

Embodied energy consumption and carbon emissions evaluation for urban industrial structure optimization

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Abstract Cities are the main material processors associated with industrialization. The development of urban production based on fossil fuels is the major contributor to the rise of greenhouse gas density, and to global warming. The concept of urban industrial structure optimization is considered to be a solution to urban sustainable development and global climate issues. Enforcing energy conservation and reducing carbon emissions are playing key roles in addressing these issues. As such, quantitative accounting and the evaluation of energy consumption and corresponding carbon emissions, which are by-products of urban production, are critical, in order to discover potential opportunities to save energy and to reduce emissions. Conventional evaluation indicators, such as “energy consumption per unit output value” and “emissions per unit output value”, are concerned with immediate consumptions and emissions; while the indirect consumptions and emissions that occur throughout the supply chain are ignored. This does not support the optimization of the overall urban industrial system. To present a systematic evaluation framework for cities, this study constructs new evaluation indicators, based on the concepts of “embodied energy” and “embodied carbon emissions”, which take both the immediate and indirect effects of energy consumption and emissions into account. Taking Beijing as a case, conventional evaluation indicators are compared with the newly constructed ones. Results show that the energy consumption and emissions of urban industries are represented better by the new indicators than by conventional indicators, and provide useful information for urban industrial structure optimization.

Keywords embodied carbon emissions, embodied

energy, industrial structure optimization, urban economy

1 Introduction

Since the Industrial Revolution, industrialization, based on fossil fuels, has fundamentally changed modes of agricultural production that have lasted for the past several thousand years. Industrialization has had a huge impact on the world’s economic and ecological structures. Intertwined industrialization and urbanization are gradually becoming the theme of global economic development and evolution. Meanwhile, the density of greenhouse gases is continuously increasing; and it is widely acknowledged that global warming has come into being. Mainstream climate change research attributes the rising average ground temperature to anthropogenic greenhouse gas emissions during the past 50 years, which mainly result from the use of fossil fuel.

As the primary material processors associated with industrialization, cities are the most intense consumers of fossil fuels. The development of urban production depends heavily on fossil fuels, and thus, is the primary source of carbon emissions (Ji and Chen, 2010; Ji, 2011). According to Stern (2007), 78% of total carbon emissions from human activities are produced in cities. As a result, cities are considered to be the center of focus in combating global climate change. Besides carbon emissions, cities face additional problems, such as energy shortages and environmental deterioration (e.g., energy supply security and urban heat islands are pressing the nerves of urban decision makers). It is believed that interventions in cities play a key role in solving some of the most complex and urgent problems facing industrialized society, such as resource shortages and environmental degradation (Wu and Wu, 2008).

The structure optimization of urban industry seems to be

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a promising solution to addressing the aforementioned economic and ecological problems of cities (Chen et al., 2011a, b). Enforcing energy conservation and reducing carbon emissions are two targets of great concern in urban industrial structure optimization; which should be conducted on the basis of scientific and comprehensive evaluation of industrial energy consumption and carbon emissions (Yuan et al., 2008). Currently, the quantitative studies on the carbon emission accounting of urban production are still inadequate, and greater efforts are needed in this field. The aim of this study is to contribute to this field by constructing a systematic evaluation framework for urban energy consumption and carbon emissions, and applying it to a case study.

The rest of this paper is organized as follows: Section 2 introduces methodological and data issues; Section 3 presents the application of the systematic evaluation framework to the Beijing case; and Section 4 presents the conclusions of this study, and provides policy implications.

2 Methodology

2.1 Direct evaluation versus embodied evaluation

Usually energy consumption and carbon emissions per unit output are used to measure the energy efficiency and environmental friendliness of an industry sector. These two indicators are based on “direct consumption” and “direct emissions” respectively, and have the advantages of immediacy and straightness. However, when those two indicators represent the immediate resource consumption and waste emissions of a product or service, they fail to take into consideration other sections of a production cycle, (i.e., the input-output linkages between sectors), (Ahmad and Wyckoff, 2003; Peters and Hertwich, 2008).

From the perspective of the entire urban socioeconomic system, each sector does not exist alone. The energy consumption and carbon emissions associated with the ubiquitous interdependencies among sectors are all related to every particular sector, either directly or indirectly. As such, evaluations based on separating one sector from the others are inaccurate, or even misleading. Therefore, a quantitative analytical method that can reflect the actual consumption and emissions of sectors and products objectively and comprehensively is required. Moreover, an embodied accounting method is a useful metric for evaluating and defining the consequences of production and energy consumption in cities. Such a method contributes meaningful information to our understanding about how to confront environmental/ecological problems.

The concept of embodied energy was initially raised in the late 1970s. Embodied energy is considered to be the total amount of energy put directly, and indirectly, into a production process. The intellectual foundation of embodied

energy methodology is the systems theory, which takes full account of the connections between sub-systems and elements. Based on the input-output model proposed by Leontief (1970), Costanza (1980) built the basic accounting framework for embodied energy that takes the direct and indirect energy usage connections between sectors into full consideration. On the basis of the U.S. input-output table, Costanza and Herendeen (1984) then calculated the embodied energy of different sectors. Judson (1989) believes that the accounting of national economy based on embodied energy is an effective supplement to the conventional evaluation framework.

The basic idea and calculation method of embodied energy later spread into fields beyond energy research. The evaluation of embodied carbon emissions is one of the most serious applications (Wyckoff and Roop, 1994). Parallel to embodied energy, embodied carbon emissions, or carbon footprints (Weber and Matthews, 2008; Davis and Caldeira, 2010), are the total direct and indirect greenhouse gas emissions generated by a product or service.

With increasingly pressing energy and climate issues, the theory and methodology of embodied energy and embodied carbon emissions has been applied to industrial optimization and the adjustment of international trade policies. This systematic view contributes new ideas to the conventional evaluation system, and is accepted by more and more scholars and policy makers. With input-output analysis, the method based on embodied energy and embodied emissions accounts for both direct and indirect energy consumption and carbon emissions for the production processes of goods and services. The introduction of embodied energy and embodied carbon emissions into the quantitative evaluation of energy consumption and carbon emission is a supplement to conventional evaluation indicators; and it is helpful in building a comprehensive monitoring and evaluating system for urban development (Fridley et al., 2012).

At present, the embodied energy and embodied carbon emissions concepts have been widely applied to national and international evaluation. In 1997, Nishimura et al. (1997) built a model of embodied carbon emissions for macroeconomic production processes. This model takes full account of intersector linkages, and was tested with the 405-sector input-output table of Japan. On the basis of the 2002 input-output table, Zhou (2008) calculated the intensities of embodied energy and carbon emissions for 42 sectors in China. With the guidance of systems ecology, and the input-output tables from 2005 and 2007, Chen et al. (Chen and Chen, 2010; Chen et al., 2010a, b) recalculated the embodied ecological endowments, including embodied energy and embodied carbon emissions, for all sectors in China, based on the improved accounting framework. Their work provides a source of reference upon which to build a resource-saving and environmentally-friendly society, from the perspective of production.

Liu et al. (2011) compared direct and indirect energy consumption in China and the United States, and identified the factors causing the different energy intensities of the two countries. The global embodied energy and embodied carbon emissions flows were also investigated to reflect the environmental consequences of international trade (Chen and Chen, 2011a, b; 2013). This research provides references for accounting and evaluations on the city scale.

2.2 Systematic evaluation framework based on input-output model

It is necessary to expand the traditional input-output table to include elements of energy and carbon emissions before the substantive application of the systematic evaluation framework. As shown in Table 1, Q_1 , Q_2 and Q_3 represent the input and output flows, the final uses, and the added values, respectively, of an urban economy. These three parts jointly create the traditional economical input-output table. The extended part of Q_0 stands for the quantities of energy and greenhouse gas emissions that enter the economic system in non-commodity form.

Two intensity indicators, namely, embodied energy intensity, and embodied carbon intensity, are used to monitor and compare the strengths of resource consumption and environmental emissions of different sectors. The two indicate the total direct and indirect, energy consumption, and greenhouse gas emissions, per unit of output in each sector. Two hypotheses are tested for accounting. The first hypothesis is that all products within one sector have the same embodied energy intensity, and embodied carbon emission intensity. The second hypothesis is that all currently used products in the same category, whether newly produced or from inventory, produced locally or imported, have the same embodied energy, and embodied carbon intensities. Based on these two hypotheses, the energy balance of any sector in the urban socioeconomic system can be represented as diagramed in Fig. 1.

Where: d_i represents the direct energy exploited from the city by sector, i , tr_i and tr_j represent the embodied energy intensities of products from the i^{th} and j^{th} sector, x_{ji} stands for the total of products from sector j used by the production of sector i , and p_i is total output of sector i .

Accordingly, the embodied energy balance equation for sector i is as follows:

$$d_i + \sum_{j=1}^n tr_j x_{ji} = tr_i p_i.$$

One embodied energy balance equation can be written for each sector and all n equations can be expressed with the following matrix equation:

$$D + TrX = TrY.$$

Where: $D=[d_i]_n$, $Tr=[tr_i]_n$, $X=[x_{ji}]_{n \times n}$, and $Y=[y_{ji}]_{n \times n}$ (When $i=j$, $y_{ji}=p_i$, and when $i \neq j$, $y_{ji}=0$). Therefore under some mathematical conditions, each sector's embodied energy intensity can be solved as follows, once the direct energy exploitation D , the input-output matrix X , and the industry's total output Y , for all sectors, are obtained:

$$Tr = D(Y - X)^{-1}.$$

The calculation of embodied carbon emission intensities is similar to that of embodied energy intensity, but only the variables are defined differently. Also, when vector D , for embodied carbon emissions, is not provided by previous statistics, the greenhouse gas emission factor of various types of energy and production, provided by IPCC (2006), are used to calculate it (see Table 2).

3 Case study

3.1 Research background

Cities are major contributors to energy consumption and

Table 1 Integrated input-output table including energy, greenhouse gases, and economic factors

		Intermediate use				Final use		
		Sector 1	Sector 2	...	Sector n	Consumptive use	Gross capital formation	Export
Intermediate inputs	Sector 1							
	Sector 2							
	...			Q_1				Q_2
	Sector n							
Net economic inputs (Value added)	Wages, taxes, surplus, etc.			Q_3				
Energy	Fossil fuel							
	Other energy							
Greenhouse gases	CO ₂			Q_0				
	CH ₄							
	N ₂ O							

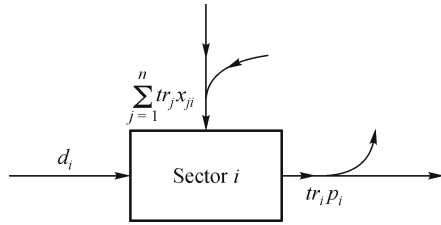


Fig. 1 Input and output flows of a sector.

emissions in China. In 2005, the urbanization rate of China reached 40%. At the same time, 75% of the total GDP is produced, and 84% of commercial energy is consumed, in cities (NBSC, 2006). The 35 largest cities in China contain 18% of the domestic population, and contribute to 40% of the country's energy consumption, and carbon emissions as well (Dhakar, 2009). In recent years, China has been promoting ecological civilization and harmonious society, and institutionalizing its energy-saving management system. However, many aspects of China's current urban development pattern are still inconsistent with respect to attaining the sustainability of the economy, energy, and environment. To look for an optimal urban development mode for China, the systematic evaluation framework of embodied energy and embodied carbon emissions will be applied to the case of Beijing, the capital and one of the economic centers of China.

3.2 Results and discussion

The input-output table for Beijing in 2005 is used in this study, in which 42 industrial sectors are covered (see Appendix). On the basis of the input-output table, and energy and carbon statistics, the direct and embodied intensities of energy consumption and carbon emissions for each sector are calculated according to the methodology introduced in Section 2.

Figures 2 and 3 present the embodied energy intensities and embodied carbon emission intensities of the 42 sectors in Beijing, respectively. It can be observed that fossil fuel is the major energy consumed, and CO₂ is the main component of greenhouse gas emissions for all sectors.

Figure 4 compares direct energy consumption intensities against embodied energy intensities, for the 42 sectors in Beijing. According to the figure, embodied energy intensities are higher than direct energy consumption across almost all sectors. The gaps are so huge for many sectors that the embodied energy evaluation leads to very different conclusions than the direct evaluation. For example, the direct energy consumption intensity of the coal mining and washing sector is only 1.88×10^5 J/CNY, which indicates that it is a very energy-saving sector. In contrast, the sector's embodied energy consumption intensity is 209 times that of the direct intensity, which makes it the most energy-intensive sector, based on the embodied perspective.

The different results between direct and embodied evaluations are due to the fact that the embodied method takes into account indirect energy inputs, such as the machinery and environmental input, but the direct method does not. Therefore, it is unfair to evaluate the energy cost of an industrial sector on the basis of only its direct energy consumption intensity. Embodied energy intensity considers the linkages between sectors, and thus, can reflect the real energy cost of each sector in a more objective and scientific way. By comparing the embodied energy intensities of different sectors, preferential sectors to be developed in Beijing are identified, which include the finance and insurance sector, the real estate sector, the wholesale and retail trade services sector, the telecommunication, computer services and software sector, the cultural, sporting and recreation services sector, the rental and business services sector, etc.

Both the direct and the embodied carbon emission intensities are also calculated using their corresponding energy consumption (see Fig. 5). The pattern based on these two indicators is basically the same as above. The embodied carbon emission intensities take full account of the direct and indirect carbon emissions per unit output. Environmental friendliness, the cross-sector system of emission reduction duties based on this index, will be more objective and comprehensive.

In order to discern whether or not an urban production system is energy-saving and low-carbon, the ideal

Table 2 Emission factors of greenhouse gases from main energy resources (IPCC, 2006)

Item	Coal	Oil	Natural gas
Emission factors of CO ₂	2.53 kg/kg	3.20 kg/kg	2.09 kg/m ³
Emission factors of N ₂ O/(kg·TJ ⁻¹)	1.4	0.6	0.1
Emission factors of CH ₄ /(kg·TJ ⁻¹)			
Agricultural sector	300	10	5
Mining sectors	1	3	1
Industrial sectors(manufacturing)	10	2	5
Transportation sector	10	20	50
Tertiary industry sectors	10	10	5

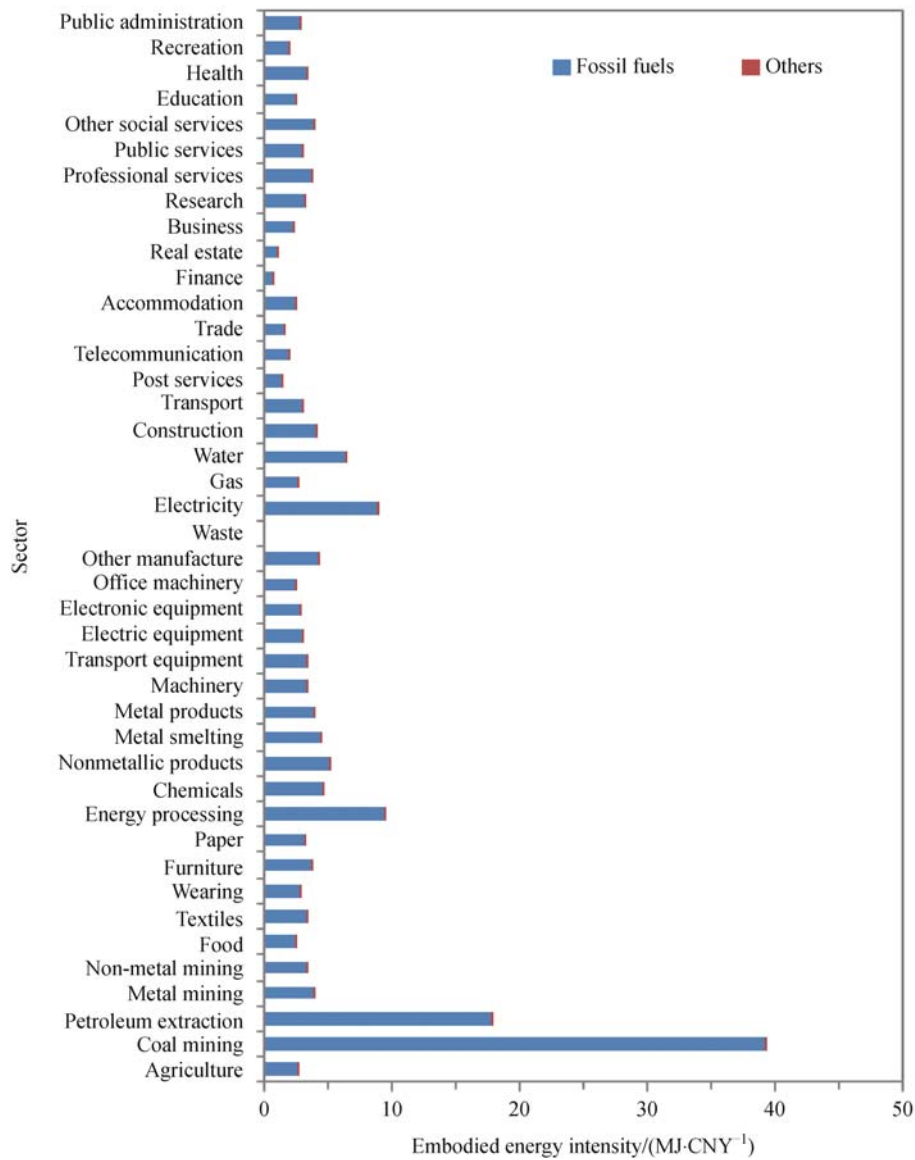


Fig. 2 Embodied energy intensity of the 42 sectors of Beijing in 2005.

approach is to make an inter-urban comparison of the “embodied energy consumption intensity” and “embodied carbon emission intensity” of the same industry. Through classifying the results of different cities, we can determine the “energy-saving” and “low-carbon” standards for each sector and establish a system of quantitative evaluation indicators. Such a system built upon Chinese or international comparison is of great significance, but is also difficult for a variety of reasons.

China’s input-output statistics on the city level are not complete, which prevents comparisons of “energy-saving” and “low-carbon” levels across cities. However, we may get a preliminary assessment of the low carbon level of a city by comparing it with the national average. China has a relatively complete national input-output table. On the

basis of the input-output table, and the energy production and consumption tables of 2005, the “embodied energy consumption intensities” and the “carbon emission intensities” across the 42 sectors in China are calculated as the average energy consumption and emissions of Chinese industries. Figures 6 and 7 compare both indicators for Beijing with the national averages.

As shown in the figures, most sectors in Beijing have lower embodied energy consumption intensities, and lower embodied carbon emission intensities than the national averages. From one perspective, the city has agglomerated economy and scale economy; and mass production in bounded space is helpful in up-grading production technologies, and dramatically lowers losses in energy allocation and circulation. These factors improve the

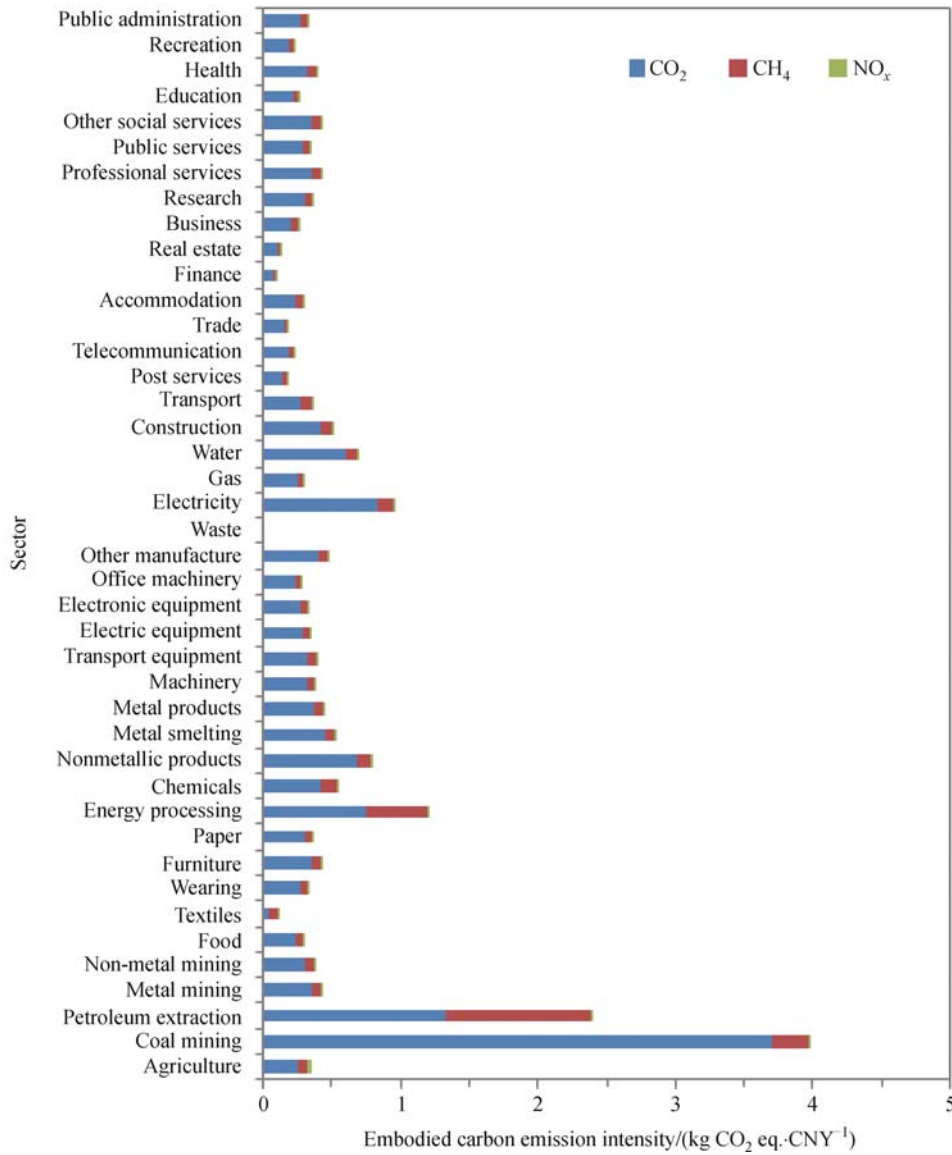


Fig. 3 Embodied carbon emission intensity of the 42 sectors of Beijing in 2005.

energy efficiencies of urban industries, and reduce the energy consumption and carbon emissions per unit output. However, as the center of China’s politics, culture and international affairs, Beijing has more technology-intensive industries. Energy-consuming and environmentally-disruptive industries are constantly moving out without affecting the city’s basic functions. Meanwhile, as the capital of China, Beijing receives policy favors and hosts a great deal of new technology and ideas, which also greatly improves its industrial efficiencies. However, there are still a number of sectors that have higher embodied energy consumption intensities and embodied carbon emission intensities than the national levels, such as, the public administration sector, the agriculture, forestry, animal husbandry and fishery sector, the social service sector,

and the wholesale and retail trade service sector. It is easy to understand that the agriculture-related sectors in Beijing are less efficient because of the geological and climate limitations, such as mountainous geomorphology and water shortages. Meanwhile, the results that Beijing’s public services-related sectors have higher than national-average embodied intensities can partly be explained by the low-tariff policy, as the intensities are inversely proportional to economic value. However, it is not clear, so far, why the wholesale and retail trade sectors in Beijing appear to be less efficient than the national average. The preferential industrial structure of Beijing can be identified by comparing the embodied intensities between this city and the whole country. It is observed that the resources-related sectors in Beijing are more efficient than the

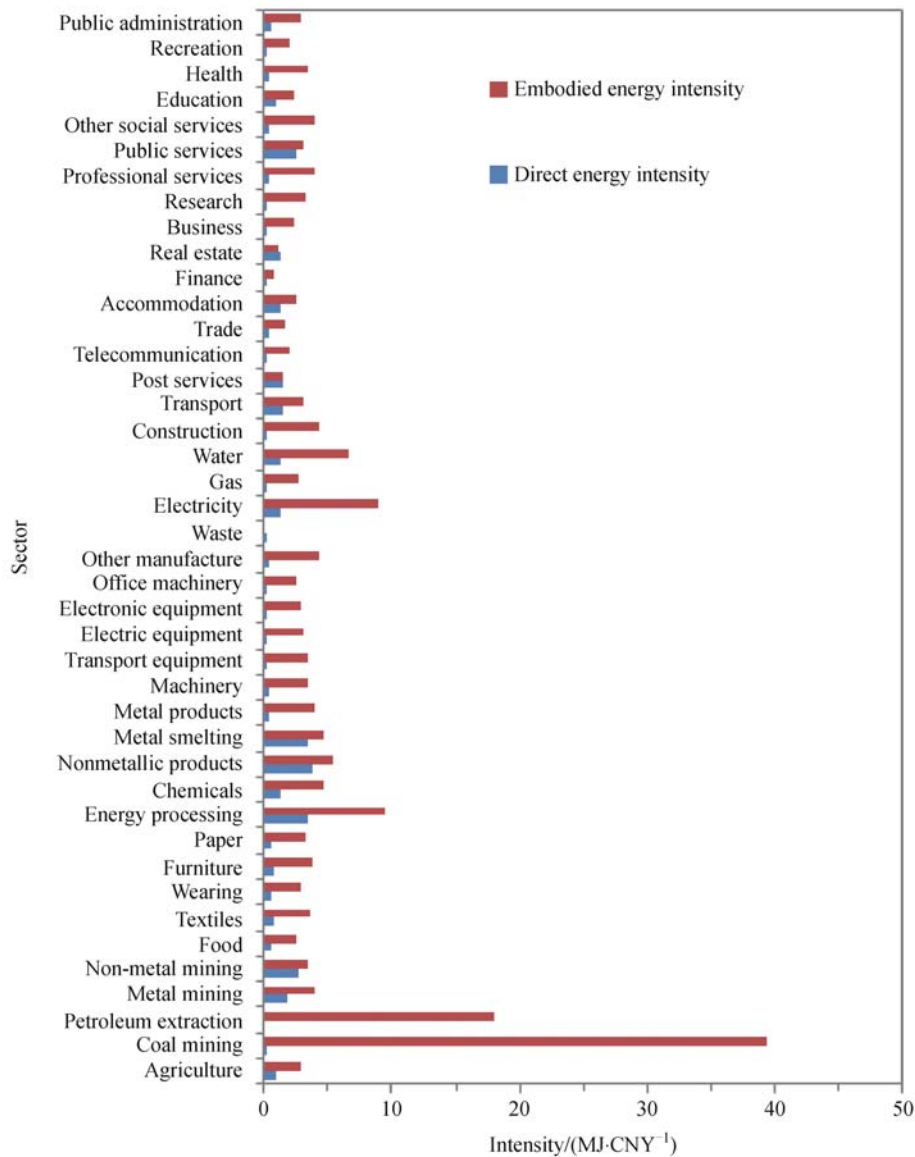


Fig. 4 Comparison between direct energy consumption intensity, and embodied energy intensity across the 42 sectors of Beijing in 2005.

national averages, which can be attributed to its more advantageous technology. For example, by using a more advantageous coal-fired power plant, the average coal consumption to generate electricity in Beijing is 315 g/kWh, while the same indicator for Sichuan province is 400 g/kWh (CEPY, 2006). However, one major factor impacting Beijing's ability to expand its resource-related industries, is that the city does not have abundant energy resources reserves. Therefore, in order to make better use of Beijing's advantage, the development of a logistics system that ensures low-cost and reliable resource transportation to Beijing is a policy priority.

The aggregate embodied energy consumption and embodied carbon emissions of different industries for the Beijing economy in 2005 are listed in the Appendix. According to the results, the construction sector contributes to a large fraction of embodied energy consumption,

and embodied carbon emissions, in Beijing, followed by petroleum processing, coking and nuclear fuel processing, electricity, steam and hot water production and supply, electronic and telecommunication equipment, and mining and coal washing sectors.

An important dimension of city-based environmental/ecological accounting is to understand the relative contributions made by different economic activities. According to Table 3, domestic cross-boundary trade has much larger impacts on Beijing's embodied energy consumption and carbon emissions than international trade. Meanwhile, Beijing is identified as a net importer of embodied energy, as well as embodied carbon.

From the example of Beijing, we can learn the advantages of applying embodied energy and embodied carbon emissions systems in making quantitative evaluations of an industry's energy consumption and emissions.

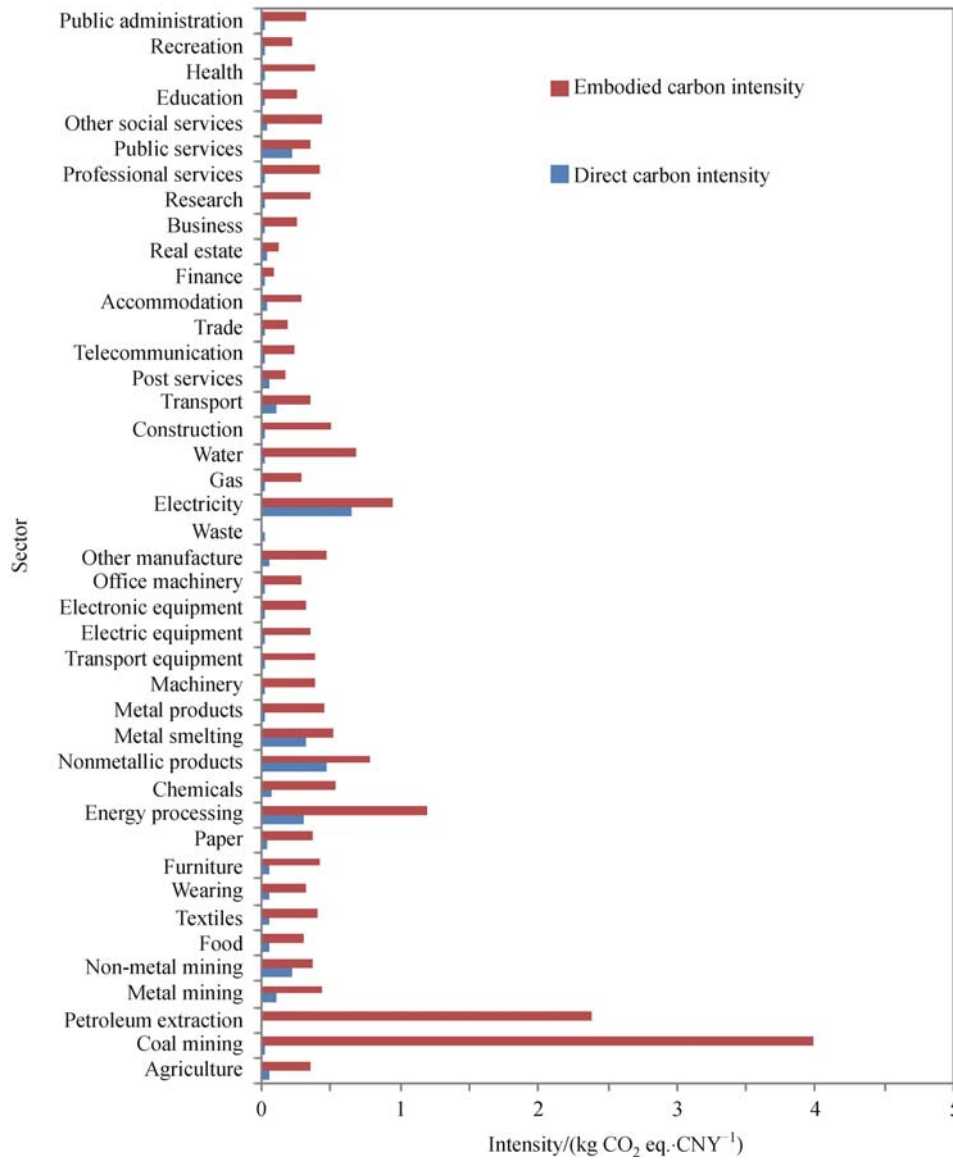


Fig. 5 Comparison between direct carbon emission intensity and embodied carbon emission intensity across the 42 sectors of Beijing in 2005.

The one-sidedness and unfairness associated with conventional evaluation systems is avoided by using evaluations based on the embodied energy and embodied carbon emissions concepts. The obtained information can be used as an important reference in making economic policies, such as taxing and ecological compensations. In addition, it may locate industries with energy inefficiency and heavy pollution, by making cross-sector and/or cross-urban comparisons, which helps to conserve energy and to reduce emissions.

4 Concluding remarks

China has been developing at a rapid pace for several decades in terms of its economic achievement. However,

environmental and ecological problems are also becoming more and more emergent because of the country's GDP growth, primarily development mode (Cao et al., 2009; Guan et al., 2011; Zheng and Cao, 2011; Gong et al., 2012; Chen and Cao, 2013; Chen, 2014). The constraints from resource shortages and environmental quality degradation are two of the most critical problems. Industrial restructuring is a promising solution to these problems. Different cities have different industrial advantages so their potential for industrial energy saving and emission reductions are different too. To optimize the industrial structures of a city requires more scientific and systematic quantitative evaluations and cross-urban comparisons. The scientifically sound indicators of embodied energy and embodied carbon emissions, based on input-output analysis, can be used as a basic tool in monitoring the energy consumption

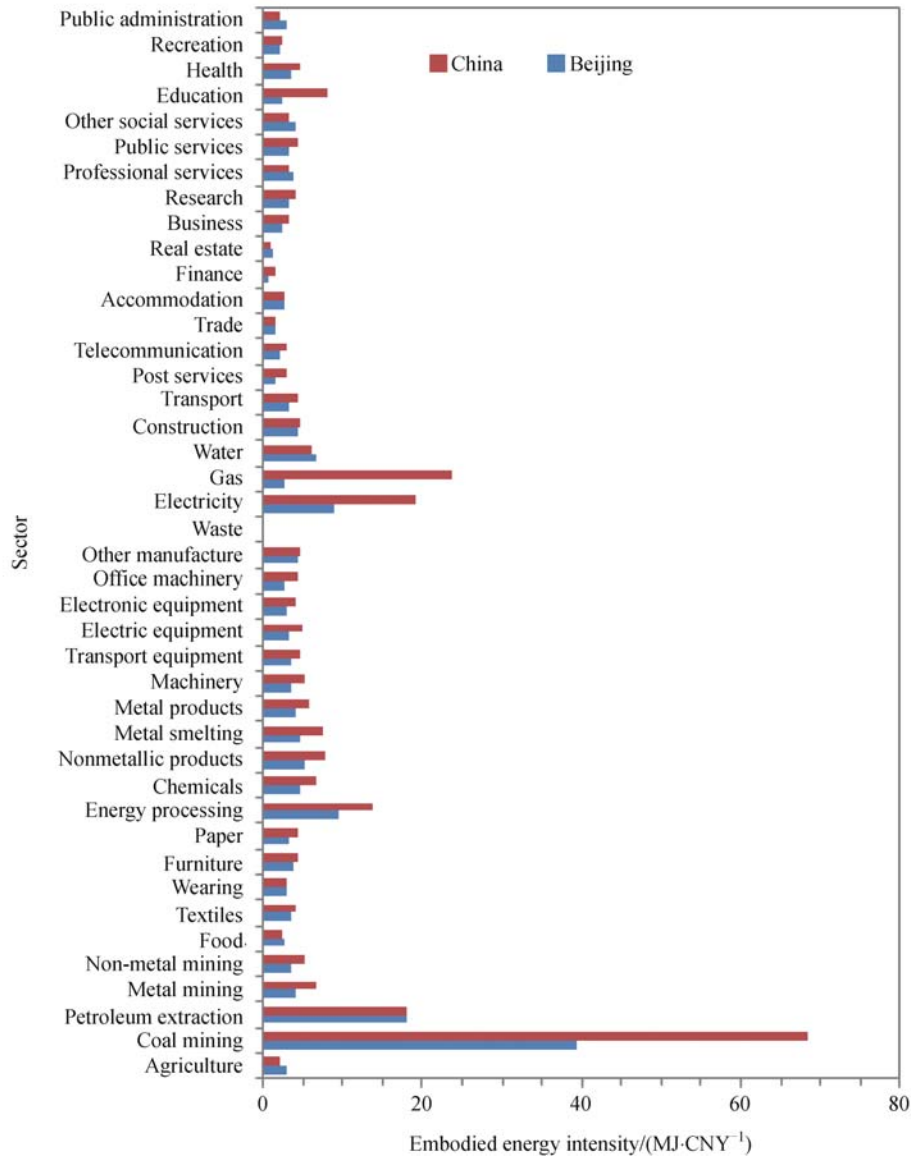


Fig. 6 Comparison of embodied energy intensity between Beijing and China in 2005.

and emissions, of production in cities. The input-output analysis is built upon detailed statistics, and its accuracy is determined by the quality of data. At present, input-output statistics on the city level are incomplete and need further improvement. Cross-urban comparisons can be made if a uniform urban input-output statistical system is established. A uniform system may identify evaluation benchmarks and a system of indicators for low carbon cities. This could be used to promote industrial restructuring across cities, as well as the optimal allocation of energy resources, and thereby contribute movement toward the realization of sustainable urban development.

Constructing such an evaluation system is crucial for urban industrial structure optimization, but the practice needs to offer economic incentives and integrate with government regulations. Accounting based on embodied

energy consumption intensities and embodied carbon emission intensities provides objective information for the evaluation of a sector's ecological costs and environmental responsibilities. Energy tax or carbon tax could be imposed on sectors with high embodied energy consumption intensities and embodied carbon emission intensities, in order to urge them to implement technological and institutional innovations, energy efficiency improvements, and emission reductions. Tax breaks, exemptions, or other incentives could be granted to sectors with low embodied energy consumption intensities and embodied carbon emission intensities, to encourage their efforts in energy-saving and emissions reduction.

The current study focused on the use of embodied, instead of direct, accounting across different industries, and presents results and discussions from this perspective.

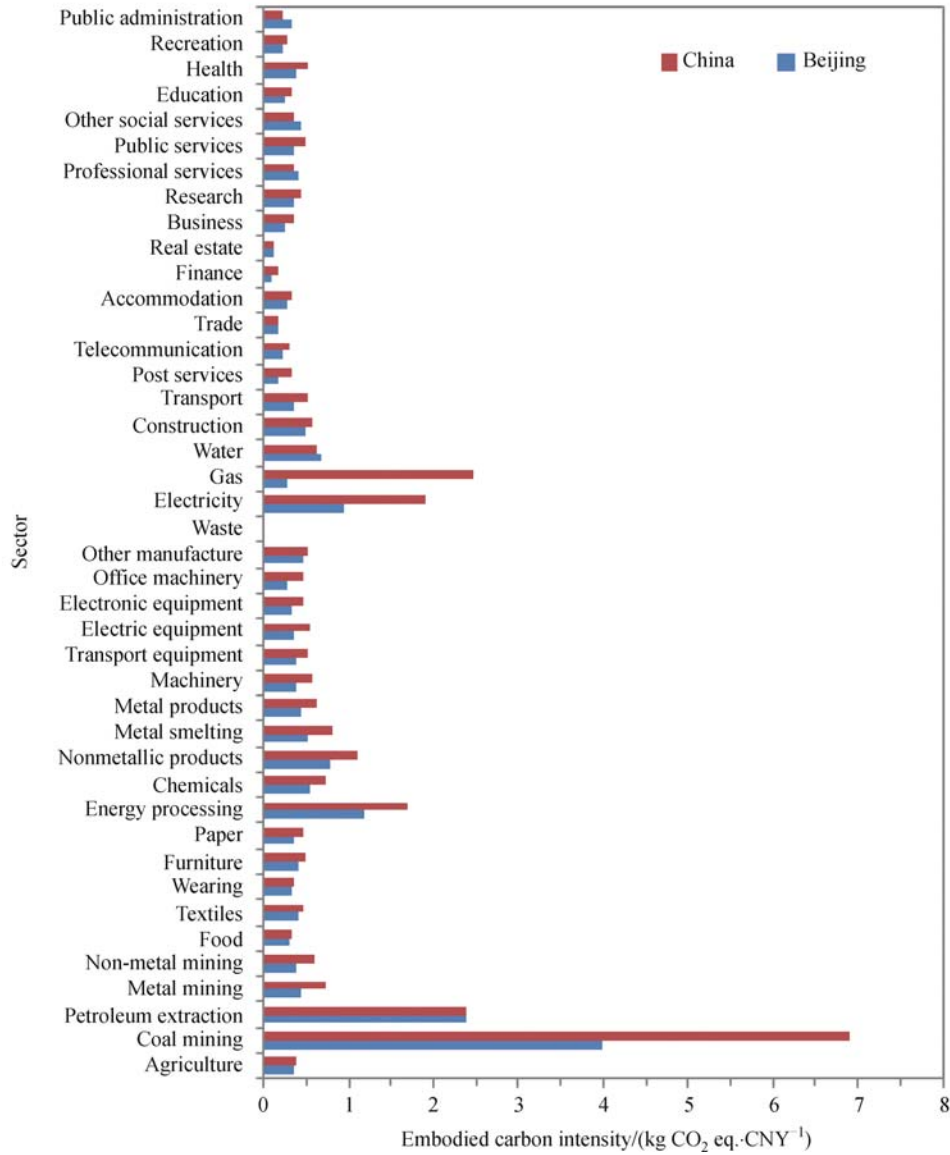


Fig. 7 Comparison of embodied carbon emission intensity between Beijing and China in 2005.

Table 3 Aggregate energy consumption and carbon emissions of different economic activities of Beijing in 2005.

Economic activities	Item	Value
Aggregate energy consumption	Direct energy use/J	7.25E + 18
	Embodied energy consumption/J	8.30E + 18
	Energy embodied in import from other provinces/J	2.31E + 18
	Energy embodied in export to other provinces/J	1.32E + 18
	Energy embodied in import from foreign countries/J	8.12E + 17
	Energy embodied in export to foreign countries	7.53E + 17
	Carbon emission	Direct carbon emissions/(kg CO ₂ eq.)
Embodied carbon emissions/(kg CO ₂ eq.)		9.35E + 11
Carbon emissions embodied in import from other provinces/(kg CO ₂ eq.)		2.63E + 11
Carbon emissions embodied in export to other provinces/(kg CO ₂ eq.)		1.49E + 11
Carbon emissions embodied in import from foreign countries/(kg CO ₂ eq.)		9.17E + 10
Carbon emissions embodied in export to foreign countries/(kg CO ₂ eq.)		8.45E + 10

However, it should be noted that this does not imply that the embodied methodology is better than or contrary to the direct methodology. As a matter of fact, we insist that each methodology has its own policy implications, (e.g., direct accounting is important for assessing the energy efficiency potential of a specific industry, while embodied accounting investigates the hidden value chain referring to the whole economy). Therefore, it is more appropriate to consider the embodied analysis methods investigated in this study as a supplement to traditional direct analysis.

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Appendix

Table A1 Sector information and aggregate embodied energy and embodied emissions of different industries.

Sector name	Abbreviation in figures	Embodied energy/J	Embodied carbon emissions/(kg CO ₂ eq.)
Agriculture, forestry, animal husbandry and fishery	Agriculture	7.64E + 13	9.63E + 06
Mining and washing of coal	Coal mining	4.88E + 14	4.93E + 07
Extraction of petroleum and natural gas	Petroleum extraction	0.00E + 00	0.00E + 00
Metal ore mining	Metal mining	7.39E + 12	7.84E + 05
Non-metal minerals mining	Non-metal mining	1.93E + 12	2.10E + 05
Manufacture of food products and tobacco processing	Food	1.13E + 14	1.31E + 07
Textiles	Textiles	2.83E + 13	3.19E + 06
Wearing apparel, leather, fur, down and related products	Wearing	3.13E + 13	3.51E + 06
Sawmills and furniture	Furniture	1.92E + 13	2.11E + 06
Paper and products, printing and record medium reproduction	Paper	5.68E + 13	6.21E + 06
Petroleum processing, coking and nuclear fuel processing	Energy processing	5.51E + 14	6.89E + 07
Chemicals	Chemicals	2.59E + 14	2.93E + 07
Nonmetallic mineral products	Nonmetallic products	1.22E + 14	1.81E + 07
Metal smelting and pressing	Metal smelting	2.65E + 14	2.99E + 07
Metal products	Metal products	6.89E + 13	7.64E + 06
General and special purpose machinery	Machinery	1.72E + 14	1.88E + 07
Transport equipment	Transport equipment	2.97E + 14	3.23E + 07
Electric equipment and machinery	Electric equipment	7.61E + 13	8.41E + 06
Electronic and telecommunication equipment	Electronic equipment	5.27E + 14	5.92E + 07
Instruments, meters, cultural and office machinery	Office machinery	4.55E + 13	5.06E + 06
Other manufacturing products	Other manufacture	3.89E + 13	4.24E + 06
Scrap and waste	Waste	0.00E + 00	0.00E + 00
Electricity, steam and hot water production and supply	Electricity	5.68E + 14	5.98E + 07
Gas production and supply	Gas	6.33E + 12	6.61E + 05
Water production and supply	Water	2.38E + 13	2.46E + 06
Construction	Construction	8.68E + 14	1.02E + 08
Transport and storage	Transport	3.20E + 14	3.68E + 07
Post services	Post services	1.23E + 13	1.37E + 06
Telecommunication, computer services and software	Telecommunication	3.31E + 14	3.65E + 07
Wholesale and retail trade services	Trade	2.00E + 14	2.21E + 07
Accommodation and food serving services	Accommodation	1.25E + 14	1.40E + 07
Finance and insurance	Finance	9.03E + 13	9.94E + 06
Real estate	Real estate	7.82E + 13	8.61E + 06
Rental and business services	Business	2.81E + 14	3.08E + 07
Scientific research	Research	5.25E + 13	5.66E + 06
Professional, scientific and technical services	Professional services	1.15E + 14	1.25E + 07
Public services	Public services	3.02E + 14	3.30E + 07
Other social services	Other social services	1.67E + 14	1.82E + 07
Educational services	Education	1.16E + 14	1.23E + 07
Health, social security and welfare	Health	1.13E + 14	1.23E + 07
Cultural, sporting and recreational services	Recreation	9.00E + 13	9.76E + 06
Public administration and other sectors	Public administration	1.42E + 14	1.53E + 07