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RESEARCH ARTICLE

Alternative industrial carbon emissions benchmark based on input-output analysis

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Abstract Some problems exist in the current carbon emissions benchmark setting systems. The primary consideration for industrial carbon emissions standards highly relate to direct carbon emissions (power-related emissions) and only a portion of indirect emissions are considered in the current carbon emissions accounting processes. This practice is insufficient and may cause double counting to some extent due to mixed emission sources. To better integrate and quantify direct and indirect carbon emissions, an embodied industrial carbon emissions benchmark setting method is proposed to guide the establishment of carbon emissions benchmarks based on input-output analysis. This method attempts to link direct carbon emissions with inter-industrial economic exchanges and systematically quantifies carbon emissions embodied in total product delivery chains. The purpose of this study is to design a practical new set of embodied intensity-based benchmarks for both direct and indirect carbon emissions. Beijing, at the first level of carbon emissions trading pilot schemes in China, plays a significant role in the establishment of these schemes and is chosen as an example in this study. The newly proposed method tends to relate emissions directly to each responsibility in a practical way through the measurement of complex production and supply chains and reduce carbon emissions from their original sources. This method is expected to be developed under uncertain internal and external contexts and is further expected to be generalized to guide the establishment of industrial benchmarks for carbon emissions trading schemes in China and other countries.

Keywords emissions trading scheme, benchmarking, carbon emissions, input-output analysis

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1 Introduction

Climate change is commonly considered as a global challenge and regarded as the threat to long-term human and ecosystem development. As a result, different emissions trading schemes (ETS), in terms of the European Union Emissions Trading System (EU ETS), the Regional Greenhouse Gas Initiative (United States), New Zealand Emissions Trading Scheme, Tokyo Metropolitan Trading Scheme, and the New South Wales Greenhouse Gas Abatement Scheme (Australia) flourished in these developed countries, in particular in the European Union (Perdan and Azapagic, 2011). However, emerging superpowers such as China and India were not constrained by the Kyoto Protocol that was adopted in 1997. As India is responsible for more than 5% of global emissions and China has become the largest emitter in the world (Anandarajah and Gambhir, 2014), the primary goal of "post-Kyoto" is to urge developing countries to bear certain responsibilities for carbon emissions reduction.

To fulfill obligations, China established a target to reduce the carbon intensity by 17% in 2015 on the basis of the emission level in 2010 in the 12th Five-Year Plan (National Development and Reform Commission of People's Republic of China, 2011), while India proposed a reduction in its emissions per unit of economic output by 20%–25% by 2020 compared to the 2005 level as a part of the Copenhagen Accord (Chandran Govindaraju and Tang, 2013; UNFCC, 2015). To achieve these targets, India established the first ETS in developing countries, which is of great significance to the establishment of ETS in the other developing countries, particularly in China.

As for emissions trading schemes, free allowances are usually distributed in the early phase of a cap-and-trade scheme to reduce adverse effects on enterprise profitability (Massetti and Tavoni, 2010). Thus, determining how to scientifically and reasonably distribute allowances among participants in emissions trading schemes is one of the bottlenecks for successful introduction of ETS. Grandfathering and benchmarking are both common allocation methods for free quotas (ICAP, 2007). With the grandfathering method, the emission allowances are distributed according to enterprises' historical emissions in a base year or over a specific period of time. However, this practice tends to reward emitters with historically high levels and requires further provisions for new entrants. The benchmarking method allocates allowances according to the industrial performance indicators. Thus it tends to reward efficient participants, meanwhile assimilating new entrants easily. However, to set comprehensive and reasonable benchmarks, reliable original data and clear allocation formulae for sectors or installations are required.

As stated previously, China has been challenged as the largest carbon emitter in the world, and the reduction effect of its carbon emissions trading schemes has drawn global concern (Ji and Long, 2016). Seven provinces and cities, namely Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen, were selected to establish pilot carbon emissions trading schemes during China's 12th Five-Year Plan (National Development and Reform Commission of People's Republic of China, 2011), with an additional national trading scheme expected to be established in 2016. Shenzhen was the first city in China to apply the benchmarking method. The benchmarking method was also adopted in Beijing and Tianjin for new equipment and in Guangzhou (Guangzhou Municipal Development Reform Commission, 2013) and Shenzhen (Shenzhen Municipal People's Congress Standing Committee, 2012) for power, cement, and steel industries, as well as aviation, airport and port enterprises.

To date, the emissions trading scheme has been one of the two most cost-effective mechanisms for controlling carbon emissions (Cui et al., 2014). Several studies have provided insight in emissions trading schemes to reduce carbon emissions more effectively, most specifically for developing countries (Zhang et al., 2013b, 2014b; Cui et al., 2014). In addition, the economic performances of these schemes and the baselines of industrial carbon emissions were analyzed in several studies (Zhou et al., 2013). These studies contributed significantly to the analyses of carbon emissions reduction and ETS establishment. However, a systematic and comprehensive carbon emissions benchmark setting method, particularly for covering both direct and indirect carbon emissions, is still lacking in the current context.

As the pioneer city of China, Beijing was chosen as the case in this study. Given the task of heavy emissions reduction, Beijing requires a set of reasonable carbon emissions benchmarks and an active carbon emissions trading scheme to achieve energy saving and emission reducing targets (Ji and Chen, 2016). Moreover, Beijing, Tianjin, and Hebei are expected to take the lead in establishing China's national carbon emissions trading scheme, emphasizing the core status of Beijing's carbon emissions trading market (China Carbon Emissions Trading Network, 2015). Several studies have provided insight into carbon emissions at an urban scale specific to Beijing, with different methods employed to conduct intensive analyses (Feng et al., 2013; Han et al., 2014a; Ji et al., 2014). The widely applied input-output analysis (IOA) method has been conducted to comprehensively quantify and analyze environmental issues at different scales (Peters and Hertwich, 2008; Chen et al., 2013; Chen and Han, 2015a, b) and can be applied in the establishment of benchmark setting systems. A set of industrial carbon emissions standards was recently established to guide the development of Beijing's ETS (Beijing Environment Exchange in China, 2008), which mainly focuses on on-site direct emissions, with some consideration to indirect emissions. Given the tertiary industry has already occupied a fundamental position in the Beijing economy over time, its carbon emissions, mainly accompanied by indirect emissions, require special attention (Chen and Chen, 2012).

The purpose of this study is to propose an embodied industrial carbon emissions benchmark setting method based on IOA taking Beijing as the case. This study is also intent on conducting analyses on Beijing's carbon emission benchmarks and facilitating further discussions on the establishment of industrial emission benchmarks in China and other countries. The remainder of the paper is structured as follows: Section 2 articulates the issues existing in the current benchmark setting systems, Section 3 puts forward the method applied in this study, Section 4 takes Beijing as a case to stimulate further discussions, ending with concluding remarks in the last section.

2 Background

A set of industrial emission standards has been established to guide the development of Beijing's ETS. Both direct carbon and some major indirect carbon emissions reflected in the form of electricity consumption are considered, while emissions generated by complex industrial production and supply chains are ignored. Even though major energy consumption caused by key inputs can be traced, some problems still exist (Lenzen, 2000, 2008). Detailed issues hidden in the current benchmark setting systems are presented below.

2.1 Issues related to electricity and heat consumption

As opposed to fuel combustion, both electricity and heat consumption lead to indirect carbon emissions, increasing carbon emissions at the power sites (Feijoo and Das, 2014; Han et al., 2014c). Thus an accounting method is applied for indirect electricity related emissions, as:

$$E_d = D \times f_g,$$

where E_d represents the carbon emissions related to electricity consumption, D represents the electricity consumed by enterprises, and f_g represents the indirect emission factor of power consumption. The factor f_g will be published every year, varying in different years.

Some electricity-related emissions are traced in the current accounting method; however, emissions originating from direct energy consumption, such as those in coal-fired power plants, are quantified twice while some intermediate input related emissions are ignored (Lenzen, 2008).

It is more complicated to quantify emissions from heat supply sources. Heat supply of the local residents of China is unitarily controlled by thermal councils and priced based on floor areas. Amounts of emissions are calculated by heat supply agencies instead of final users. If only commercial heat supply is taken into consideration, its indirect emissions are always accompanied by electricity consumption, raising amounts of emissions emitted at the power sites (Beijing Environment Exchange in China, 2008). Due to various reasons, the heat-related emissions have not been included in the current accounting scope.

2.2 Issues related to other sectors

The same problem remains in the other sectors. In fact, all of the commodities consumed at urban economies lead to carbon emissions during their production processes. However, only direct emitting processes, such as fuel combustion, are covered in the current accounting scope (Lin and Sun, 2010). For example, construction engineering processes are conducted based on various materials inputs. In this case, some carbon emissions will be emitted in the production processes of intermediate materials such as steel, cement, and concrete.

During the last couple of decades, local factors are no longer the most significant determinants (Guan et al., 2008; Weber et al., 2008). Through re-matching supply and demand by expanding production and supply chains, indirect impacts associated with trade flows have been increasingly significant (Chen and Yang, 2013). In this case, systematic accounting and analyses, including impacts originating from production layers, are required, thus avoiding truncation errors and laying a solid foundation for carbon emissions assessment (Lenzen et al., 2003b).

2.3 Systems accounting method vs. standard accounting method

Taking Beijing as an example, the set of established standards is divided into three parts of carbon emissions: 1) existing facilities, namely those generated by corporate facilities before 2013; 2) new facilities, which only have a partial accounting formula; and 3) quota adjustments for enterprises, which can be adjusted according to the enterprise application. For the existing facilities, the discharge coefficient will slowly decrease every year, and enterprises will have annual reduction responsibilities for carbon emissions. Emission quotas for new facilities are closely related to the advanced degrees of facilities, which always take the average emission intensities derived from the top 10% of enterprises as the upper limits and from the bottom 20% as the lower limits.

From the view of systems theory, fragmented information cannot be effectively applied to evaluate a whole situation, particularly with a mix of sources. In this context, adopting the external emissions as exogenous to the economy and integrating the environmental emissions with complex production and supply chains can systematically solve the problem. At present, IOA, well-established to quantify resources and emissions through inter-industrial connections, has been applied to account for carbon emissions from an academic aspect at different scales (Guan et al., 2008; Peters and Hertwich, 2008; Chen and Chen, 2010; Zhang et al., 2014a). In addition, multi-scale and multi-regional input-output analyses have drawn due attention in analyzing embodiments of resource uses and environmental emissions in economic activities with interactions and linkages among regions and sectors (Zhang et al., 2013a, 2016). Embodiments of energy consumption and carbon emissions were fully analyzed at the urban scale and discussed by different researchers (Chen et al., 2013, 2014; Chen and Chen, 2015). With regard to small-scale engineering projects, the embodiments of energy consumption and carbon emissions of ecological engineering and renewable energy projects were fully analyzed (Chen et al., 2011; Han et al., 2013, 2014b; Shao et al., 2014). Due to the rapid development of IOA in academics, it is necessary for the current carbon emissions benchmark setting systems to be generalized.

3 Method and data sources

In this study, a systematic accounting framework is presented for embodied intensity-based industrial carbon emissions benchmarks based on the corresponding direct industrial carbon emissions and IOA.

3.1 Input-output analysis

Developed and refined by Leontief (1986), IOA played an important role in describing the relationship between final demand and total outputs from the up-down perspective. Stimulated by the oil crisis (Costanza, 1980) and derived from the concept of embodiment put forward by Odum (1983), IOA was further developed in the 1970s (Hannon et al., 1983; Davis and Caldeira, 2010). This method presented a swift extension to ecological and environmental accounting and was quickly developed to investigate various ecological resources and environmental emissions on various economic scales (Peters and Hertwich, 2008; Davis and Caldeira, 2010; Zhang and Chen, 2010).

Detailed emission flows for a typical sector at an urban economy are described in Fig. 1, in which, $\varepsilon_i x_i$ represents the emission flow embodied in outputs, $\sum_{i=1}^{n} \varepsilon_j z_{j,i}$ represents the emission flow embodied in intermediate inputs, and m_i represents the direct emission flow.

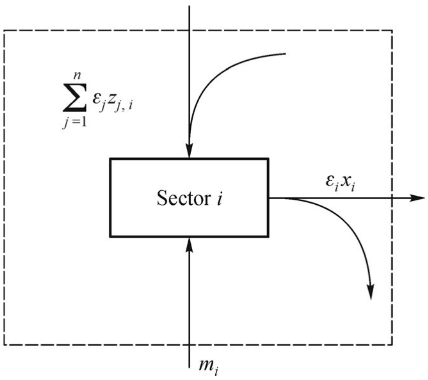

Fig. 1 Emission flows for a typical sector at an urban economy.

Based on the physical balance, the formulae of carbon emissions and monetary flows of the economy with n sectors are presented as follows:

$$m_i + \sum_{j=1}^{n} \varepsilon_j z_{j,i} = \varepsilon_i x_i,$$

$$x_i = \sum_{j=1}^{n} z_{i,j} + f_i.$$

In the formulae, m_i represents the direct emission of Sector i, ε_j represents the embodied intensity of Sector j, $z_{j,i}$ represents the intermediate output from Sector j to Sector i, x_i represents the output of Sector i, and f_i represents the final use of Sector i.

Subsequently, the matrices form can be expressed as follows:

$$\boldsymbol{M} + \boldsymbol{E}\boldsymbol{Z} = \boldsymbol{E}\hat{\boldsymbol{X}}, \ \hat{\boldsymbol{X}} = \boldsymbol{Z} + \hat{\boldsymbol{F}},$$

in formulae, $\boldsymbol{M} = [m_i]_{1\times n}$, $\boldsymbol{E} = [\varepsilon_i]_{1\times n}$, $\boldsymbol{Z} = [z_{i,j}]_{n\times n}$, diagonal matrix $\hat{\boldsymbol{X}} = [x_{i,j}]_{n\times n}$, where $i,j \in (1,2,...,n)$, $x_{i,j} = x_i \ (i = j)$ and $x_{i,j} = 0 \ (i \neq j)$, and $\hat{\boldsymbol{F}} = [f_{i,j}]_{n\times n}$, where $i,j \in (1,2,...,n)$, $f_{i,j} = f_i \ (i = j)$ and $f_{i,j} = 0 \ (i \neq j)$.

With the given direct emissions matrix $\boldsymbol{M}$, intermediate inputs matrix $\boldsymbol{Z}$, and total outputs matrix $\hat{\boldsymbol{X}}$, the embodied intensity matrix can be obtained as follows:

$$\boldsymbol{E} = \boldsymbol{M}(\hat{\boldsymbol{X}} - \boldsymbol{Z})^{-1}.$$

Based on IOA, the intensity $\boldsymbol{E}$ complexly consists of carbon emissions emitted directly and indirectly during the production processes. When expanded to a multi-scale analysis, the carbon emissions in a small-scale economy can be quantified and analyzed linked with the impacts from large scales based on related databases.

3.2 Data sources

By applying IOA, this study attempts to set reasonable carbon emission benchmarks for industries by accounting embodied carbon emission intensities. As the dominant part, an economic input-output table is adopted to reflect the systematic structure and industrial interactions of an economy (BSY, 2014). The input-output table is obtained from the Beijing Bureau of Statistics with 42 sectors (Table 1) at current prices. Relevant energy consumption data of various sectors are derived from the Beijing Statistical Yearbook (BSY, 2014), and the direct carbon emissions inventory is compiled according to the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2006).

The intensity obtained by IOA is principally applied for all the economic flows and represents the emissions emitted directly and indirectly in the production processes to meet one monetary output of a sector. It is assumed that the embodied intensities are equal for all commodities from the same industrial sector. As only CO_2 emissions are covered in the current industrial emissions standards, a set of embodied industrial CO_2 emissions benchmarks of Beijing is presented in this study.

4 Results and discussion

4.1 Direct and indirect carbon emissions in Beijing

Beijing is the capital and economic center of China, with an area of 1.64 million hectares and a population of 20 million. In the context of rapid economic growth, Beijing's energy consumption increased from 19.08 million to 71.78 million tons of standard coal equivalent between 1980 and 2012 with an average annual growth of 8.63%. The energy supply of the municipality heavily relies on other provinces, i.e., 65% of electricity, 97% of coal, and all natural gas (Chen et al., 2013). As a secondary energy carrier mainly imported from other domestic provinces, electricity consumption in Beijing increased from 2.78E + 04 million kWh in 1997 to 9.12E + 04 million kWh in 2012 (BSY, 2000, 2014). With a growing electricity share, indirect carbon emissions embodied in electricity consumption is increasing. In addition, Beijing is the fourth largest importer and exporter in China (CSY, 2014). As a net-imported city, Beijing's amount of exported commodities (mainly high-tech products) has increased since 1980 with an average annual growth of 46.79%. Meanwhile, its imports (mainly cars and resources), with an annual rate of 72.07% (BSY, 2014), are much larger than its exports which may result in an increase in indirect carbon emissions in other regions.

Beijing was the first level city in China to adopt a carbon emissions trading pilot scheme, officially approved on November 28, 2013. Until September 25, 2015, the total trading volume of carbon emissions in Beijing's emissions trading platform was 5.30 million tons, with a total amount of 237.62 million CNY (Chinese Yuan) (Beijing Environment Exchange in China, 2008). All participants with CO_2 emissions larger than (inclusive of) 10,000 tons will be given free annual carbon emission quotas. Emissions in excess must be offset by purchasing credits from other participants or be subject to a penalty that is 3 to 5 times the average prices.

4.2 Industrial CO_2 emissions benchmark for Beijing

Based on IOA, the embodied industrial CO_2 emissions intensity inventory is quantified and presented in Table 1 and the standard industrial CO_2 emissions intensity inventory is presented in Table 2 for comparison.

The CO_2 emitted in Beijing is typically from two sources: fuel combustion and industrial processes such as *Manufacturing of Non-metal Mineral Products* and *Steel Smelting and Pressing*. At present, the local government continuously eliminates high-energy-consuming and emission-intensive industries. Thus, Beijing's carbon emissions are primarily indirect as opposed to direct. In this case, the newly proposed method can systematically integrate environmental emissions with complex industrial chains and reflect the industrial emission levels through product delivery processes.

The differences can be found in the comparisons between Table 1 and Table 2. Obviously, the industrial classification is different. The existing set of standards refers to Beijing's current industrial structure, and the other refers to the Industrial Classification Standards of China (GB/T 4754-2011). From a long-term perspective, Industrial Classification Standards of China can be better expanded to national levels. In addition, different units are adopted in both sets of benchmarks. The existing set uses physical units, while the other uses currency units to reflect the relationship between monetary value and carbon emissions. The dominant difference is coverage. The accounting procedure for one set covers the direct emissions and part of the indirect emissions that originate from power systems as opposed to the other set which covers emissions embodied in industrial production processes based on systems analysis method, leading to a large gap between the two sets of data. The intensity obtained by IOA principally represents the emissions emitted directly and indirectly during the production processes to meet one monetary output. In the embodied carbon emissions benchmark, the largest intensity is in the *Electricity and Heat Production and Supply Sector*, which means in the complex economic systems, per unit of outputs of this sector leads to the largest emissions. Thus to accelerate carbon emissions reduction, enterprises can autonomously choose lower-carbon emission upstream and decrease carbon emissions through industrial chains beyond terminal enterprises (Huang et al., 2009), as in the cases presented by Lenzen et al. (2003a) and Wiedmann et al. (2009).

However, problems still exist in this method. It may increase the burden to the final consumers, which would then be passed to previous emitters. However, from this perspective, this accounting method would enable participants to reduce emissions where it is most efficient and would also form a set of benchmarks reflecting emissions through inter-industrial chains. Moreover, the current matching systems are not sound enough to support this method. It is challenged by current regulatory design and still needs efforts to coordinate dynamic relations among clear carbon emissions measurement and complex industrial production and supply chains.

5 Concluding remarks

With the current context of globalization, new international responsibilities need to be undertaken, especially in the aspect of carbon emissions reduction. To standardize carbon emissions trading schemes and efficiently reduce carbon emissions under constraints, this paper proposes an embodied industrial carbon emissions benchmark setting method and takes Beijing as a case study to design a new set of intensity-based benchmarks for improvement of the carbon emissions trading scheme from a systematic view. The detailed accounting method tends to reduce emissions from the original sources and relates the emissions directly to total product delivery chains. Overall, this method may create a burden for the final consumers and require sound systems to match and support it. However, from a practical perspective, it not only refreshes the traditional theoretical model of a cap-and-trade scheme with new thoughts, but also contributes to carbon emission reduction by providing effective regulations and reasonable quantitative limits. From another point of view, this approach also enables participants to reduce emissions where it is most efficient and forms a set of benchmarks that reflects total emission embodiments through inter-industrial chains. Thus, this method is expected to be developed under the uncertain internal and external contexts and further expected to be generalized to guide the establishment of industrial carbon emissions benchmarks of trading schemes in China and other countries.

Table 1 Embodied CO_2 emissions intensities

No.	Sector content	Abbreviation	Embodied intensity /(kg $CO_2 \cdot 10E-4$ CNY)
1	Agriculture, Forestry, Animal Husbandry and Fishery	Agriculture	741.68
2	Coal Mining and Dressing	Coal Mining	1086.57
3	Petroleum and Natural Gas Extraction	Petroleum Extraction	204.91
4	Metal Mineral Mining and Dressing	Metal Mineral Mining	798.36
5	Non-metallic Mineral and Other Mineral Mining and Dressing	Non-metallic Mineral Mining	350.99
6	Food and Tobacco	Food	623.10
7	Textiles Products	Textiles	723.38
8	Wearing Apparel, Leather, Fur, Feather and Related Products	Wearing	559.32
9	Wood Processing Products	Wood Products	632.13
10	Paper Processing, Printing, Education and Sports Products Processing	Paper Processing	581.50
11	Petroleum, Coking and Nuclear Fuel Processing	Petroleum	341.40
12	Chemical Products	Chemicals	482.18
13	Non-metallic Mineral Processing	Non-metallic Mineral Processing	619.25
14	Metal Smelting and Pressing	Metal Smelting	796.94
15	Metal Products	Metal Products	731.37
16	General Equipment	General Equipment	595.64
17	Special Equipment	Special Equipment	594.54
18	Transport Equipment	Transport Equipment	530.62
19	Electrical Equipment and Machinery	Electrical Equipment	610.66
20	Telecommunication Equipment, Computers and Other Electronic Equipment	Electronic Equipment	587.87
21	Instruments and Meters	Instruments	532.30
22	Other Manufacturing Products	Other Products	625.60
23	Waste	Waste	263.95
24	Services for Metal Products, Machinery and Equipment Repair	Repair	487.31
25	Electricity and Heat Production and Supply	Electricity and Heat	2618.32
26	Gas Production and Supply	Gas	364.69
27	Water Production and Supply	Water	638.94
28	Construction	Construction	558.83
29	Wholesale and Retail	Wholesale and Retail	277.50
30	Transport, Storage and Post	Transport	1113.77
31	Hotels and Restaurants	Accommodation and Catering	510.16
32	Telecommunication, Software and Information Technology Services	Telecommunication	299.72
33	Finance	Finance	196.37
34	Real Estate	Real Estate	269.81
35	Rental and Business Services	Rental	282.64
36	Scientific Research and Technology Services	Research	406.27
37	Hydropower, Environment and Public Equipment Management	Public Management	477.61
38	Residential Services, Repair and Other Services	Other Services	393.88
39	Education	Education	303.22
40	Health and Social Work	Health	404.31
41	Culture, Sports and Recreation	Culture	393.75
42	Public Administration, Social Security and Social Organizations	Public Administration	381.64

Table 2 Standard industrial CO_2 emissions intensities

No.	Industry	Sub-class	Units	Advanced intensity
1	Beer		kg CO_2/ kL	162.56
2	Manufacture of Paper Products		kg CO_2/10E4 CNY	88.39
3	Manufacture of Beverages		kg CO_2/10E4 CNY	110.06
4	Manufacture of Non-Metallic Mineral Products	Non-Metallic Mineral Products	kg CO_2/10E4 CNY	46.97
		Non-Metallic Materials	kg CO_2/10E4 CNY	261.77
5	High Schools and Engineering Technology Research and Development	Science, Engineering and Comprehensive Type	kg CO_2/m^2	33.42
		Literary, Historical, Financial, Normal , Political and Legal Type	kg CO_2/m^2	33.32
		Vocational High Schools and Specialized Institutions	kg CO_2/m^2	24.38
		Engineering Technology	kg CO_2/m^2	46.94
6	Manufacture of Metal Products		kg CO_2/10E4 CNY	101.87
7	Manufacture of Parts and Accessories of Automobiles and Railroads		kg CO_2/10E4 CNY	10.22
8	Automobiles[a)]	Standard Sedan	kg CO_2/unit	410.91
		Sedan Limousine and SUVs	kg CO_2/unit	1094.02
		Medium and Heavy-duty Trucks	kg CO_2/unit	881.18
		Multi-functional Car	kg CO_2/unit	410.53
9	Retail Trade and Government Organizations	Government Organizations	kg CO_2/m^2	42.28
		Commodity Retail Trade	kg CO_2/m^2	79.24
		Supermarket Retail Trade	kg CO_2/m^2	60.70
10	Heat Power		kg CO_2/GJ	62.11
11	Finance		kg CO_2/m^2	52.60
12	Hotels and Restaurants	Hotels	kg CO_2/m^2	49.05
		Restaurants	kg CO_2/m^2	285.50
13	Electric Power	Heat Supply	kg CO_2/GJ	59.78
		Power Supply E-class $<=0.3$	kg CO_2/MWh	368.30
		Power Supply E-class >0.3	kg CO_2/MWh	341.15
		Power Supply F-class $<=0.3$	kg CO_2/MWh	345.49
		Power Supply F-class >0.3	kg CO_2/MWh	312.37
14	Other Services	Real Estate and Business Services	kg CO_2/m^2	29.13
		Culture and Sports	kg CO_2/m^2	57.88
15	Manufacture of Electrical Equipment, Machinery, Computers, Communication and Other Electronic Equipment	Manufacture of Optoelectronic Devices and Other Electronic Devices	kg CO_2/10E4 CNY	267.93
		Manufacture of Electronic Devices and Components	kg CO_2/10E4 CNY	319.20
		Other Electronic and Electrical Products	kg CO_2/10E4 CNY	182.49
16	Medical Institutes		kg CO_2/m^2	73.47
17	Information Transmission	Telecommunication	kg CO_2/10E4 CNY	137.93
		Other Enterprises	kg CO_2/m^2	55.46
18	Manufacture of Food		kg CO_2/10E4 CNY	73.35
19	Manufacture of Chinese Traditional Medicines		kg CO_2/10E4 CNY	131.95
20	Manufacture of Western Medicines		kg CO_2/10E4 CNY	109.22
21	Manufacture of Raw Chemical Materials and Chemical Products		kg CO_2/10E4 CNY	569.31
22	Processing of Farm and Sideline Products		kg CO_2/10E4 CNY	116.21
23	Property Management		kg CO_2/10E4 CNY	484.73

a) Exclude the production of engines. The advanced intensity of engine production accounts for 18.46% of the vehicle production.

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