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Study on the Carbon Reduction Effect of Urban Domestic Waste Treatment in Sichuan Province

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Abstract: The report of the 20th National Congress of the Communist Party of China proposed that China should "deeply promote pollution prevention and control" and "actively and steadily promote carbon neutralization", while winning the battle for blue sky is an important measure to build a beautiful China. The article proposes the concept of carbon reduction effect of waste treatment, and studies the carbon reduction effect of urban domestic waste treatment in Sichuan Province. Firstly, the system dynamics model of carbon emission problem in domestic waste treatment process is constructed, and the carbon reduction effect value of urban domestic waste in Sichuan province from 2011 to 2020 is calculated, and the relevant data in urban domestic waste treatment in Sichuan province from 2021 to 2030 are predicted. Secondly, in order to continuously improve the carbon reduction effect of urban domestic waste treatment in Sichuan Province in the future, three optimization schemes are proposed based on the share of waste treatment methods. The results show that ① the carbon reduction effect and the total carbon emission reduction equivalent in Sichuan Province from 2011 to 2020 are steadily increasing, and the carbon reduction effect shows a trend of steady improvement. ② From the predicted data of 2021-2030, the carbon reduction effect and the total carbon emission reduction equivalent are steadily increasing, and the carbon reduction effect is more and more significant. ③ From the optimization scheme, the advantages of low carbon emission of aerobic composting and anaerobic fermentation can effectively reduce the total carbon emission, while the advantages of high carbon emission reduction of incineration treatment method can effectively increase the carbon emission reduction equivalent and carbon reduction effect. Based on the above conclusions, Sichuan Province should reduce the sanitary landfill treatment of domestic waste in the future, and use more incineration for domestic waste treatment, while moderate use of aerobic composting and anaerobic fermentation and other waste treatment methods, in order to achieve a good carbon reduction effect and contribute to the realization of the "double carbon" goal. To contribute to the achievement of the "double carbon" goal.

Keywords: Municipal household waste, Carbon reduction effect, System Dynamics.

1. Introduction

The construction of ecological civilization is a fundamental plan for the sustainable development of the Chinese nation, and a good ecological environment is the most universal welfare of people's livelihood. China is now in the critical period of fighting the battle of pollution prevention and control, continuously improving environmental quality and building a beautiful China, and it is also the initial stage of the "double carbon" strategy, and the report of the 20th National Congress of the Communist Party of China proposed that China should "thoroughly promote pollution prevention and control" and "actively and steadily promote carbon peaking and carbon neutral". The report of the 20th CPC National Congress proposed that China should "promote pollution prevention and control" and "actively and steadily promote the carbon neutralization of carbon peaks".

The research results of domestic and foreign scholars on carbon reduction are relatively fruitful, but there is a lack of research on carbon reduction in domestic waste disposal. Brunnermeier et al. found that green technological advances can lead to lower carbon emissions by studying environmental innovations in the U.S. manufacturing industry[1]. brian et al. concluded that technological innovations can achieve carbon reduction by improving energy use efficiency[2]. Burtraw et al. found that CO2 emission reduction policies adopted by the US power sector also significantly reduced traditional air pollutants[3].Chae found that switching to low-sulfur fuels could achieve air quality improvements and CO2 emission reductions at minimal cost[4].Morgenstern et al. found that a policy of phasing out small boilers in the Taiyuan region of Shanxi approximately The policy of phasing out small boilers in Taiyuan, Shanxi Province, resulted in a reduction of carbon emissions by 50% to 95%[5]. Xu proposed that in order to effectively reduce carbon emissions, China needs to vigorously develop clean energy[6]. Shaofen Zhong et al. conducted a scenario analysis of carbon emissions through the STIRPAT model, and the results showed that population size has the greatest impact on carbon emissions, which is an important guide to achieve carbon reduction targets[7]. Guo Shiyi et al. studied the reduction of carbon emission intensity by adjusting industrial structure in developed countries, which provided empirical insights for China to achieve carbon reduction[8]. Huang Xiulian took some provinces and cities in China as case samples to explore the low-carbon development path, and finally proposed a "three-step" strategy for carbon reduction in China[9]. Zhang Youguo studied the transformation of China's carbon reduction policy system and proposed the difficulties and challenges faced by the transformation and upgrading of China's carbon reduction policy system[10].

Greenhouse gas emissions have a natural connection with environmental pollution management, which will inevitably lead to greenhouse gas emissions in the process of pollutant management. Controlling greenhouse gas emissions in pollutant management is an important link to achieve low-carbon economic development, and is a major initiative for sustainable economic and social development. In the new macro environment, based on the system dynamics theory, this paper studies the carbon reduction effect of urban domestic waste in Sichuan Province based on the data related to urban domestic waste, providing a basis for the government to formulate relevant policies and a reference for investors' decision making.

2. Research Methodology

(1) Calculation of carbon emission equivalents of different waste disposal methods

① Sanitary landfill for domestic waste

For large anaerobic landfills, the methane produced during the anaerobic landfill of domestic waste is collected, and the collection efficiency of the landfill gas collection system is between 30% and 80%[11], and the middle value of 55% is taken here, then the CH_4 and CO_2 emissions of domestic waste in the anaerobic landfill process are:

$$E_{CH4} = W \times DOC \times DOC_f \times MCF \times F \times \frac{16}{12} = 0.046W \quad (1)$$

$$E_{CO2} = W \times DOC \times DOC_f \times (1 - MCF \times F) \times \frac{44}{12} = 0.128W \quad (2)$$

Where, W is the mass of domestic waste; DOC is the degradable organic carbon, here take the IPCC recommended value of 14%; DOC_f is the proportion of actual decomposition of degradable organic carbon, take the IPCC recommended value of 50%; MCF is the methane oxidation factor, in the anaerobic landfill, this value is taken as 100%; F is the proportion of CH_4 volume in landfill gas, here take the IPCC recommended value of 50%; (16/12) is the CH_4/C molecular weight ratio; (44/12) is the CO_2/C molecular weight ratio.

Considering that CH_4 can be combusted purely to generate electricity and thus achieve carbon emission reduction, biogas power generation efficiency is generally in the range of l.68-2.00kW.h/m[12]. Approximately 0.2 kg of CH_4 can recover 1 kW- h of electricity, and the unit CO_2 emissions of major thermal power companies in China are around 0.7-0.8 kg/kW-h for electricity generation[13], and 0.8 kg/kW-h is taken here and below, so 1 kg of CH_4 for electricity generation can reduce coal-fired CO_2 emissions by 4 kg, and the emission reduction is calculated according to the 55% gas collection efficiency as:

$$E_R = W \times DOC \times DOC_f \times MCF \times F \times \frac{16}{12} \times 0.55 \times 4 = 0.103W \quad (3)$$

The greenhouse effect index of methane (CH_4) is 25, so the final carbon dioxide emission equivalent of sanitary landfill of domestic waste is:

$$E_{F1} = E_{CH4} \times 25 + E_{CO2} - E_R = 0.103W \quad (4)$$

② Incineration of domestic waste

Waste incineration is one of the main ways of municipal domestic waste treatment, and the carbon emissions generated by the municipal domestic waste incineration process are:

$$E_{CO2} = W \times CF \times OF + E_{CO2} - E_R = 0.103W \quad (5)$$

In this case, CF is the combustible carbon content of domestic waste, compared with DOC, mainly more carbon in rubber and plastic, according to the average level of plastic content in domestic waste in China in recent years, 7%-12% [14], and the carbon content of rubber and plastic recommended by IPCC, 67%-75%, the carbon contained in rubber and plastic components accounts for about 4%-9% of the total weight of waste, here taken as 6.5%, plus 14% of DOC, the final value of CF The final value of CF is 20.5%; OF is the oxidation factor, considering the level of mixed waste incineration and incineration technology in China, 85% is taken here [15].

Domestic waste incineration can be used to generate electricity, China's incineration plant unit waste power generation is generally between 0.2 to 0.4 kW- h/kg, this paper is calculated on the basis of 0.3kW- h/kg, the incineration of 1kg of waste is equivalent to 0.24kg CO_2 emission reduction:

$$E_R = 0.24W \quad (6)$$

Therefore, the final CO_2 equivalent emissions from domestic waste incineration treatment are:

$$E_{F2} = E_{CO2} - E_R = 0.399W \quad (7)$$

③ Aerobic composting of domestic waste

In the static aerobic composting process with forced ventilation, most of the DOC of domestic waste is converted to CO_2 and microbial organisms, and the carbon emissions from the composting process are:

$$\mathrm{E_{CO2} = W \times DOC \times DOC_f \times \frac{44}{12} = 0.257W} \quad (8)$$

Where, DOC is degradable organic carbon, here take the IPCC recommended value of 14%, DOCf is the proportion of actual decomposition of degradable organic carbon, take the IPCC recommended value of 50%, (44/12) is the CO2/C molecular weight ratio.

④Anaerobic fermentation treatment of kitchen waste

Municipal domestic waste contains a large amount of kitchen waste with high water content and salt content, which seriously affects the subsequent incineration or landfill treatment, so the separate treatment of kitchen waste has been rapidly developed in recent years, and this paper takes anaerobic fermentation to produce methane utilization as an example, anaerobic decomposition will convert most of DOC into CH4 and CO2, where the CH4 content is between 50% - 55%, and CH4 is finally converted into CO2. The final combustion of CH4 is converted to CO2. the degradable organic carbon content DOC in kitchen waste is taken here as 7% [16], DOCf is the proportion of degradable organic carbon actually decomposed, and the IPCC recommended value of 50% is taken, then the carbon emission formed by the final combustion of methane is:

$$\mathrm{E_{CO2} = W \times DOC \times DOC_f \times \frac{44}{12} = 0.128W} \quad (9)$$

Also, considering that methane power generation instead of coal combustion will have carbon reduction effect, therefore, substituting DOC=7%, DOCf=0.5, MCF=1,F=0.5, the final total carbon reduction is:

$$E_R = W \times DOC \times DOC_f \times MCF \times F \times \frac{16}{12} \times 4 = 0.093W \quad (10)$$

Therefore, the total final carbon emissions from the anaerobic fermentation treatment are:

$$E_{F3} = E_{CO2} - E_R = 0.035W \quad (11)$$

(2) Calculation of carbon reduction effect

In this paper, the sum of carbon dioxide equivalent produced by different treatment methods of domestic waste is taken as the total carbon emission of pollutants, and the sum of carbon emission reduction brought about by the phenomenon of replacing coal-fired power generation due to the effective use of carbon-containing substances in the process of domestic waste treatment is called the total carbon emission reduction of pollutants. The carbon reduction effect of domestic waste treatment can be defined according to the total carbon emission reduction of pollutants and the total carbon emission of pollutants:

$$S = \frac{\text{Total carbon reduction of pollutants ER}}{\text{Total carbon emissions of pollutants SC}} \quad (12)$$

Total carbon emissions of pollutants SC = sanitary landfill amount Q1 × sanitary landfill equivalent E1 + incineration amount Q2 × incineration equivalent E2 + aerobic composting amount Q3 × aerobic composting equivalent E3 + anaerobic fermentation amount Q4 × anaerobic fermentation equivalent E4.

E_1=1.175t$CO_{2\text{-eq}}$/t, E_2=0.399t$CO_{2\text{-eq}}$/t, E_3=0.257$CO_{2\text{-eq}}$/t, E_4=0.035t$CO_{2\text{-eq}}$/t

Total pollutant carbon emission reduction ER = sanitary landfill amount Q1 × sanitary landfill carbon emission reduction equivalent Er1 + incineration amount Q2 × incineration carbon emission reduction equivalent Er2 + aerobic composting amount Q3 × aerobic composting carbon emission reduction equivalent Er3 + anaerobic fermentation amount Q4 × anaerobic fermentation carbon emission reduction equivalent Er4

Er_1=0.103t$CO_{2\text{-eq}}$/t, Er_2=0.24t$CO_{2\text{-eq}}$/t, Er_3=0t$CO_{2\text{-eq}}$/t, Er_4=0.093t$CO_{2\text{-eq}}$/t

Where, the carbon reduction effect S is a dimensionless value, and the units of total pollutant carbon reduction and total pollutant carbon emission are tCO2-eq, i.e. tons of carbon dioxide equivalent.

3. Harmless Treatment of Municipal Waste in Sichuan Province

(1) 2011-2020 Status of urban household waste disposal in Sichuan Province

The data related to sanitary landfill, incineration, aerobic composting, anaerobic fermentation and other harmless waste treatment of urban domestic waste in Sichuan Province from 2011 to 2020 were obtained from the urban amenity and environmental health report in the China Urban and Rural Construction Statistical Yearbook, in which anaerobic fermentation is the treatment method of kitchen waste, and its proportion is 0.1% of the harmless treatment volume, and the data analysis shows that most of the treatment methods are sanitary landfill and incineration. For details, see Table 1.

Table 1. 2011-2020 Sichuan Province urban waste harmless treatment data table

Year	Harmless disposal volume (million tons)	Sanitary landfill (million tons)	Percentage of sanitary landfill	Incineration (million tons)	Incineration share	Others (million tons)	Other Percentage
2011	591.58	520.71	0.880	70.87	0.120	0	0.000
2012	620.44	603.31	0.972	17.13	0.028	0	0.000
2013	712.98	512.2	0.718	200.78	0.282	0	0.000
2014	743.90	494.18	0.664	249.72	0.336	0	0.000
2015	797.10	517.72	0.650	279.38	0.350	0	0.000
2016	874.22	512.3	0.586	361.93	0.414	0	0.000
2017	975.41	508.55	0.521	456.81	0.468	10.04	0.010
2018	1005.95	439.71	0.437	558.19	0.555	8.04	0.008
2019	1166.48	446.68	0.383	706.58	0.606	13.21	0.011
2020	1136.49	370.54	0.326	749.30	0.659	16.65	0.015

From the data in the table, in the past ten years, with the continuous progress of treatment technology, the proportion of urban household waste harmless treatment methods in Sichuan Province has also changed, with the proportion of sanitary landfill decreasing from 0.88 in 2011 to 0.326 in 2020 year by year, while the proportion of incineration has increased rapidly, from 0.12 in 2011 to 0.659 in 2020, while from 2017, Sichuan Province began to adopt new waste treatment methods, although the treatment ratio is very low, but also shows a year-by-year rising trend. Ten years ago, sanitary landfill was the main method, supplemented by incineration, while today, incineration is the main method, supplemented by sanitary landfill, compared to sanitary landfill, incineration is nothing less than a more excellent waste treatment method. In recent years, aerobic composting and anaerobic fermentation are two treatment methods that are developing rapidly, and these two methods have low carbon emission equivalents and can achieve the goal of carbon reduction.

(2) Analysis of the Carbon Reduction Effect of Harmless Treatment of Municipal Domestic Waste in Sichuan Province

① Model Building

Based on the system dynamics theory, Vensim software is used for modeling. From the connotation of carbon reduction effect, the higher the value of carbon reduction effect represents the better effect. For the carbon reduction effect and the total carbon equivalent emissions of pollutants, when the total carbon equivalent emissions of pollutants rise, the carbon reduction effect will decrease, and the two show a negative feedback relationship; when the unit carbon equivalent emissions of pollutants rise, the total carbon equivalent emissions of pollutants will also rise, so it shows a positive feedback relationship; while for the total carbon equivalent emissions of pollutants and the total carbon emission reduction of pollutants, the two obviously show a negative feedback relationship; when the unit carbon equivalent emissions of pollutants rise, the total carbon emission reduction of pollutants will also rise, so it shows a positive feedback relationship; When the unit carbon emission reduction of pollutants rises, the total carbon emission reduction of pollutants also rises, thus presenting a positive feedback relationship; when the total carbon emission reduction of pollutants rises, it indicates that the effect of carbon reduction improves, thus presenting a positive feedback relationship. The feedback diagram of the causal relationship of carbon reduction effect is shown in Figure 1. Meanwhile, according to the composition of total carbon emission reduction of pollutants and total carbon emission of pollutants, the stock flow diagram of carbon reduction effect is drawn as shown in Figure 2.

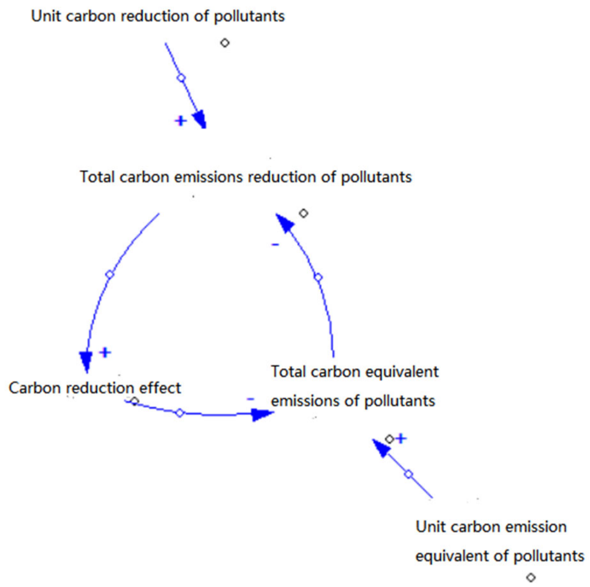

Figure 1. Feedback diagram of the causal effect of carbon reduction

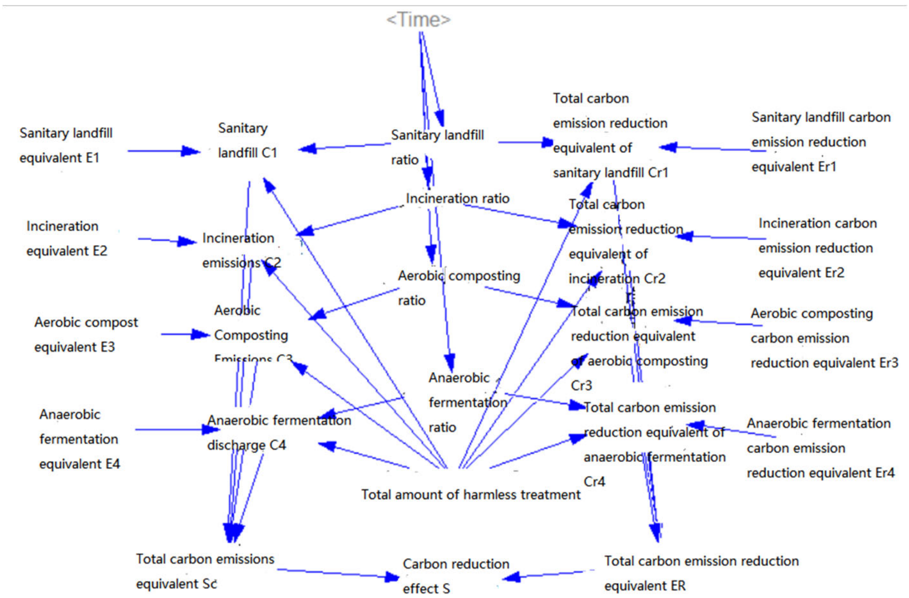

Figure 2. Carbon reduction effect stock flow map

Carbon emission equivalents of different waste treatment methods: E1=1.175 for sanitary landfill, E2=0.321 for incineration, E3=0.334 for aerobic composting, E4=0.035 for anaerobic fermentation, and the units of the above carbon emission equivalents are tCO2-eq/t.

The carbon equivalent quantity of different waste treatment methods: the carbon equivalent quantity of sanitary landfill C1=E1×total amount of environmentally sound treatment×the proportion of sanitary landfill in tCO2-eq. The same can be obtained: the carbon equivalent quantity of incineration C2, the carbon equivalent quantity of aerobic composting C3, and the carbon equivalent quantity of anaerobic fermentation C4.

Total carbon emission equivalent Sc=C1+C2+C3+C4.

The carbon emission reduction equivalents of different waste treatment methods: Er1=0.103 for sanitary landfill, Er2=0.24 for incineration, Er3=0 for aerobic composting, Er4=0.093 for anaerobic fermentation, and the above carbon emission reduction equivalents are in tCO2-eq/t.

The amount of carbon emission reduction equivalents of different waste treatment methods: the amount of carbon emission reduction equivalents of sanitary landfill Cr1 = Er1 × total amount of environmentally sound treatment × sanitary landfill share in tCO_2-eq. The same can be obtained: the amount of carbon emission reduction equivalents of incineration Cr2, the amount of carbon emission reduction equivalents of aerobic composting Cr3, and the amount of carbon emission reduction equivalents of anaerobic fermentation Cr4.

Total carbon emission reduction equivalent ER=Cr1+Cr2+Cr3+Cr4.

The total amount of waste disposal is set by the table function in t. The proportion of sanitary landfill, incineration, aerobic composting and anaerobic fermentation are set by the table function in dimensionless units.

② Calculation of carbon reduction effect

According to the relevant data in the urban amenities and environmental sanitation report in the China Urban and Rural Construction Statistical Yearbook, the carbon reduction effect of the harmless treatment of urban domestic waste in Sichuan Province from 2011 to 2020 is calculated, as shown in Table 2.

Table 2. 2011-2020 Sichuan Province, urban household waste disposal related data

Year	Total Carbon Emission Equivalent of Urban Household Waste Harmless Treatment in Sichuan Province (million tons of carbon dioxide equivalent)	Total carbon emission reduction equivalents of harmless urban domestic waste treatment in Sichuan Province (million tons of carbon dioxide equivalents)	Carbon Reduction Effect of Harmless Treatment of Municipal Domestic Waste in Sichuan Province
2011	640.11	70.64	0.110
2012	715.72	66.25	0.093
2013	681.95	100.94	0.148
2014	680.30	110.83	0.163
2015	719.79	120.38	0.167
2016	746.36	139.63	0.187
2017	782.18	162.11	0.207
2018	741.22	179.35	0.242
2019	809.91	215.70	0.266
2020	738.38	218.10	0.295

From the definition of carbon reduction effect, the higher the value of carbon reduction effect means the better the carbon reduction effect. In the last decade, the total carbon emission equivalent shows a fluctuating upward trend, from 6.411 million tons of carbon dioxide equivalent in 2011 to 7.383838 million tons of carbon dioxide equivalent in 2020; while the total carbon emission reduction equivalent shows a steady upward trend, from 706,400 tons of carbon dioxide equivalent in 2011 to 2.810 million tons of carbon dioxide equivalent in 2020. The calculated carbon reduction effect also steadily increases from 0.110 in 2011 to 0.295 in 2020, which shows that Sichuan Province has achieved significant carbon reduction effect by continuously adjusting its waste disposal methods.

4. Prediction and Optimization of Carbon Reduction Effect of Harmless Municipal Waste Treatment in Sichuan Province

(1) Predicted carbon reduction effect

① Waste disposal data forecasting

According to the data related to the harmless waste disposal in Sichuan Province from 2011 to 2020 in Table 2, the data were fitted with linear, logarithmic, exponential, and 2nd order polynomial by adding trend lines, and the results showed that the R2 after several fitting methods were 0.9748, 0.9747, 0.9751, and 0.9777, respectively, and the comparative analysis showed that the 2nd order polynomial curve had the highest fit and the best fit, See Figure 3 for details. The regression analysis was performed using the regression analysis tool, and the regression results are detailed in Table 3.

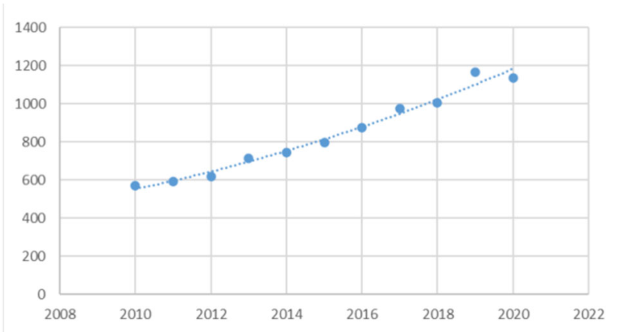

Figure 3. 2011-2020 Sichuan Province harmless waste disposal data fitting chart

Table 3. Regression statistics table

Regression Statistics	
Multiple R	0.987305072
R Square	0.974771306
Adjusted R Square	0.971617719
Standard Error	34.32592758
Observations	10

Table 4 Analysis of variance

	df	SS	MS	F	Significance F
Regression analysis	1	364202.2	364202.2	309.0992	0.000000112
Residuals	8	9426.154	1178.269		
Total	9	373628.3			

Based on the results of the regression analysis, the correlation coefficient R was obtained as 0.987305072, indicating a high positive correlation, and the Significance F (F significance statistic) was 1.12E-07, which is less than the significance level of 0.05, indicating a significant regression effect. The 2nd order polynomial equation was obtained: y = 1.4398x2 - 5737.6x + 5716181.

Meanwhile, the amount of sanitary landfill and other treatment are projected in the same way, so as to obtain the amount of harmless waste disposal, sanitary landfill, incineration and other treatment from 2021 to 2030, as shown in Table 5.

Table 5. Forecast data for 2021-2030

Year	Harmless disposal volume (million tons)	Sanitary landfill (million tons)	Percentage of sanitary landfill	Incineration (million tons)	Incineration share	Others (million tons)	Other Percentage
2021	1147.60	393.46	0.343	735.87	0.641	18.27	0.016
2022	1158.39	382.26	0.330	755.81	0.652	20.33	0.018
2023	1169.17	371.03	0.317	775.75	0.664	22.39	0.019
2024	1179.96	359.82	0.305	795.69	0.674	24.44	0.021
2025	1190.75	348.61	0.293	815.63	0.685	26.50	0.022
2026	1201.53	337.40	0.281	835.58	0.695	28.56	0.024
2027	1212.32	326.19	0.269	855.52	0.706	30.61	0.025
2028	1223.11	314.96	0.258	875.46	0.716	32.67	0.027
2029	1233.89	303.77	0.246	895.40	0.726	34.73	0.028
2030	1244.68	292.56	0.235	915.34	0.735	36.79	0.030

② Carbon emission related data calculation

Based on the predicted data of urban domestic waste treatment in Sichuan Province from 2021 to 2030 in Table 5, the carbon emission related data of urban domestic waste treatment in Sichuan Province from 2021 to 2030 are calculated using Equation 12, as shown in Table 6.

Table 6. 2021-2030 Carbon Emission Related Data of Urban Household Waste Harmless Treatment in Sichuan Province

Year	Total Carbon Emissions Equivalent	Total carbon emission reduction equivalents (million tons of carbon dioxide equivalent)	Carbon reduction effect value
2021	760.37	217.24	0.286
2022	755.68	220.87	0.292
2023	750.99	224.51	0.299
2024	746.29	228.14	0.306
2025	741.60	231.77	0.313
2026	736.91	235.40	0.319
2027	732.22	239.03	0.326
2028	727.53	242.67	0.334
2029	722.84	246.30	0.341
2030	718.15	249.93	0.348

(2) Optimization of environmentally sound waste disposal methods

From the data in Table 2, sanitary landfill and incineration are still the two treatment methods that dispose more waste in China, and in recent years, the proportion of other waste treatment methods has been increasing. From the viewpoint of the last decade, the proportion of sanitary landfill has been decreasing, and the proportion of incineration and other waste disposal methods has been increasing. Therefore, in order to enhance the carbon reduction effect of the harmless municipal waste treatment in Sichuan Province from 2021 to 2030, three optimization options are set in this paper.

Optimization option 1: Reduce the proportion of sanitary landfill by 10%, and transfer the reduced portion to waste incineration, while other proportions remain unchanged.

Optimization option 2: Reduce 10% of sanitary landfill, convert the reduced portion to aerobic composting, and keep the incineration ratio unchanged, while setting the anaerobic fermentation ratio at 0.1%.

Optimization plan 3: reduce the sanitary landfill ratio by 10%, reduce the part to anaerobic fermentation, the incineration ratio remains unchanged, and the aerobic composting ratio remains unchanged.

① Optimization option 1

Accelerate the rate of decline in the proportion of sanitary landfill and increase the rate of increase in the proportion of incineration, so the annual proportion of sanitary landfill will be reduced by 10% of its own proportion, and the reduced portion is converted to incineration treatment, while the proportion of other treatment methods remains unchanged. This calculates the relevant data, see Table 7 for details.

Table 7. Comparison table of before and after data of optimization scheme 1

Year	Total Carbon Emissions		Carbon reduction		Carbon reduction effect value		Percentage increase in the value of the carbon reduction effect
	Before optimization	After optimization	Before optimization	After optimization	Before optimization	After optimization	
2021	760.37	729.83	217.24	222.63	0.286	0.305	6.77%
2022	755.68	726.01	220.87	226.11	0.292	0.311	6.56%
2023	750.99	722.19	224.51	229.59	0.299	0.318	6.34%
2024	746.29	718.37	228.14	233.07	0.306	0.324	6.13%
2025	741.60	714.55	231.77	236.55	0.313	0.331	5.93%
2026	736.91	710.73	235.40	240.02	0.319	0.338	5.72%
2027	732.22	706.91	239.03	243.50	0.326	0.344	5.52%
2028	727.53	703.09	242.67	246.98	0.334	0.351	5.31%
2029	722.84	699.27	246.30	250.46	0.341	0.358	5.12%
2030	718.15	695.45	249.93	253.94	0.348	0.365	4.92%

② Optimization option 2

Accelerate the rate of decline of the proportion of sanitary landfill, increase the rate of increase of the proportion of other waste disposal methods, reduce the proportion of sanitary landfill by 10% per year, and the reduced portion is transferred to the proportion of aerobic composting, while the proportion of incineration, thus calculating the relevant data, see Table 8 for details.

Table 8. Comparison table of before and after data of optimization scheme 2

Year	Total Carbon Emissions		Carbon reduction		Carbon reduction effect value		Percentage increase in the value of the carbon reduction effect
	Before optimization	After optimization	Before optimization	After optimization	Before optimization	After optimization	
2021	760.37	724.25	217.24	213.19	0.286	0.294	2.92%
2022	755.68	720.59	220.87	216.94	0.292	0.301	3.10%
2023	750.99	716.92	224.51	220.68	0.299	0.308	2.95%
2024	746.29	713.26	228.14	224.43	0.306	0.315	2.83%
2025	741.60	709.60	231.77	228.18	0.313	0.322	2.74%
2026	736.91	705.94	235.40	231.93	0.319	0.329	2.99%
2027	732.22	702.28	239.03	235.67	0.326	0.336	2.94%
2028	727.53	698.62	242.67	239.42	0.334	0.343	2.61%
2029	722.84	694.96	246.30	243.17	0.341	0.350	2.61%
2030	718.15	691.30	249.93	246.92	0.348	0.357	2.64%

③ Optimization option 3

Accelerate the rate of decline of the proportion of sanitary landfill, increase the rate of increase of the proportion of other waste disposal methods, reduce the proportion of sanitary landfill by 10% per year, the reduced part of the anaerobic fermentation, while the proportion of incineration remains unchanged, the proportion of aerobic composting remains unchanged, thus calculating the relevant data, see Table 9 for details.

Table 9. Comparison table of before and after data of optimization scheme 3

Year	Total Carbon Emissions		Carbon reduction		Carbon reduction effect value		Percentage increase in the value of the carbon reduction effect
	Before optimization	After optimization	Before optimization	After optimization	Before optimization	After optimization	
2021	760.37	715.51	217.24	216.85	0.286	0.303	5.97%
2022	755.68	712.10	220.87	220.49	0.292	0.310	6.04%
2023	750.99	708.69	224.51	224.13	0.299	0.316	5.77%
2024	746.29	705.27	228.14	227.78	0.306	0.323	5.55%
2025	741.60	701.86	231.77	231.42	0.313	0.330	5.34%
2026	736.91	698.45	235.40	235.06	0.319	0.337	5.50%
2027	732.22	695.04	239.03	238.71	0.326	0.343	5.35%
2028	727.53	691.63	242.67	242.35	0.334	0.350	4.91%
2029	722.84	688.21	246.30	245.99	0.341	0.357	4.82%
2030	718.15	684.80	249.93	249.64	0.348	0.365	4.75%

④ Optimization option 4

Looking at the 3 optimization options. Optimization option 1 has the most significant carbon reduction effect and the best effect; optimization option 3 has the most amount of change in total carbon emission equivalent and good effect. However, although the effect of optimization option 3 is excellent in terms of total carbon emission equivalent, and the percentage increase of carbon reduction effect is not low, the actual situation is that kitchen waste accounts for a very limited amount of total domestic waste, and the percentage of anaerobic fermentation treatment is not likely to increase significantly, so optimization option 3 should not be considered in practical applications. Aerobic composting has low carbon emissions, while incineration has the advantage over aerobic composting in that it can be used to generate electricity and reduce carbon emissions. Although aerobic composting does not have the advantage of carbon emission reduction, it has the advantage of low carbon emission, which can play a role in carbon reduction to a certain extent. Therefore, the combination of optimization scheme 1 and optimization scheme 2 can be used in the future when household waste is treated in an environmentally sound manner.

(3) Optimization suggestions

Through the comparative analysis of different optimization schemes, the problems of different combinations of ways of harmless urban domestic waste treatment in Sichuan Province are found, and thus relevant suggestions are put forward.

Increase the waste classification, refine the classification and treatment of kitchen waste and general household waste, and increase the proportion of anaerobic fermentation and aerobic composting, especially for kitchen waste, which should be treated by complete anaerobic fermentation.

Increase the investment in the construction of waste incineration plants and raise the proportion of waste incineration treatment. Considering the current domestic waste treatment, sanitary landfill and incineration is still the main treatment method, especially waste incineration is the waste treatment method advocated at home and abroad, incineration can replace fossil fuel power generation and effectively achieve the effect of carbon reduction.

In the short term, sanitary landfill is still a mainstream waste treatment method, so it is recommended that when building sanitary landfill, biogas collection and utilization facilities must be the key construction content, so as to improve the efficiency of biogas collection.

In the long run, the high carbon emission value of sanitary landfill is not conducive to the carbon reduction effect, so it is recommended to develop a plan to reduce the proportion of landfill year by year, and eventually realize the zero landfill program.

5. Conclusion

From the results of data analysis in this paper, in the first few years during 2011-2020, Sichuan Province relied excessively on the sanitary landfill treatment method and the proportion of sanitary landfill was too high, which led to the poor carbon reduction effect of urban domestic waste treatment in Sichuan Province, and then Sichuan Province continuously adjusted the proportion of harmless waste treatment methods, reduced the proportion of sanitary landfill, increased the proportion of incineration, and adopted new The carbon reduction effect of municipal domestic waste treatment in Sichuan Province has become more and more effective, which reflects that Sichuan Province pays more and more attention to the carbon emission problem of domestic waste treatment, and the work done has remarkable effect. In order to continuously improve the carbon reduction effect of urban household waste treatment in Sichuan Province from 2021 to 2030, it can be seen from the comparative analysis of the three optimized options that Sichuan Province should increase the proportion of waste incineration year by year, reduce the sanitary landfill, and moderately adopt aerobic composting and anaerobic fermentation waste treatment methods, so as to achieve the "double carbon This will contribute to the realization of the "double carbon" goal.

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References

[1] Brunnermeier S.B.,Cohen M.A.Determinants of environmental innovation in US manufacturingindustries[J]. Journal of Environmental Economics and Management,2003, 45(2):278-293.

[2] Heap B.,KasemoB.Panel discussiononenergy efficiency [J]. Ambio, 2010, 39(1):22-25.

[3] BURTRAW D, KRUPNICK A, PALMER K, et al.Ancillary benefits of reduced air pollution in the US from moderate greenhouse gas mitigation policies in the electricity sector [J]. Journal of environmental economics and management, 2003, 45(3): 650-673.

[4] CHAE Y.Co-benefit analysis of an air quality management plan and greenhouse gas reduction strategies in the Seoul metropolitan area [J]. Environmental science&policy, 2010, 13(3): 205-216.

[5] MORGENSTERN R, KRUPNICK A, ZHANG X H.The ancillary carbon benefits of SO2 reductions from a small-boiler policy in Taiyuan, PRC [J]. The journal of environment & development, 2004, 13(2): 140-155.

[6] Xu Mi. Accelerate the development of nuclear power, effectively reduce carbon emissions [J]. Science and Technology Herald, 2017,35(13):1.

[7] Zhong Shaofen, Guo Xiaojuan, Liu yuping, Mo Jianwen. Carbon emission scenario analysis based on STRPAT model[J]. Science and Technology Management Research, 2019, 39 (17): 253-258.

[8] Guo Shiyi, Liu Wenqiang, Zhao Weidong. International comparison and empirical insights on adjusting industrial structure to reduce carbon emission intensity[J]. Strategic Study of CAE, 2021,23(06):22-32.

[9] Huang Xiulian. Exploring China's low-carbon development path based on the perspective of histories--Chinese style carbon reduction "three-step" strategy[J]. Soft Science, 2022, 36 (07): 90-96.

[10] Zhang Youguo. Transformation and Upgrading of China's Carbon Reduction Policy System[J]. Tianjin Social Sciences, 2022(03):90-99.

[11] Ran Guowei, Zhang Rukun, Feng Aiguo. Analysis of the current situation of biogas power generation technology and discussion of the development direction[J]. Journal of Agricultural Mechanization Research, 2006(03):189-191+194.

[12] Greenpeace. China Power Generation Group Climate Impact Ranking[R]. Beijing, 2009

[13] Du Wupeng, Gao Qingxian, Zhang Enchen, Miu Qilong, Wu Jianguo. Analysis of the current situation and composition of urban domestic waste discharge in China[J]. Research of Environmental Sciences, 2006(05):85-90.

[14] Zhao Tiantao, Ge Ning, Zhao Youcai. Greenhouse gas reduction and control technology in the field of environmental engineering[M]. Beijing: Chemical Industry Press, 2009:51.

[15] Ji Chongzhe, Liu Tongwu, Zhang Enchen. Study on the estimation method of degradable organic carbon of urban domestic waste [J]. Environmental Sanitation Engineering, 2005(03):7-9+13.