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Analysis of the Current Situation and Influencing Factors of China's Carbon Emissions—Based on the Multiple Linear Regression Model

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Abstract: The rapid economic development has further contributed to the global carbon emission problem, and studying the influencing factors of carbon emission is very valuable. Therefore, this paper selects five indicators: the stock of social financing (SFS), the percentage of fossil energy consumption (FEC), urbanization level (UL), energy processing and conversion efficiency (EPE), and per capita carbon emissions (CEP), to conduct an empirical study of their time series data from 2005 to 2020. Moreover, the results show that there is a positive correlation between the scale of social financing, the proportion of fossil energy consumption and per capita carbon dioxide, and a negative correlation between the urbanization level, energy processing and conversion efficiency, and per capita carbon emissions. Finally, reasonable development suggestions are proposed for promoting carbon emission reduction from three aspects: government, enterprise, and individual.

1. Introduction

Under the driving of economic globalization, reform, and innovation, many enterprises have sprung up, and the industry and service industry has gradually become the main components of China's GDP, which plays an active role in the rapid growth of the domestic economy. Concurrently, China's carbon emissions and energy consumption per unit of GDP are among the highest in the world's major economies. The secondary industry is the primary field of energy consumption and pollution emission in China, and its rapid growth may induce a series of problems, such as environmental degradation and ecological imbalance, affecting the sustainable development of China's economy. In recent years, many countries have paid more attention to the relationship between economy and ecology, and China has put forward the "3060" carbon peaking and carbon neutrality goals, placing the ecological civilization construction in an important position. In this context, it is significant to deeply study the issue of economic development and carbon emission in China.

2. Literature review

Zhang Wei et al.[1] analyzed the influencing factors of carbon emissions with the help of Kaya's identical equation and used it to construct a carbon emission model. The study results showed that

China's industrial system is biased toward the model of energy structure change, and energy use efficiency is mainly affected by industrial development. Wang Fenfen et al.[2] found through empirical analysis that economic growth, energy consumption, and carbon dioxide emissions are positively correlated, while financial development is negatively correlated with carbon dioxide emissions. Nie Ying et al.[3] used the PSTR model to study the impact of foreign direct investment (FDI) on carbon emissions in countries along the "Belt and Road", showing that such behavior exacerbates carbon emissions, but its impact slows down with the maturity of national economic development. Hu Bentian et al.[4] used a panel fixed-effects model and a mediating-effects model to show that inclusive digital finance has carbon emission reduction effects.

Taghizadeh-Hesary Farhad et al.[5] explored the asymmetric effects and transmission mechanisms in the relationship between green development and carbon emissions by constructing a green development index, and concluded that green development showed a negative relationship with carbon dioxide emissions. The results of Mirziyoyeva Ziroat et al.[6] Milindi Chris Belmert et al.[7] believe that renewable energy production and the development of climate-related innovations is supplement each other. The environmental-related patents only respond positively to carbon emissions in high-income countries, and developing countries should not neglect to promote green innovation as a pivotal condition for achieving carbon neutrality. Dogah Kingsley E. et al.[8] used a logarithmic (t) club convergence approach to find that urbanization plays a critical role in the convergence path of carbon emissions and called for urgent efforts to decarbonize infrastructure processes associated with urbanization.

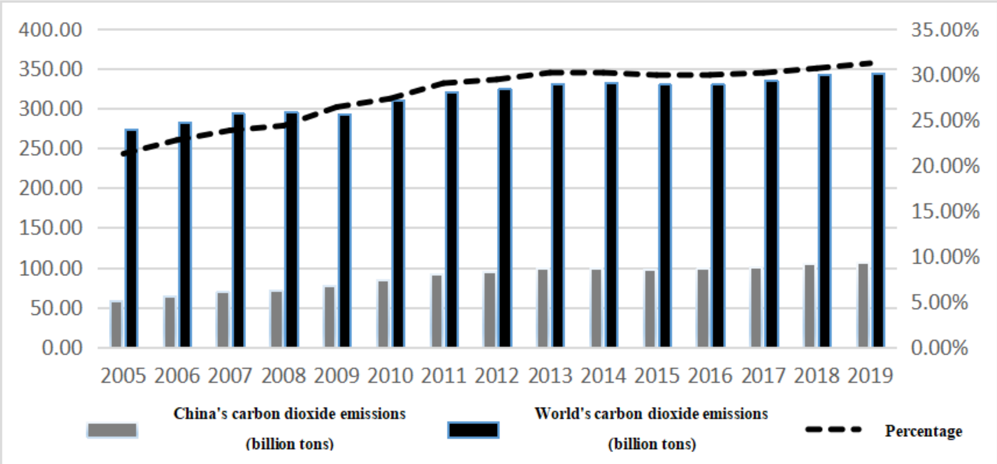
On this basis, this paper further explores the perspectives that can lead to carbon emission reduction, which takes into account the current status of carbon emission and integrates the effects of economic factors, social factors, energy factors and technological factors.

3. Research status

Carbon emission usually refers to the emission of carbon dioxide. The rapid development of the global economy (especially industry) in the past hundred years consumes a large amount of fossil energy, and the greenhouse gases produced by it have caused a series of ecological and environmental problems, such as rising sea levels and desertification intensification, and so on. Furthermore, these negative impacts have gradually interfered with the normal production and life of human beings, which have attracted the attention of many countries. This part will briefly describe the current situation of carbon emissions in China from 2005 to 2019, trying to illustrate the level and stage of carbon emissions in China and provide the basis for the empirical study later.

3.1 Total carbon dioxide emissions

In recent years, China's carbon dioxide emissions have overall shown an upward trend. In terms of its specific emissions, the emissions were 5.825 billion tons in 2005 and subsequently rose continuously to 100.07 billion tons from 2006 to 2014. However, the emissions decreased in 2015 to 9.861 billion tons and continued to rise from 2016 to 2019, reaching a maximum of 10.707 billion tons in the last fifteen years. Moreover, according to figure 3.1.1, China's carbon dioxide emissions are relatively similar to the world's carbon dioxide emissions, which are 34.344 billion tons as of 2019, an increase of 6.930 billion tons compared to 2005 emissions. Secondly, the percentage of China's carbon dioxide emissions to the world's carbon dioxide emissions has been rising overall, with the average percentage of carbon emissions from 2013 to 2019 as high as 30.29% and the percentage in 2019 as high as 31.18%. (As shown in figure 1)

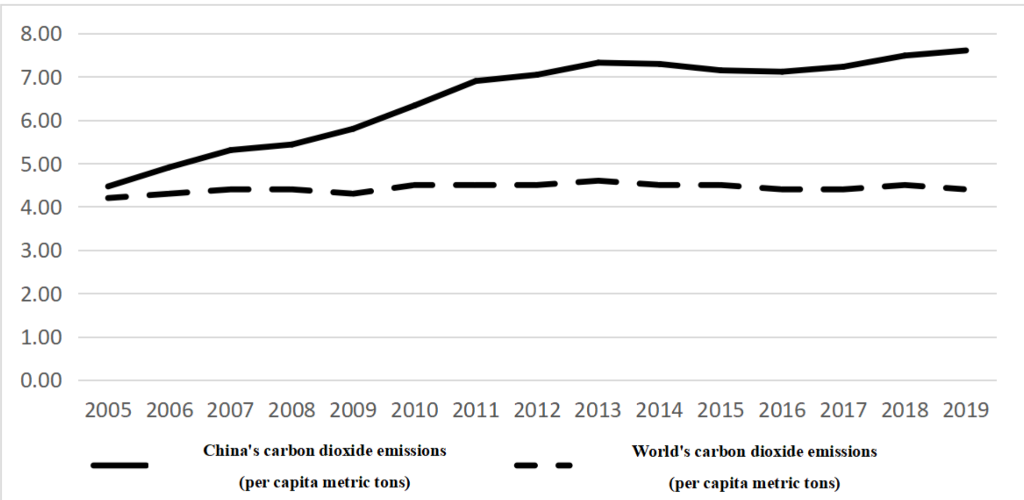


(Data sources: World Bank Open Data)

Figure 1: China's total carbon dioxide emissions

Both the absolute amount of carbon dioxide emissions and the relative percentage of the world's carbon emissions show that China's carbon dioxide emissions have been rising. The relevant data in China Statistical Yearbook shows that China's secondary and tertiary industries account for a higher percentage, the six major energy-consuming enterprises account for more than 21% of the total number of private enterprises in China in the past 15 years, and the total energy consumption is as high as 3,937,460,000 tons of standard coal on average, with fossil energy consumption accounting for more than 85%. These data are enough to show that although rapid economic and social development promotes the progress of human society, it also affects the balance of the ecological environment, and the rise of carbon dioxide emissions is a more obvious signal.

3.2 Per capita carbon dioxide emissions



(Data sources: World Bank Open Data)

Figure 2: China's per capita carbon dioxide emissions

From figure 2, it can be found that China's per capita carbon dioxide emissions show an overall upward trend. Furthermore, from 2005 to 2013, China's per capita carbon dioxide emissions rose from 4.97 tons to 7.32 tons, an increase of 2.85 tons; from 2015 to 2016, these three years declined slightly; from 2017 to 2019, it has risen year by year until 7.61 tons per capita. However, the world's per capita carbon dioxide emissions have changed less, with 4.4 tons of carbon dioxide emissions per capita in the last 15 years. It can be seen that China's carbon dioxide emissions per capita are higher than the world's carbon dioxide emissions by 2.07 tons. China's carbon dioxide emissions account for more than 30% of the world's carbon dioxide emissions, and the per capita emissions are higher than the world level, affecting the economy's sustainable development.

4. Empirical study

4.1 Variable selection and data sources

Table 1: Variable selection and data sources

Variable selection		Specify	Data sources
Explained variables	CEP	Per capita carbon dioxide emissions	World Bank Open Data
Explanatory Variables	SFS	Stock of social financing scale	China Statistical Yearbook
	FEC	Percentage of fossil energy in total energy consumption	China Statistical Yearbook
	UL	Urbanization level	China Statistical Yearbook
	EPE	Energy processing conversion efficiency	China Statistical Yearbook

Table 2: Sample data

Years	Percentage of fossil energy	Stock of social financing scale (RMB trillion)	Urbanization level	Energy processing and conversion efficiency	Carbon dioxide (per capita metric tons)
2005	0.9260	22.4265	0.4299	0.7110	4.4677
2006	0.9260	26.4500	0.4390	0.7090	4.9103
2007	0.9250	32.1326	0.4494	0.7120	5.3064
2008	0.9160	37.9765	0.4568	0.7150	5.4351
2009	0.9150	51.1835	0.4834	0.7240	5.7983
2010	0.9060	64.9869	0.4995	0.7250	6.3354
2011	0.9160	76.7791	0.5127	0.7220	6.9013
2012	0.9030	91.4675	0.5257	0.7270	7.0462
2013	0.8980	107.5217	0.5373	0.7300	7.3241
2014	0.8870	122.9386	0.5477	0.7310	7.2942
2015	0.8800	138.2824	0.5610	0.7340	7.1464
2016	0.8700	156.0044	0.5735	0.7350	7.1154
2017	0.8640	174.7000	0.5852	0.7300	7.2310
2018	0.8550	200.7000	0.5958	0.7280	7.4873
2019	0.8470	251.4000	0.6271	0.7330	7.6059
2020	0.8410	284.4000	0.6389	0.7340	7.6070

This paper selects relevant data in China from 2005 to 2020 as the sample and constructs a time series model. Four factors, namely, the stock of social financing scale, the percentage of fossil energy in total energy consumption, urbanization level, and energy processing and conversion efficiency, are selected from four aspects, namely, economic factors, energy factors, social factors, and technological factors, to empirically analyze the factors affecting carbon dioxide emissions, and the econometric model is run with Eviews 7.0 software. The variables selection and data sources are shown in table 1.

From table 2, it can be seen that per capita carbon dioxide emissions show a year-on-year rise. Moreover, from 4.4677 per capita metric tons in 2005 to 7.6070 per capita metric tons in 2020, an increase of 70.27% in 15 years; along with the adjustment of energy consumption structure, the percentage of fossil energy in total energy consumption has declined, from 92.60% to 84.1% in 2005, but still occupies the main position of all energy consumption; the stock of social financing has grown considerably, from 22.4265 trillion to 284.4 trillion, almost a 12-fold increase; the urbanization level has been increasing with economic growth to 63.89%, and the energy processing and conversion efficiency has been maintained relatively stable at an average level of 72%.

4.2 Descriptive statistics and correlation analysis

Before conducting the multiple regression analysis, the variables selected in this paper were first subjected to descriptive statistical analysis to observe each variable's mean, median, maximum, minimum, standard deviation, and number of observations. Among them, carbon dioxide emissions per capita (CEP), stock of social financing scale (SFS), and energy processing and conversion efficiency (EPE) are treated in logarithmic form.(As show in table 3-4)

Table 3: Data descriptive statistics

	lnCEP	lnSFS	FEC	UL	lnEPE
Mean	1.868413	4.473108	0.892188	0.528931	-0.321653
Median	1.957375	4.596838	0.900500	0.531500	-0.318142
Maximum	2.029069	5.650382	0.926000	0.638900	-0.307885
Minimum	1.496874	3.110243	0.841000	0.429900	-0.343900
Standard deviation	0.171565	0.806328	0.029288	0.066051	0.012158
observation	16	16	16	16	16

Table 4: Data correlation analysis

Correlation	lnCEP	lnSFS	FEC	UL	lnEPE
lnCEP	1.000000				
lnSFS	0.946986	1.000000			
FEC	-0.798973	-0.947317	1.000000		
UL	0.909066	0.993445	-0.970096	1.000000	
lnEPE	0.927344	0.928021	-0.818308	0.897889	1.000000

Through correlation analysis, the correlation coefficients of lnCEP with lnSFS, FEC, UL, and lnEPE are obtained as 0.95, -0.80, 0.91, and 0.93, respectively. Among them, the correlation coefficients of the explained variables and the three explanatory variables are above 0.9, which can be interpreted as a significant correlation between per capita carbon dioxide emissions and the stock of social financing scale, urbanization level, and energy processing and conversion efficiency. However, it is found that the correlation coefficients between some explanatory variables are relatively high, which indicates that the problem of multicollinearity may exist internally and needs to be further tested and adjusted.

4.3 Model construction

Regression analysis explains the relationship between variables and studies the effects of the stock of social financing scale, the proportion of fossil energy consumption, urbanization level, and energy processing and conversion efficiency on per capita carbon emissions. The regression model constructed in this paper is as follows:

$$\mathrm{lnCEP_t} = \beta_0 + \beta_1 lnSFS_t + \beta_2 FEC_t + \beta_3 UL_t + \beta_4 lnEPE_t + \delta_t$$

Where t=1, 2,…T denotes the time and year, β_0 is the constant term, β_1, β_2, β_3, β_4 are the estimated parameters, and δ is the residual term.

4.4 Empirical analysis

4.4.1 Unit root test

Since the time series of some variables have more same development trend, the regression of these data is likely to have high fit coefficients. However, these variables often have no obvious direct relationship, and they do not have typical economic significance. To ensure the smoothness and validity of the estimation results and avoid the phenomenon of spurious regression, the ADF unit root test is applied here to judge the test equation based on the minimum criterion of AIC value, SC value, and HQ value before the regression analysis of the panel data, and the test results are shown in table 5.

Table 5: ADF test results

Variables	ADF test		ADF tests the significant level of critical value			Conclusions
	t-statistic	P-value	1%	5%	10%	
lnCEP	-1.969774	0.2949	-4.004425	-3.098896	-2.690439	Non-stationary
lnSFS	-1.988451	0.2880	-3.959148	-3.081002	-2.681330	Non-stationary
FEC	-2.119801	0.4949	-4.728363	-3.759743	-3.324976	Non-stationary
UL	-2.369567	0.3776	-4.728363	-3.759743	-3.324976	Non-stationary
lnEPE	-2.332812	0.1769	-4.057910	-3.119910	-2.701103	Non-stationary
D(lnCEP)	-2.023180	0.0448	-2.740613	-1.968430	-1.604392	Stationary**
D(lnSFS)	-2.277295	0.0913	-4.004425	-3.098896	-2.690439	Stationary*
D(FEC)	-6.564241	0.0007	-4.800080	-3.791172	-3.342253	Stationary***
D(UL)	-4.103162	0.0084	-4.004425	-3.098896	-2.690439	Stationary***
D(lnEPE)	-4.261707	0.0259	-4.886426	-3.828975	-3.362984	Stationary**

Note: D() is the first-order difference series of the variables, *, **, *** denote significance at 10%, 5%, and 1% levels of significance, respectively.

From the results in Table 5, it can be obtained that the original series of lnCEF, lnSFS, FEC, UL, and lnEPE are all non-stationary and cannot pass the significance test. Therefore, the first-order difference ADF test was performed on the variables, and the final test results showed that all first-order difference series passed the ADF test. Specifically, lnSFS passed the ADF test with a significance level of 10%, lnCEP and lnEPE passed the ADF test with a significance level of 5%, and FEC and UL passed the ADF test with a significance level of 1%.

4.4.2 Co-integration test

All variables passed the first-order difference ADF unit root test, and the next step of the co-integration test can be performed using the E-G two-step method. The residual series passed the ADF test with a significance level of 1%, and the co-integration relationship between the variables can be judged, and the ADF test results of this series are shown in table 6.

Table 6: ADF test for residual series

Variables	ADF test		ADF tests the significant level of critical value			Conclusions
	t-statistic	P-value	1%	5%	10%	
Residuals	-4.889844	0.0001	-2.728252	-1.966270	-1.605026	Stationary***

Note: *, **, *** denote significance at 10%, 5%, and 1% levels of significance, respectively.

4.4.3 Regression equation

The least square method was used to perform the regression analysis, and the regression results are shown in table 7.

Table 7: Results of regression analysis

Variables	Coefficient	Std.Error	t-statistic	Prob.
C	-4.115412	0.749784	-5.488795	0.0002***
lnSFS	0.608066	0.052506	11.58088	0.0000***
FEC	4.437711	0.546677	8.117610	0.0000***
UL	-2.721840	0.708021	-3.844291	0.0027***
lnEPE	-2.313914	0.838108	-2.760877	0.0185**
R-squared:0.996389		F-statistic:758.8611		
Adjusted R-squared:0.995076		Prob(F-statistic):0.000000		

Note: *, **, *** denote significance at 10%, 5%, and 1% levels of significance, respectively.

$$\mathrm{lnCEP_t} = -4.115 + 0.608 lnSFS_t + 4.438 FEC_t - 2.722 UL_t - 2.314 lnEPE_t$$

The regression equation results show a correlation between the stock of social financing, the percentage of fossil energy consumption, urbanization level, energy processing and conversion efficiency, and per capita carbon dioxide emissions. This is shown as follows:

(1) There is a positive relationship between the stock of social financing scale and per capita carbon dioxide emissions. The scale of social financing mainly refers to the balance of funds obtained by the real economy from the financial system at the end of the period, which to a certain extent, shows the active degree of production and investment in the economic development market. Moreover, it shows that for every 1% increase in the stock of social financing, the average increase in per capita carbon dioxide emissions is 0.608%. This indicates that finance supports economic growth and the rapid development of the real economy, which can affect the level of carbon emissions from different perspectives.

(2) There is a positive correlation between the percentage of fossil energy consumption and per capita carbon dioxide emissions. In 2020, China's coal consumption accounted for 56.8%, and fossil energy consumption is the primary reason for the increase in carbon dioxide emissions. The data show that for every one-unit increase in the percentage of fossil energy consumption, the average increase in per capita carbon dioxide emissions is 4.438%. Additionally, the secondary and tertiary industries are important pillars of China's economy and require a large amount of energy and material as the basis for powering them, contributing to carbon emissions to a certain extent.

(3) There is a negative relationship between the urbanization level and per capita carbon dioxide emissions. Some research literature in the urban sector suggests that the increase in urbanization density can reduce energy use. According to the experimental study of Sun Qiuyuan's[9] threshold model, the advancement of urbanization is beneficial to carbon emission reduction. However, the study of Xu Shichun[10] found that the development of urbanization in the western and central regions of China does not promote carbon emissions. The regression results of this paper show that for every

one-unit increase in urbanization level, the average per capita carbon dioxide emission decreases by 2.722%, which can be interpreted as an incentive effect of urbanization on carbon emission reduction.

(4) There is a negative correlation between energy processing and conversion efficiency and per capita carbon dioxide emissions. Energy processing and conversion efficiency measure the degree of technological development for effective energy use, which can reveal the level of conversion technology and management ability. Furthermore, for every 1% increase in energy conversion efficiency, the average per capita carbon dioxide emission decreases by 2.314%. This means that improving energy processing and conversion efficiency and enhancing comprehensive energy utilization efficiency is beneficial to greatly promote carbon emission reduction efforts.

4.4.4 Granger causality test

Granger causality test was used to determine whether lnCEF, lnSFSlnx1, FECx2, ULx3, and lnEPElnx4 were a causality relationship with each other. The results of the test are shown in table 8.

Table 8: Results of the Granger causality test

Null hypothesis	F-statistic	Prob.
lnSFS is not the Granger causality of lnCEF	1.00918	0.4023
lnCEF is not the Granger causality of lnSFS	0.28234	0.7605
FEC is not the Granger causality of lnCEF	1.04526	0.3907
LnCEF is not the Granger causality of FEC	5.02357	0.0343**
UL is not the Granger causality of lnCEF	0.41186	0.6743
LnCEF is not the Granger causality of UL	0.15489	0.8587
LnEPE is not the Granger causality of lnCEF	1.33838	0.3098
LnCEF is not the Granger causality of lnEPE	9.41613	0.0062***
FEC is not the Granger causality of lnSFS	0.49226	0.6268
LnSFS is not the Granger causality of FEC	1.32505	0.3130
UL is not the Granger causality of lnSFS	0.83489	0.4649
lnSFS is not the Granger causality of UL	1.31820	0.3147
lnEPE is not the Granger causality of lnSFS	0.97969	0.4122
lnSFS is not the Granger causality of lnEPE	2.28444	0.1576
UL is not the Granger causality of FEC	0.98600	0.4100
FEC is not the Granger causality of UL	0.90197	0.4395
LnEPE is not the Granger causality of FEC	0.71782	0.5138
FEC is not the Granger causality of lnEPE	0.14667	0.8656
LnEPE is not the Granger causality of UL	0.77304	0.4900
UL is not the Granger causality of lnEPE	1.98633	0.1930

Note: *, **, *** denotes significance at 10%, 5%, and 1% level of significance, respectively.

From table 8, it can be found that there is a unidirectional or bidirectional Granger causality relationship between per capita carbon dioxide emissions, the percentage of fossil energy consumption, and energy processing and conversion efficiency. Specifically: there is a unidirectional Granger causality test between per capita carbon dioxide emissions and the percentage of fossil energy consumption at the 5% significance level and a unidirectional Granger causality test between per capita carbon dioxide emissions and energy processing and conversion efficiency at the 1% significance level.

5. Conclusion and recommendations

From the perspective of influencing factors of carbon emissions, this paper conducts an empirical study using relevant data from 2005 to 2020. The results show that there is a positive relationship between the stock of social financing, the percentage of fossil energy consumption and per capita carbon dioxide emissions. However, there is a negative relationship between the urbanization level, energy processing and conversion efficiency and per capita carbon dioxide emissions. In response to the carbon emission problem, China has put forward the "3060" carbon peaking and carbon neutrality goals, which are extremely important for the sustainable development of China and the world. Nevertheless, achieving the carbon peak and carbon neutral goals requires the joint efforts of all social subjects. Therefore, this paper will make recommendations from three levels: government, enterprises, and individuals:

5.1 Optimize the energy consumption structure and learn from advanced experience at home and abroad

The carbon emission reduction is not about reducing the absolute amount of energy consumption but about promoting the transformation of the energy consumption structure. Therefore, the government should formulate a carbon emission reduction plan with Chinese characteristics and cooperate with neighboring countries on energy.

5.2 Promoting the construction of energy management system and strengthening the exploration of industrial energy conservation

The enterprises should respond to the national policy on carbon emission, accelerate the digitalization and informatization transformation and upgrading, establish a visualized energy management system, introduce pollution emission treatment terminals, further improve energy utilization efficiency, and produce more products with limited resources. Additionally, the enterprises should use their own funds and financial subsidies to drive the replacement of internal machinery and equipment and gradually solve the problem of high energy consumption and high emissions caused by outdated technology and low efficiency.

5.3 Developing low-carbon living habits and green environmental awareness

Carbon emission reduction is not only the responsibility of countries and enterprises, but every citizen should participate in it. Since 100 cars emit 1350 kg of carbon per day and almost 1/3 of the world's food is wasted, it almost accounts for 8% of the greenhouse gas emissions. Therefore, residents can start from trivial matters around them and make joint efforts to protect the environment.

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