & taxation policies are also needed. In terms of comprehensive utilization of products, China needs to strengthen the supervision of waste reduction and carbon reduction in all aspects of the whole life cycle products, and strengthen the construction of standard systems for the safety, technicality, quality assessment, pollution control and other standards of recycled resource products in order to enhance competitiveness in the world.

Combined with the OECD countries' experience in solid waste management, the following measures can be taken to promote the coordinated development of "Waste-free City" construction and carbon emission reduction:

(1) Top-level design

According to the different stages of the construction of "Waste-free City", formulate corresponding waste reduction and carbon reduction goals and plans to reduce urban carbon emissions while reducing solid waste.

(2) Source reduction

Eliminate the waste of resources, improve the utilization rate of resources, optimize the production process, and reduce the generation of solid waste from the source.

(3) Strengthen waste collection and transportation management

Establish municipal systematic solid waste recycling services and garbage collection boxes, etc., collect and transport them regularly, strengthen the construction of waste collection infrastructure, and increase the rate of solid waste collection.

(4) Waste disposal management

Through laws and taxes, imp rove different solid waste disposal processes and methods.

(5) Government guidance

Governments need to lead by example by encouraging or mandating green procurement. Incorporate "no waste" goals into contracts for procurement and services. Support reusable and recycled materials within the jurisdiction for municipal road construction and maintenance. Work with service providers to develop recycling goals and provide technical assistance to increase waste recycling or composting rates.

(6) Strengthen publicity and education

The improvement of public awareness of environmental protection will contribute to the construction of "Waste-free City" and carbon emission reduction.

(7) Technical support

Non-governmental organizations and environmental protection departments at all levels can organize and implement a series of waste reduction and emission reduction plans and provide "no waste" technical guidance to residents, enterprises, and government departments.

The construction of a "Waste-free City" requires careful planning and precise layout to achieve carbon reduction while reducing waste and give full play to the synergistic effect of the two, thereby accelerating the pace of urban green and low-carbon development.

Funding Programs

1. The 2021-2022 Philosophy and Social Science Planning Project of Zhuhai City "Research on the Tax Collection and Management of Zhuhai's Construction of a 'Waste-free City' from the Perspective of Circular Economy" (Project No.: 2021YBC103).

2. The key project of the 2020-2021 Philosophy and Social Science Planning of Jinwan District, Zhuhai City "Research on the Accounting Standards and Operating Mechanisms of the Circular Economy System of the Virtual Eco-Industrial Park in Jinwan District Based on

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