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# The Application of Carbon Footprint Analysis in Hunan Province

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## Abstract

Based on interpreting carbon footprint's definition and its effecting factors, making positive analyses by using the data of cities in Hunan Province from 2005 to 2009, this paper constructs the calculating model of carbon footprint and analyses the relationship between carbon footprint and population, economy development level, industrial structure and energy structure. Meanwhile, on the basis of above analyses, this paper puts forward effective ways to advance the low-carbon development of Hunan Province from four aspects.

**Key words:** Carbon footprint; Energy consumption; Low-carbon development

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## INTRODUCTION

Recent years, the accumulating effects of energy consumption gradually have revealed. Global warming is deteriorating the environment and seriously hindering the economy development. Therefore, we have to deeply rethink about the present mode of economy development. In order to increase the usable capacity of energy, we must greatly advocate developing low-carbon economy mode which is environment-friendly. Because it is the quantitative index of carbon emission, the study of carbon footprint's application in Hunan Province not only can help to understand the real state of utilizing energy in Hunan Province, but also can find out the factors which effect carbon footprint, through calculating. These all are helpful to clearly track the carbon footprint of Hunan Province and improve the consciousness of saving energy and reducing pollutants discharge in our province. They are also helpful to the optimization of energy structure and the transformation of economic growth mode in our province.

## 1. CARBON FOOTPRINT

### 1.1 The Definition of Carbon Footprint

Carbon footprint is the amount of carbon dioxide and other greenhouse gases directly or in directly emitted over the full lifecycle of an activity and products 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, group (Zhao & Huang, 2010). The difference from the amount of greenhouse gases, carbon footprint is defined from the perspective of consumption, and it 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. Through making sure their carbon footprints, Individuals and groups can control and restrict their behaviour to achieve the target of saving energy and reducing pollutants discharge.

### 1.2 The Effecting Factors of Carbon Footprint

The effecting factors of carbon footprint are complicated.

Usually the important factors to change the amount of carbon emission are as follows: First, the population. Usually the more people are there, the more carbon emitted. As a province having large population, the amount of carbon emission of our province is much more than that of the provinces having less population; Second, the efficiency of utilizing energy. Different industry has different efficiency of utilizing energy. For example, the efficiency of the industry is different from that of agriculture. Even the same industry has different efficiency because of different technology level. The more advanced the technology, the higher the efficiency of utilizing energy, and the less the amount of carbon emission. Third, the structure of energy. The amount of carbon emission is closely related to the variety of energy. Different energy has different coefficient of carbon emission. The coefficient of carbon emission among the common energy in daily life, such as coal, petroleum, natural gas, is decreased in turn. The coefficient of carbon emission of coal is 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 (Chen, Wang & Fang, 2004). Fourth, the mode and the size of economy development. Compared to intensive form of economy development, extensive form of economy development gives off more amount of carbon emission. In addition, the amount of carbon emission will gradually grow with the increasing expansion of the size of economy and the improvement of economy development level.

## 2. THE MODEL OF CARBON FOOTPRINT

According to the definition of carbon footprint, based on the analysis of energy consumption, the calculating 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 (GFDP); $\sum_i \frac{C_i}{Y}$ is the amount of carbon emission of unit of GDP.

According to the above factors, the parameters in the model can be further divided. GDP can be the product between 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 of unit of GDP and the amount of carbon emission of unit of GDP (or the coefficients of carbon emission).

## 3. THE APPLICATION OF THE MODEL OF CARBON FOOTPRINT

### 3.1 The Collection of Data

Based on the date provided by the statistical yearbook of Hunan Province from 2005 to 2009, we got the data of the GDP and the per capita GDP of 14 cities in Hunan Province from 2005 to 2009. The data are showed in Table 1:

**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 |

Source: The statistical yearbook of Hunan Province from 2005 to 2009.

According to date on the Energy consumption indicator Bulletin announced by the Statistical Bureau and the Economic Committee of Hunan Province, we got the data of the amount of carbon emission of unit of GDP of the cities in Hunan Province from 2005 to 2009. The data are showed in Table 2. And in it, the coefficient of carbon emission is 0.7329 ton/ ten thousand tons of standard coal.

**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 |

Source: http://www.hntj.gov.cn/

**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 |

### 3.2 The Calculation of Carbon Footprint

Putting the above data into the model of carbon footprint, we got the data of carbon footprint of the cities in Hunan Province from 2005 to 2009. The data are in Table 3:

### 3.3 The Analysis of Carbon Footprint in Hunan Province

#### 3.3.1 The Analysis of the Trend of Carbon Footprint

From Figure 1, we can find out that the carbon footprint of Hunan Province remains on a repeatedly upward trend during the years from 2005 to 2009. In years of 2005 and 2006, the changes of carbon footprint are relatively slow. In the next few years, the speed of changes went 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 find out that, in recent years, the carbon footprint of unit of GDP of cities from 2005 to 2009 decreased year after year, following the transformations of economic growth mode and the construction of the Two-oriented Society.

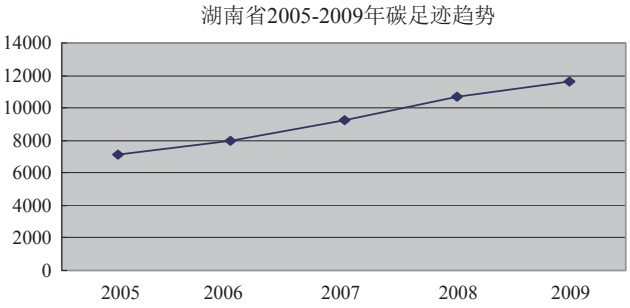


**Figure 1**
**The Trend of Carbon Footprint in Hunan Province From 2005 to 2009**

#### 3.3.2 The Influence the Economy Development Level Can Make on Carbon Footprint

In order to testify the relationship between economy development level and carbon emission, this paper selects the data of Hunan Province from 2005 to 2009, uses per capita GDP to indicate economy development level, and conducts regression analysis through using EXCEL. Finally this paper reveals the regression relationship between the carbon footprint and the per capita GDP in Hunan Province. Table 4 gives detailed information.

**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 |

From Table 4, we know goodness of fit is good, and it is greater than 0.85 in the regression model between the carbon footprint and the per capita GDP about 14 cities in Hunan Province. P-value is less than 0.05, and it shows the significance test of regression equation is good. That means the linear relation between carbon footprint and per capita GDP is obvious, and the related coefficients are all greater than 0. All these indicate that the positive correlation of carbon footprint and per capita GDP about 14 cities in Hunan Province is obvious, and that is to say the amount of carbon emission of cities in Hunan Province will increase with the growth of per capita GDP. The faster the economy develops, the higher the energy is consumed, the greater amount the carbon is emitted.

#### 3.3.3 The Influence the Population Can Make on Carbon Footprint

Usually the population and the amount of carbon emission are positively correlated. Because the more population a region has, the more activities related to carbon emission the region has. But from the data showed in Table 3, the correlation between the two is not obvious. Shaoyang City, the most populous city, has relatively lower carbon footprint. This shows population can make influence on the amount of carbon emission, but it is not the main factor.

#### 3.3.4 The Influence the Industrial Structure Can Make on Carbon Footprint

From Table 2, we know, in the last five years, 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 industrialstructure is oriented towards the industries of steel, coal and cement. The production run of steel, coal and cement is over millions of tons. These industries have the characteristics of high consumption and high amount of carbon emission. Relatively speaking, the industrial structure of Changsha City and Zhangjiajie City, which have lower unit of GDP, is quite different from that of Loudi City. While Zhangjiajie City mainly develops the competitive industries, such as tourism and tea, which are low-carbon industries, Changsha City mainly develops the industries of culture, new materials and mechanical engineering, which have lower energy consumption. Through comparative analysis, we find that industrial structure can make obvious influence on carbon footprint.

#### 3.3.5 The Influence the Energy Structure Can Make on Carbon Footprint

Energy structure is also the important factor to influence carbon footprint. From the present state of energy consumption in our province, the consumption of coal and petroleum takes a large proportion in the energy consumption of cities, and it accounts for 20% of the total amount of the province. Coal and petroleum belong to normal energy which is high pollution and high emission. While the consumption of clean energy as hydropower and wind energy takes a low proportion. All these are some of important factors to cause rapid development of carbon footprint in Hunan Province.

## 4. THE EFFECTIVE WAY TO PROMOTE LOW-CARBON DEVELOPMENT IN HUNAN PROVINCE

### 4.1 To Optimize the Industrial Structure and to Establish the Mechanism of Low-carbon Development

In the energy consumption of Hunan Province, energy consumption of industry has held a dominant position. Therefore, in order to promote lower-carbon development in Hunan Province, we should start with the reduction of energy consumption of industry, optimize the industrial structure and make innovation in development, seizing the chance of developing new industrialization in the province. We also should change the intensive form of economy development; develop economy depending on technology improvements, firmly control the development of industries which have high energy consumption,

high pollution and low value-added industries. We have to do some relative researches on laws of developing low-carbon economy and ensure the establishment of long-term mechanism of Low-carbon development. Meanwhile, according to the needs to the construction of the Two-oriented Society and the work of saving energy and reducing pollutants discharge, with the perfection of 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 industries of steel, cement**,** paper making, flat glass etc.,the work of eliminating industries having low production capacity. The government also should reduce the industries of high energy consumption and high pollution and promote the development of industries which have high tech, saving resources, and friendly environment.

### 4.1 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 waste of energy, enhancing the production of secondary energy, and cutting down the emission of energy. In the meantime, the structure of energy consumption in our province should be optimized because of the energy structure cantered on coal industry, which was determined by poor resources of coal, natural gas, and petroleum in Hunan Province. In order to promote the low-carbon development of Hunan Province, on the one hand, we should develop regenerative energy, such as wind power, waterpower, solar energy etc., and raise the proportion of new 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 disposable energy, something like coal and petroleum, should be effectively reduced (Wang & Zhu, 2008).

### 4.3 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 sidedly 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 as nonferrous metals and metallurgy and the recycling use of resources, and try to establish low-carbon lifestyle and build a low-carbon environment. We must introduce the ideas of saving energy and reducing pollutants discharge into our daily life, advocate saving energy nationwide, and exploit the potentials of saving energy in buildings, in countryside, in the industries of commerce, and in civilian industries. For the purpose of reducing carbon emission in our daily life, we should encourage to use clean energy things like wind power and solar energy, and use materials and electric appliances of saving energy.

### 4.4 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 set up 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 having independent innovation ability, and make systematic researches on the fields of low-carbon energy, technology, policies and strategies, and the development of regenerative energy and alternative energy, by fully pooling excellent 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, build the network for sharing the fruits of low-carbon researches, improve efficiency in transformation of research fruits, and increasingly develop low-carbon technology and low-carbon products.

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