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To cite this article: Fang Xinyi and Ji Junping 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **310** 032028

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Research on public institutions carbon quota allocation scheme in Shenzhen

Fang Xinyi¹ and Ji Junping²

¹School of Environment and Energy, Peking University, Shenzhen, Guangdong, 518055, China

²Lawrence Berkeley National Laboratory, Shenzhen, Guangdong, 518055, China

Abstract. The problem of high energy consumption in public institutions has become increasingly prominent, and China has not implemented carbon trading mechanisms in the public institutions at present. This paper firstly analyzes the energy consumption of public institutions in Shenzhen, and then formulates the carbon quota allocation scheme for public institutions in Shenzhen. The historical method and baseline method are used to allocate carbon quotas to public institutions in Shenzhen, and the energy consumption data calculated by the two methods are compared with real energy consumption data. The results show that there are large differences among public institutions, it is difficult to find a suitable baseline, and the historical method is more suitable for the initial allocation of carbon emission quotas. Finally, the effectiveness of the carbon quota allocation scheme is evaluated, hoping to provide a reference for the establishment of a carbon emission trading system for public institutions in Shenzhen.

1. Introduction

The construction industry is the second largest carbon emission producer after industry in China[1]. The energy consumption of buildings in China is equivalent to the sum of that in the Middle East, twice that of Africa, or the sum of that in Japan and South Korea[2]. Public buildings are the main source of the growth of building carbon emissions, and the problem of high energy consumption in public buildings is increasingly prominent, becoming one of the key areas of energy conservation and emission reduction in China.

Market driven carbon trading mechanism of the construction industry was first put forward in 2011, it was not until 2014 that the five carbon trading pilot except hubei and chongqing in China expanded carbon trading department to buildings, such as office buildings, hotels, restaurants, but there was no real implementation of the construction carbon trading mechanism[3]. The reasons for the absence of carbon trading in the construction industry are as follows: compared with other industries, the small reduction in carbon emissions of a single building leads to relatively high transaction costs[4], and the individual ownership units in the construction industry is decentralized[5].

There are many scholars researching in carbon trading system in the construction field. Song et al. explored the optimal strategy of China building owners to study the cause of that the carbon trading does not include construction industry, the research showed that the government's probability, violations of environmental review and reputation loss of the owner would make the building owner to comply with the carbon trading[6]. Chen et al. found that the construction industry consumes one quarter of the energy in China, and analyzed the sustainable carbon trading mode for buildings in China[7]. Zhang et al. established the carbon emission trading system for public buildings, based on



the analysis of the carbon emission of public buildings in China[8]. Ren et al. compared the implementation of construction carbon trading at home and abroad, and put forward Suggestions on the carbon trading framework in China's construction sector from the perspective of the total carbon emission, carbon quota allocation method and implementation path [9].

Carbon quota is a hot topic in the research. Xuan analyzed the international experience in the practice of carbon emission quota allocation, and its enlightenment for carrying out the carbon emission quota allocation in the domestic carbon trading pilot[10]. Through the comparative analysis of the six carbon market quota allocation methods, Li found that the carbon market quota allocation methods had some common characteristics, but each had its own characteristics[11]. Xiong compared China's carbon trading pilot with the carbon quota allocation mechanism of the EU and California, analyzed the unique mechanism characteristics and the existing problems of each pilot system in China[12].

Both the Tokyo cap-and-trade system and the tianjin civil building energy efficiency trading provide precedents and experience for building carbon trading. In China, Beijing, Shanghai and Shenzhen also mention public buildings in the scope of carbon emission control. Shenzhen public institutions has taken the lead in implementing the batch contract energy management mechanism, and the public buildings completed the contract energy management, which lay a good foundation for low carbon and energy saving work. If Shenzhen can take the lead in the field of public institutions carbon trading, Shenzhen energy conservation and emissions reduction work of public agencies is expected to be promoted.

At present, there are few researches on the public institutions carbon emission trading in Shenzhen, and there are very few researches on the calculation and analysis of the carbon quota allocation scheme using empirical data. The public institutions carbon emission trading in Shenzhen is of great significance for the energy conservation and emission reduction in Shenzhen and even the whole country. Based on the preliminary research data, this paper uses the historical method and the baseline method to allocate the carbon quota of public institutions in Shenzhen, so as to formulate the carbon quota allocation scheme for public institutions in Shenzhen.

2. Analysis of public institutions energy consumption in shenzhen

According to *the China building energy consumption research report (2018)*, China's building energy consumption in 2016 reached 899 million tons of standard coal, accounting for 20.62% of the total national energy consumption, among which the energy consumption of public buildings reached 346 million tons of standard coal, accounting for 38.53% of the total building energy consumption. In 2015, there were about 1.76 million public institutions nationwide in China, and the total energy consumption was 183 million tons of standard coal, accounting for 4.26% of the total energy consumption. There were about 42,000 public institutions in Guangdong province, and the total energy consumption was 2.09 million tons of standard coal.

This paper obtained the survey data of 2013-2015 energy consumption of public institutions in Shenzhen from an energy saving technology company in Shenzhen. According to the statistical analysis of the data, there are 1,803 public institutions in Shenzhen with a total area of 22.85 million square meters and a total carbon emission of 1.28 million tons, and 461 public institutions' building area are more than 10,000 square meters. According to data characteristics and the classification of public institutions industry codes in China, public institutions with a construction area of more than 10,000 square meters are divided into four categories: schools (246), hospitals (50), other public institutions (49) and state organs (116).

According to *the Specification with Guideline for Quantification and Reporting of Building Greenhouse Gas Emission(trial)*, the greenhouse gas emissions are be calculated by using the emission factor method, which is calculated according to the following formula:

$$C = \sum_{i=1}^n (D_i \times F_i) \quad (1)$$

Where C represents the greenhouse gas emissions of buildings in tons of carbon dioxide, D_i represents the activity data of emission sources category i, that is, the actual energy consumption of

category i in international units, and F_i represents the carbon dioxide emission factor of energy category i .

According to the statistical analysis of the data, the construction area of public institutions in Shenzhen ranges from 73 to 1,068,700 square meters, and there are 461 public institutions with a construction area of more than 10,000 square meters, with total construction area of 2,018 million square meters and total carbon emission of 1.08 million tons. Among them, 191 buildings have a carbon emission of more than 1,000 tons of CO₂, 114 buildings have a carbon emission of more than 2,000 tons of CO₂.

According to the survey data, the state organs of Shenzhen emitted 537,900 tons of CO₂ in 2015, accounting for 49.67%. The university emitted 242,900 tons of CO₂, accounting for 22.43%. The hospital emitted 238,400 tons of CO₂, accounting for 22.01%. Other public institutions emitted 63,800 tons of CO₂, accounting for 5.89%.

According to the classification statistical analysis of schools, hospitals, other public institutions and state organs, in terms of land use and employment, the average building area of state organs is the largest, reaches 62,235 square meters. The average number of energy users in the hospital is the highest, reaches 6,036. In terms of vehicles, the average number of state organs' vehicles is the largest, which is 91. In terms of carbon emission, the average carbon emission of hospitals and state organs is the largest, reaches about 4,700 tons, while the average carbon emission of schools is the smallest with less than 1,000 tons.

According to regression analysis of energy consumption influencing factor, the indicators that have a significant effect on energy consumption under the significance level of 1% are: whether is school, whether is hospitals, whether is other institutions, land area, construction area, number of energy users. The significant influence to carbon emissions of building area is more significant than that of number of energy users, the vehicle has no effect on energy consumption.

3. Public institutions Carbon quota allocation scheme in Shenzhen

Free allocation, auction allocation and mixed allocation are the main carbon quota allocation methods. Although the transaction cost of the free distribution method is very low and is easily accepted by the public, in terms of the distribution effect, the public is not compensated accordingly, and the owner of the emission enterprise occupies all the scarcity value. Comparatively, the auction method is more in line with the coase theorem, which can reduce the cost of social regulation and improve the economic efficiency to the greatest extent, but the emission enterprises included in the carbon trading system have a poor acceptance of compensable distribution. As China's carbon quota trading system is still in the primary exploration stage, it is necessary to adopt the free allocation method with auction and fixed price sales as the supplement for carbon quota allocation. In terms of carbon quota allocation methods, the historical method and the energy consumption baseline method are considered to explore appropriate quota allocation schemes.

3.1. Public institutions carbon quota allocation method in Shenzhen

According to the historical method, the formula for public institutions carbon quota allocation is:

$$C_i = CH_i * (1 - \alpha) \quad (2)$$

Where C_i is the carbon quota amount obtained of public institution i , CH_i is the historical average carbon emission of public institution i , and α is the emission reduction coefficient.

Historical method may lead to the unfair allocation of quotas. Enterprises with good energy conservation and emission reduction effects will get fewer quotas due to their low historical carbon emissions. On the contrary, enterprises with poor energy conservation effects will get higher quotas, and the authenticity of historical data of enterprises will be difficult to be guaranteed. In addition, the historical method does not take the industry gap into account. For these reasons, the baseline approach based on industry emissions is relatively more equitable.

Considering that building area has a more significant impact on carbon emissions than the number of energy users. Therefore, in the initial stage of carbon trading, carbon emissions per unit building

area of each category should be selected as the baseline. According to the baseline method, the formula for public institutions carbon quota allocation is:

$$C_i = E_i * A_i * (1 - \alpha) \quad (3)$$

Where C_i represents the carbon quota amount obtained by public institution i , E_i represents the baseline of the category of public institution i , A_i represents the building area of public institution i , and α represents the emission reduction coefficient.

3.2. Calculation of public institutions carbon quota allocation in Shenzhen

According to the public institutions energy consumption data in Shenzhen from 2013 to 2014, the public institutions carbon quota allocation in 2015 was conducted by using the historical method and the baseline method respectively, and then the calculation was compared with the actual public institutions energy consumption data in 2015. The difference was calculated to evaluate the advantages and disadvantages of the two schemes.

3.2.1. Public institutions carbon quota allocation historical method. After screening and analysis, there were 58 valid data of public institutions from 2013 to 2015. According to the annual energy consumption data and the carbon emission calculation method mentioned above, the carbon emissions of each public institution in 2013 and 2014 were calculated respectively, and then the average carbon emissions of each public institution in these two years were taken to obtain the carbon quota allocation value of public institutions in 2015. Then, the difference between the quota allocation value of public institutions in 2015 and the actual carbon emissions of public institutions was made for data comparison.

In 2015, the total difference between the quota allocation value and the actual carbon emissions of public institutions is -75,400 tons of CO₂, which means that in addition to the quota obtained, there is a carbon emission gap of 75,400 tons that needs to be acquired in the carbon trading market, accounting for 6% of the public total institutions actual carbon emissions in Shenzhen in 2015. In 2015, the absolute sum of the difference between the quota allocation value of public institutions and the actual carbon emissions is 230,000 tons of CO₂, accounting for 18% of the public institutions total actual carbon emissions in Shenzhen in 2015.

3.2.2. Public institutions carbon quota allocation baseline method. The operating characteristics of different types of public institutions vary greatly, so the public institutions are classified first when determining the baseline. In the preliminary study, public buildings in Shenzhen were divided into five categories: public institutions, schools, hospitals, other public institutions and municipal districts.

There are three methods to determine industry baseline: based on statistical data, using parameter calculation, combining statistical data with parameter calculation. In view of the diversity of buildings and the availability of data, this paper selects the method based on statistical data in determining the industry baseline. Effective data of 58 public institutions were classified by 27 public institutions, 9 schools, 2 hospitals, 10 other public institutions and 10 municipal districts. According to the analysis of energy consumption data above, building land is the most important factor affecting the carbon emission of public institutions. Therefore, the total carbon emissions of each building type are divided by the total area to obtain the carbon emissions per unit area of each type, which is taken as the baseline of each type. The energy consumption baseline of public institutions, schools, hospitals, other public institutions and municipal districts is 90, 48, 120, 127 and 50 kgCO₂/m³ respectively.

The building area of public institutions in 2015 was multiplied by the energy consumption baseline to obtain the carbon emission data of public institutions. The difference between the quota allocation value of public institutions and the actual carbon emissions in 2015 was compared. In 2015, the sum of the difference between the quota allocation value of public institutions and the actual carbon emissions is -227,500 tons of CO₂, accounting for 18% of the public institutions total actual carbon emissions in Shenzhen in 2015. The absolute sum of the difference between the public institutions

quota allocation value and the actual carbon emissions is 309,600 tons of CO₂, accounting for 24% of the total actual carbon emissions of public institutions in Shenzhen in 2015.

According to the calculation above, the use of public institution carbon quota historical method for carbon quota allocation is closer to the public institution actual carbon emissions, which can make the carbon quota allocation more accurate. Further analysis shows that the characteristics of each public institution under the public institution type and other public institution type in the baseline method are different, and there are significant differences in energy consumption and carbon emission per unit area. For example, in the type of public institution, the carbon emission per unit area of Shenzhen meteorological bureau is up to 367 kgCO₂/m³ due to high power consumption, while the carbon emission per unit area of Shenzhen justice bureau is only 43.6 kgCO₂/m³, the difference is more than eight times. Among the other institutions, the carbon emission per unit area of the Shenzhen national supercomputing center is 710 kgCO₂/m³, while the carbon emission per unit area of the Shenzhen justice bureau is only 5.5 kgCO₂/m³, and the difference is even 130 times. Therefore, even under the same category, the characteristics of public institutions are still quite different. It is difficult to find a suitable baseline, and the baseline method is not operable. Therefore, in the early stage of public institutions carbon trading, the historical method should be used for carbon quota allocation.

3.3. Public institutions carbon quota allocation scheme in Shenzhen

Shenzhen is still in the primary stage of carbon emission trading, so it should give priority to free distribution and add paid distribution such as auction when needed, so as to promote the development of carbon emission trading. Based on the calculation and analysis of the historical method and baseline method above, it can be seen that the characteristics of public institutions are quite different, it is difficult to find a suitable baseline. The baseline method is not operable, so the historical method should be used for the initial allocation of carbon emission quota.

Setting appropriate emission reduction targets is crucial to facilitate the implementation of carbon emission trading. The total carbon emission control target of public institutions in Shenzhen should be set according to the existing targets of China and Shenzhen, such as China's commitment to the United Nations Framework Convention on Climate Change, the requirements of the 13th five-year plan to control greenhouse gas emissions, and Shenzhen's commitment to reach the peak target.

The allocation of carbon quota of new public institutions in Shenzhen can be based on the public institutions with similar functions, and the free allocation method can be selected. The quota amount that should be allocated is:

$$C_i = C_j * \beta \quad (4)$$

$$\beta = \frac{A_i}{A_j} \quad (5)$$

Where, C_j represents the quota amount obtained by public institution j of the same type as new public institution i, β represents the adjustment coefficient, A_i represents the area of new public institution i, and A_j represents the area of public institution j of the same type.

4. Evaluation of public institutions carbon quota allocation scheme in Shenzhen

We evaluate the environmental effectiveness of the public institutions carbon quota allocation scheme in Shenzhen, we mainly consider the incentive degree of the policy for emission reduction. According to the average carbon price of carbon emission trading in Shenzhen, the carbon price fluctuates around 35 yuan/ton. According to the 2015 energy consumption data of public institutions in Shenzhen collected by this program, the average building area of each public institution is 12,700 square meters, and the annual carbon emission is 711 tons. If the purchase is completely compensable, the annual carbon quota will cost about 24,885 yuan. If the price of carbon rises in the future, the annual cost of carbon quota will rise. The survey shows that this figure can effectively motivate public institutions to take the initiative to reduce emissions, so this plan has an obvious incentive to reduce emissions.

5. conclusion

Carbon trading is an important means to control carbon trading effectively. Public institutions have large energy consumption, high emissions and great potential for emission reduction. This paper uses historical method and baseline method to calculate and compare the energy consumption data obtained, selects appropriate quota allocation scheme, and evaluates the environmental effectiveness of this system. The public institutions carbon quota allocation scheme in Shenzhen established in this paper is effective in environment and provides a reference for the establishment of public institutions carbon emission trading system in Shenzhen.

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