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Research and Development of Carbon Footprint Analysis In Hunan Province

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Abstract

Based on the definition of carbon footprint and elements that affect it, a model was constructed for empirical research, using data of cities in Hunan Province from 2005 to 2009, to calculate the amount of carbon footprint and to analyze the relationships between carbon footprint and each of the elements, including population, level of economic development, industrial structure and energy structure. In addition, this paper also puts forward solutions to further low-carbon development of Hunan Province in the areas of low-carbon development mechanism、energy structure、low carbon life style and talent development.

Keywords: carbon footprint; energy consumption; low-carbon development

1. Introduction

In recent years, the cumulative effects of energy consumption, including global warming and environmental degradation, have increasingly become more apparent and have greatly hindered the development of society and the economy. Therefore, we have to seriously rethink the present model of

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economic development. In order to increase energy efficiency, the development of a more environmentally friendly low-carbon economic model is essential. Since carbon footprint is the quantitative index of carbon emission, the study of carbon footprint in Hunan Province can not only illustrates the real state of energy utilization in Hunan Province, but can also determine the factors that affect carbon footprint through calculations, allowing clearer tracking of the carbon footprint of Hunan Province, improved energy saving awareness and reduced pollutant discharges in Hunan. Furthermore, the study is also helpful in the optimization of the energy structure and the transformation of the economic growth model of Hunan Province.

2. Carbon Footprint

2.1 The Definition of Carbon Footprint

Carbon footprint is the amount of carbon dioxide and other greenhouse gases directly or indirectly emitted over the full lifecycle of an activity, product or service. It is an index which is used to evaluate the effects on the environment caused by carbon dioxide emission due to the consumption of a particular person or group [1]. Carbon footprint differs from the amount of greenhouse gases since it is defined from the perspective of consumption, which breaks down the narrow conception of carbon emission. This definition vividly describes how a person or a group leaves their footprints during the process of producing greenhouse gases. So far, the application of carbon footprint can be divided into four parts: individual carbon footprint, products carbon footprint, enterprises carbon footprint and cities carbon footprint. By being conscious of their carbon footprints, Individuals and groups can control and limit their behaviors to achieve the goals of energy saving and reduction of pollutant discharges.

2.2 The Factors that Affect Carbon Footprint

The factors that affect carbon footprint are complicated. The prevalently used important factors that affect carbon emission are as follows: First, the population. Normally, more people lead to more carbon emission. Hunan Province has a large population and thus has more carbon emission than that of the provinces with less population; Secondly, energy efficiency. Different industries have different levels of energy efficiency. For example, manufacturing efficiency is different from that of agriculture. Even firms within the same industry may have different levels of energy efficiency due to different levels of technology. The more advanced the technology, the higher the energy efficiency and the lesser the amount of carbon emission. Thirdly, the energy structure. The amount of carbon emission is closely related to the source of energy. Different types of energy have different coefficient of carbon emission. The coefficient of carbon emission among the common energies used in daily life in decreasing order is coal, petroleum and natural gas, with the coefficient of carbon emission of coal as the highest. That means coal will emit the highest amount of carbon, and natural gas will emit the lowest amount while consuming the same amount of energy [2]. Fourth, the model and the scale of economic development. Compared to a capital intensive form of economic development, a labour intensive form of economic development gives off a greater amount of carbon emission. In addition, the amount of carbon emission will gradually grow along with the expansion of the economy and the improved level of economic development.

3. The Model of Carbon Footprint

According to the definition of carbon footprint and based on the analysis of energy consumption, the model of carbon footprint is as follows:

$$CFP = \sum_i C_i = \sum_i \frac{C_i}{Y} \times Y$$

Notes: CFP is carbon footprint; C_i means the amount of carbon emission of the i type; Y represents gross domestic product（GDP）; $\sum_i \frac{C_i}{Y}$ is the amount of carbon emission per unit of GDP

According to the above factors, the parameters of the model can be further divided. GDP can be the product of the population and the per capita GDP. While the amount of carbon emission of unit of GDP can be the product between the amount of energy consumption per unit of GDP and the amount of carbon emission per unit of GDP（or the coefficients of carbon emission）.

4. The Application of the Model of Carbon Footprint

4.1 The Collection of Data

The data on the GDP and the per capita GDP of 14 cities in Hunan Province from 2005 to 2009 are based on the data provided by the statistical yearbook of Hunan Province from 2005 to 2009. The data are showed in the following table:

Table 1. The GDP of Cities in Hunan Province (billion yuan) / per capita GDP (yuan)

	2005	per capita	2006	per capita	2007	per capita	2008	per capita	2009	per capita
Changsha	1520	23968	1798.9	29745	2190	33432	3001	45705	3744.8	57968
Yueyang	628.6	12408	733.45	13925	915.8	17312	1105.7	22036	1272.2	23130
Changde	627.6	11689	723.84	12044	864.1	15679	1049.7	19296	1239.2	20182
Hengyang	590.1	8888	672.1	9466	823.5	12192	1000.1	15135	1168	16088
Zhuzhou	525.7	14497	605.3	16270	748.7	19137	909.57	24544	1022.6	26909
Chenzhou	477	11197	546.2	12005	649.4	14928	734.06	17148	821.54	17442
Xiangtan	367	13014	422.08	15021	523.1	18873	654.76	23978	739.38	22680
Shaoyang	362.7	5439	409.5	5656	487.3	7369	561.57	8731	600.69	7903
Yongzhou	361.5	7186	414.5	7395	506.4	9299	592.69	11760	640.04	11035
Yiyang	329.2	8169	336.2	7454	408.9	11201	511.28	12244	591.62	12777
Loudi	312.5	8238	359.1	8959	449.5	9747	528.4	14013	569.79	13618
Huaihua	296.5	6592	333.9	6874	408.9	8150	503.69	10782	559.15	11080
Zhangjiajie	110.6	7588	127.5	8072	151.3	10072	183.98	12496	203.1	12951
Xiangxi	123.9	4991	148.8	5293	184.8	7405	226.66	9562	268.97	9961

*The source of the data: the statistical yearbook of Hunan Province from 2005 to 2009

The data on the amount of carbon emission of unit of GDP of the cities in Hunan Province from 2005 to 2009 are according to the data on the Energy consumption indicator Bulletin announced by the Statistical Bureau and the Economic Committee of Hunan Province. The data are shown in table 2, with the coefficient of carbon emission being 0.7329 ton/ten thousand tons of standard coal [4].

Table 2. Carbon emissions of Unit of GDP of cities in Hunan Province

(tons / ten thousand tons of standard coal)

	2005	2006	2007	2008	2009
Changsha	0.754887	0.725571	0.6918576	0.6493494	0.6200334
Yueyang	1.165311	1.1220699	1.0641708	1.0048059	0.9469068
Changde	0.8252454	0.8069229	0.7702779	0.7307013	0.6867273
Hengyang	1.018731	0.9960111	0.9498384	0.8978025	0.8516298
Zhuzhou	1.187298	1.1550504	1.0964184	1.018731	0.9637635
Chenzhou	1.2935685	1.2444642	1.2422655	1.1345292	1.0685682
Xiangtan	1.568406	1.5105069	1.4430801	1.3309464	1.2591222
Shaoyang	1.0729656	1.0590405	1.0150665	0.960099	0.9043986
Yongzhou	1.0802946	1.0649037	1.0194639	0.9571674	0.9021999
Yiyang	0.967428	0.9329817	0.886809	0.8464995	0.8047242
Loudi	2.169384	2.0872992	1.9810287	1.8579015	1.7692206
Huaihua	1.0495128	1.0275258	0.9828189	0.9139263	0.8662878
Zhangjiajie	0.7783398	0.7761411	0.7431606	0.6940563	0.6603429
Xiangxi	1.1088777	1.0744314	1.0377864	0.9505713	0.9036657

The source of the data: http://www.hntj.gov.cn/

4.2 The Calculation of Carbon Footprint

By inputting the above data into the carbon footprint model, we calculated the carbon footprint data of the cities in Hunan Province from 2005 to 2009. The data are in table 3:

Table 3. Carbon footprint of cities in Hunan Province (tons)

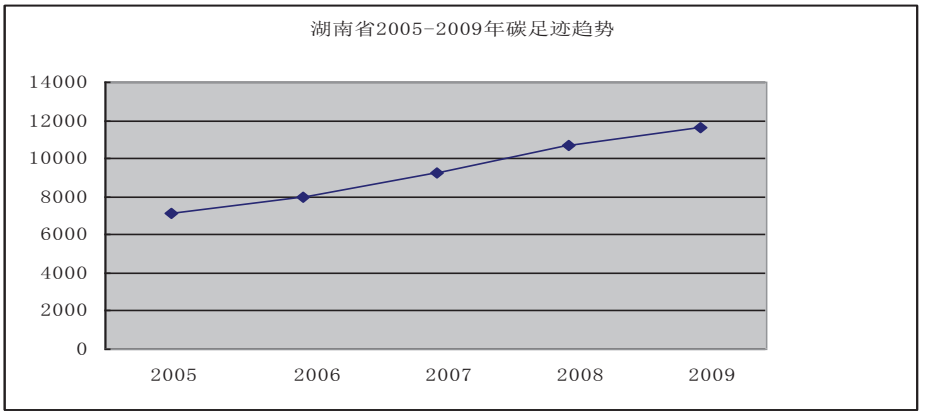
	2005	2006	2007	2008	2009	population（ten thousand）
Changsha	1147.35275	1305.22967	1515.34111	1948.6846	2321.87627	646
Yueyang	732.514495	822.982168	974.610185	1111.0541	1204.60749	550
Changde	517.924013	584.083072	665.597133	767.01715	851.013072	614
Hengyang	601.193912	669.41906	782.201421	897.87432	994.712123	726
Zhuzhou	624.162559	699.152007	820.888456	926.60716	985.515642	380
Chenzhou	617.032175	679.726346	806.727216	832.8125	877.871519	471
Xiangtan	575.605002	637.554752	754.8752	871.45046	930.969772	326
Shaoyang	389.164623	433.677085	494.641905	539.1628	543.263195	760
Yongzhou	390.526498	441.402584	516.256519	567.30355	577.444024	580
Yiyang	318.477298	313.668448	362.57186	432.79826	476.090931	463
Loudi	677.9325	749.549143	890.492211	981.71515	1008.08421	418.4
Huaihua	311.180545	343.090865	401.825507	460.33554	484.384823	504.63
Zhangjiajie	86.0843819	98.9579903	112.469925	127.69248	134.115643	156.82
Xiangxi	137.389947	159.875392	191.803682	215.45649	243.058963	270
Total	7126.5407	7938.36858	9290.30233	10679.965	11633.0077	6865.85

4.3 The Analysis of Carbon Footprint in Hunan Province

4.3.1 The analysis on the trend of carbon footprint

From the following graph, we can see that the carbon footprint of Hunan Province remains on a continuous upward trend during the years from 2005 to 2009. During 2005 and 2006, carbon footprint changed relatively slow. In the next few years, the speed of upward trend became notably faster. From table 3, we can see the trend of carbon footprint in the cities is similar to the trend of carbon footprint in the whole province. But from table 2, we can see that, in recent years, the carbon footprint per unit of GDP of cities from 2005 to 2009 decreased year from year, following the transformations of the economic growth model of Hunan and the construction of the two-oriented Society.

Fig.1 The trend of carbon footprint in Hunan Province from 2005 to 2009



4.3.2 The effects of the economic development on carbon footprint

In order to test the relationship between economic development and carbon emission, carbon footprint of Hunan Province from 2005 to 2009 and per capita GDP, as an indicator of economic development, were regressed against each other. The results of the regression analysis between the carbon footprint and the per capita GDP in Hunan Province are shown in Table 4.

Table 4. The regression analysis between the carbon footprint and the per capita GDP about the cities in Hunan Province

	Regression Equation	R^2	P-value
Changsha	CFP=0.035x+301.79	0.994	0.0001
Yueyang	CFP=0.0407x+245.17	0.983	0.002
Changde	CFP=0.0333x+151.16	0.957	0.004
Hengyang	CFP=0.049x+181.53	0.98	0.002
Zhuzhou	CFP=0.028x+242.8	0.972	0.002
Chenzhou	CFP=0.037x+219.69	0.953	0.004
Xiangtan	CFP=0.031x+176.11	0.944	0.004
Shaoyang	CFP=0.045x+163.68	0.917	0.007
Yongzhou	CFP=0.037x+148.54	0.921	0.0009
Yiyang	CFP=0.027x+94.4	0.867	0.021
Loudi	CFP=0.049x+322.46	0.859	0.011
Huaihua	CFP=0.034x+103.59	0.96	0.003
Zhangjiajie	CFP=0.008x+30.53	0.968	0.0008

Xiangxi	CFP=0.017x+57.34	0.948	0.002

The goodness of fit (R2)(From Table 4) of the regression of carbon footprint and per capita GDP is high, and is greater than 0.85 in all 14 cities in Hunan Province. The P-value is less than 0.05 for all 14 cities and would pass significance test at the 5 percent level. This means the linear correlation between carbon footprint and per capita GDP is strong, and the related coefficients are all greater than 0. All of this indicate that the amount of carbon emission of cities in Hunan Province will very likely increase with the growth of per capita GDP. The faster the economy of Hunan Province grows, the higher the energy consumption and the greater the amount of carbon emission.

4.3.3 The effects of population on carbon footprint

Normally, population and carbon emission are positively correlated because the more population a region has, the more activities related to carbon emission the region has. From the data showed in Table 3, the correlation between the two is not clear. Shaoyang City, the most populous city, has relatively low carbon footprint. This could mean that population affects the amount of carbon emission, but is not the only factor.

4.3.4 The effects of the industrial structure on carbon footprint

From Table 2, the unit of GDP was highest in Loudi City, which was closely related with the city's industrial structure. Loudi City is the energy raw material base of Hunan Province, and its industrial structure is oriented towards the industries of steel, coal and cement. The production capacity of steel, coal and cement is over tens of millions of tons. These industries have the characteristics of high energy consumption and high carbon emission. The industrial structure of Changsha City and Zhangjiajie City, which have lower unit of GDP, is quite different from that of Loudi City. Changsha City mainly develops the industries of culture, new materials and mechanical engineering, which have lower energy consumption, while Zhangjiajie City mainly develops the light industries, such as tourism and tea, which are low-carbon industries. Through comparative analysis, it is apparent that industrial structure of a city is a factor of carbon footprint.

4.3.5 The effect of energy structure on carbon footprint

Energy structure is also an important factor that influences carbon footprint. From the present state of energy consumption in Hunan Province, the consumption of coal and petroleum make up a large proportion of the energy consumption of cities, and account for 70% of the total energy consumption in the province. Coal and petroleum are energy sources that cause high pollution and high emission. While clean energy sources such as hydropower and wind energy make up a low proportion of Hunan's total energy consumption. All these are some of the important factors causing rapid growth of carbon footprint in Hunan Province.

5. The Effective Way to Promote Low-Carbon Development in Hunan Province

5.1 To Optimize the Industrial Structure and to establish the Mechanism of Low-carbon Development

Within the total energy consumption of Hunan Province, energy consumption by the manufacturing industry has held a dominant position. Therefore, in order to promote low-carbon development in Hunan Province, there should first be a focus on reduction of energy consumption in the manufacturing industry, optimization of the industrial structure and innovation in production, to take advantage of the province's effort for developing new industries. The labor intensive form of economic development should be changed to a capital intensive one focused on improvements of technology. The development of industries with high energy consumption, high pollution and low value-added should be firmly controlled. Relative researches must be made on laws of developing low-carbon economy and ensure the establishment of a long-term mechanism for low-carbon development. Meanwhile, according to the needs

to the construction of the Two-oriented Society and the goal of saving energy and reducing pollutants discharge, with the perfection of the evaluation system of carbon emission, the government should adopt strict measures for examination and approval, perfect the elimination mechanism for production capacity, and seriously carry out the work of integration of industries, such as steel, cement, paper making, flat glass etc., with the goal of eliminating industries with low production capacity. The government also should reduce the industries of high energy consumption and high pollution and promote the development of industries which are high tech, resources saving, and environmentally friendly.

5.2 To increase the capacity of Utilizing Energy and to optimize the Structure of Energy Consumption

Nowadays, the growth of carbon emission is quite evident due to lagging technology. There is more space for saving energy by using technology. First, the development of technology of clean coal, regenerative energy and energy saving should be emphasized; Secondly, the improvement of the traditional industries should be made, the equipments of high waste and low efficiency should be eliminated, and the efficiency of utilizing energy should be increased from its source, through reducing energy waste, enhancing the production of secondary energy, and cutting down the emission of carbon. In the meantime, the structure of energy consumption in our province should be optimized because the energy structure is centered on the coal industry, while Hunan province is poor in resources such as coal, natural gas, and petroleum. In order to promote the low-carbon development of Hunan Province, on the one hand, we should develop renewable energy, such as wind power, waterpower, solar energy etc., and raise the proportion of renewable energy in the overall consumption of energy; on the other hand, low-carbon technology should be further introduced into Hunan Province, and carbon emission from the consumption of nonrenewable energy, something like coal and petrol, should be effectively reduced [5].

5.3 To greatly advance circular economy and to make low-carbon life style and low-carbon environment

As well as getting experience from experimental unit of circular economy, such as the units of Zhuzhou Smelter Group Co. Ltd., Miluo Terminal Market of Renewable Resources etc., we should all spread the development of circular economy, and spread them to every field of economic development. We also should draw up plans to prevent pollution under the guidance of fully utilizing resources, to advance the low-carbon production of important industries, such as nonferrous metals and metallurgy , the recycling of resources, establish low-carbon lifestyle and build a low-carbon environment. We must put the concept of energy saving and pollutants discharge reducing into our daily life, advocate energy saving nationwide, and exploit the potentials of energy saving in buildings, rural areas, commercial industries, and civilian industries. For the purpose of reducing carbon emission in our daily life, we should encourage each other to use clean energy like wind power and solar energy, and use materials and electric appliances that saves energy.

5.4 To cultivate talents and establish the low carbon research system and to advance the research of low-carbon economy

Talents are one of the important factors to advance the low-carbon development in Hunan Province. Focusing on the long-term strategic development of the province, as well as paying attention to the cultivation of talents of low-carbon economy, we make clear plans to develop low-carbon technology and establish the implementing system. We should build labs of low-carbon energy, establish the low carbon research system with independent innovation ability and make systematic researches on the fields of

low-carbon energy, technology, policies and strategies; and the development of renewable energy and alternative energy, by fully pooling the best resources, both domestic and overseas, and arousing the enthusiasm of the staff. At the same time, we should try to push forward the process of the integration of industry, education and research, to build a network for knowledge sharing of low-carbon researches, improve efficiency in transformation of research results, and increase development of low-carbon technology and low-carbon products.

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