

Embodied Energy of Service Trading in Hong Kong

Abstract

Purpose - Energy is a resource of strategic importance for high density cities. International trade reshapes the urban economy and industrial structure of a city, which will indirectly affect energy use. As an international trade hub, Hong Kong relies on the import and export of services. Energy performance in the international trading of these services needs to be properly understood and assessed for Hong Kong's urban renewal efforts.

Design/methodology/approach - This study evaluates Hong Kong's embodied energy in service trades based on an input-output analysis. The three criteria used for assessment include trading areas, industry sector, and trade balance.

Findings - Analyzed by region, results show that Mainland China and the USA are the two largest sources of embodied energy in imports of services, while Mainland China and Japan are the two largest destinations of exports. In terms of net embodied energy transfer, Hong Kong mainly receives net energy import from Mainland China and the USA and supplies net energy export to Japan, the UK and Taiwan. Among industry sectors, *Manufacturing services*, *Transport and Travel* contribute most significantly to the embodied energy in Hong Kong's imported services, while *Transport and Travel* contribute most to the energy embodied in exported services.

Originality/value - This study identifies the characteristics of energy consumption of service trading and establishes a feasible approach to analyze energy performance of service trade in energy-deficient Hong Kong for the first time. It provides necessary understanding and foundation for developing energy strategies in a service-based, high density urban economy.

Key Words: Embodied energy, input-output analysis, service trading, Hong Kong,

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trade balance, sustainability

1. Introduction

As one of the most densely populated cities in the world, the population of Hong Kong reached 7.19 million and the population intensity was up to 6898 people per km² in 2013 (CSDHK, 2013). As a free trade zone, Hong Kong has been a major service economy contributed by low tax and free trade policies. The service industry accounted for 93% of Hong Kong's total GDP in 2012 according to the latest statistics (CSDHK, 2014b). Hong Kong's total imports and exports of service trade values reached HK\$594.3 billion and HK\$764.0 billion respectively in 2012 (CSDHK, 2014b).

Facing the increasing pressure brought upon by population and economic growth, Hong Kong is experiencing intensified competition for limited local resources. Energy, as one of the most basic natural resources for human survival, has been a worldwide concern (Brennand, 2004; Han et al., 2013; Meza, 2014; Sadorsky, 2012; Sheng et al., 2014). With virtually no energy supply of its own, Hong Kong is highly dependent on the external energy provision: all the coal products, oil products and part of the electricity in Hong Kong are imported from the outside (CSDHK, 2014a). Therefore, energy security should be strengthened to make sure the basic function of this modern economy. To achieve this, Hong Kong has been trying to implement energy policies to ensure sustainability. It proposes to optimize the fuel mix and improve the energy efficiency to reach the energy saving target as “reducing energy intensity by 45% by 2035 and carbon intensity by 50-60% by 2020 based on 2005 level” (APEC, 2014). A basic energy end-use database has also been provided by the Electrical and Mechanical Services Department in Hong Kong for policy making (EMSD, 2013).

In addition to the efforts by the governments, academic research is also focusing on energy saving in Hong Kong. Chow (2001) studied the sectoral household energy

consumption in Hong Kong during 1984-1997. Ma et al. (2014) established a simulation model for Hong Kong's energy system to examine the present energy structure and analyze future sustainable energy strategies. However, most of the studies concerning energy in Hong Kong are limited to the direct energy use. Indirect energy use triggered by the imported services, which involve a significant level of energy intensive activities during the production process. The concept of "embodied energy" is defined as "the total (direct plus indirect) energy required to produce goods and services in the concerned economy" by Constanta (1980). Currently, energy and carbon emission performances in some cities have been assessed by considering both the direct and indirect energy and carbon emissions, such as Singapore (Niels B, 2010), Macao (Li et al., 2014) and Beijing (Guo and Chen, 2013; Guo et al., 2012b). Results show that indirect energy use is over two times as that of direct energy in high density cities (Li et al., 2014). As Hong Kong is an important global financial and trade center and is vying to become a world sustainable city, it's of fundamental importance to assess the embodied energy performance of its service trade, which provides the most vibrant economic activities in this service-based international metropolitan.

Energy is an important strategic resource for developing sustainable cities, especially for those who have virtually no energy supply of its own. As a service-oriented high density city, Hong Kong's service industries inevitably need a large number of external energy to support its production. Its high dependency on the external supply can affect energy security, which is an important part for urban sustainability. However, despite its importance, no research has focused on the energy issues of Hong Kong's service trade.

This study attempts to draw a full picture of embodied energy use of Hong Kong's service trade with its major trading partners from 2010-2012. The employed method

input-output analysis (IOA) can not only trace the places where energy use really occur based on the regional analysis, but also reveal the industry-wide profiles according to the sectoral analysis. Results of this study can provide a basic database and serve as a foundation for the development of energy strategies in a service-based urban economy. The rest of the paper is organized as follows: Section 2 describes the method used in this study and detailed data sources; the results of Hong Kong's embodied energy in imports and exports with major trading partners are shown in Section 3; and finally, conclusions are drawn in Section 4.

2. Methodology and Data

2.1 Method

Life cycle assessment (LCA) and input output analysis (IOA) are two main methods suited for the analysis of embodied energy. LCA method aims to assess the cradle-to-grave embodied energy impacts of the products, materials and processes (White and Shapiro, 1993). IOA provides a quantitative method to combine energy flows into the whole economy based on the physical balance and analyzes the industrial interdependence in terms of the energy pressure (Wiedmann et al., 2006). There are several major differences between these two methods. In general, the scale of the research objective for LCA method is usually targeted at one specific project (Arvesen and Hertwich, 2012; Arvesen et al., 2014; Bilec et al., 2010; Dahlstrøm et al., 2012; Hertwich, 2005; Lenzen, 2008b) and the scale for IOA method is much larger than that of LCA method, such as the national scale, urban scale and et al (Andrew et al., 2013; Arvesen et al., 2010; Cohen et al., 2005; Guo and Shen, 2014; Lenzen, 1998; Lenzen et al., 2004). Because of the limited tracking process, truncation error cannot be avoided when using LCA method (Majeau-Bettez et al., 2011; Shao and Chen, 2013). In contrast, taking into the consideration of the whole net economy, the

truncation error can be avoided by the IOA method (Lenzen, 2008a). Due to the lack of input-output table in Hong Kong, this study attempts to analyze the imported and exported energy based on the general equilibrium theory from the top-down perspective, which is also the theoretical basis for the IOA method. The detailed IOA-based methodical approach and data analysis procedures are described as follows.

As for an important international free trade port, the import and export trades in Hong Kong play a significant role in redistributing the energy resources between Hong Kong and the rest of the world. Therefore, embodied energy in imports (EEI) and embodied energy in exports (EEE) are two important indicators in this study to thoroughly reflect embodied energy in trading pattern (Tang et al., 2013; Weitzel and Ma, 2014).

Since Hong Kong's external service trade is the research objective, EEI can be calculated as the imported service trade volumes I_{ij} multiply the corresponding embodied energy intensities ε_{ij} (Chen et al., 2013), given as:

$$EEI = \sum_i^j \varepsilon_{ij} I_{ij}, \quad (1)$$

where i represents the place where the import occurs, and j is the service industry.

Similarly, EEE can be obtained as the exported service trade volumes E_{kj} multiply the corresponding embodied energy intensities ε_j (Guo et al., 2012a), given as:

$$EEE = \sum_k^j \varepsilon_j E_{kj}, \quad (2)$$

where k denotes the place where the export occurs.

The difference of EEE and EEI is defined as embodied energy in trade balance, EEB (Guo et al., 2014). This indicator explains the energy transfer flows. A positive value

means Hong Kong is a net supplier of its own energy resources, while a negative one denotes that it is a net receiver of energy resources from the outside (Chen and Chen, 2011), which can be formulated as:

$$EEB = EEE - EEI. \quad (3)$$

This paper presents the energy embodied in Hong Kong's external trade during 2010-2012, with the recent available statistic data. IOA can not only trace the place where the energy consumption really occur based on the regional analysis, but also reveal the industrial-wide profiles of EEI, EEE and EEB along with the trading structures and policies change according to the industrial analysis. Analyzed by region and industry, embodied energy in imported and exported services in industry sectors (as categorized by the Census and Statistic Department in Hong Kong) between Hong Kong and its major trading partners is presented.

2.2 Data sources

The import and export database of external service in Hong Kong has been published annually by the Census and Statistic Department in Hong Kong since 1995. The service trade data of Hong Kong used in this study, i.e., service trade data over the period of 2010-2012, are obtained from the latest official statistic yearbook "Hong Kong Trade in Services Statistics in 2012" (CSDHK, 2014b), released in February 2014. According to these statistic materials, Hong Kong has established good business relationships with the regions in Asia, Australasia and Oceania, Central and South America, North America, Western Europe and others. The major service trading partners include the mainland of China (Mainland China), United States of America (USA), United Kingdom (UK), Japan and Taiwan and their shares of total trade in services were 39.4%, 13.4%, 6.1%, 5.9% and 4.2% in 2012, respectively. The service component in Hong Kong can be clarified as 12 sectors, as listed in Table 1. The two

largest service industries in import in Hong Kong are Sector 4 (Travel) and Sector 3 (Transport), accounting for 33.6% and 32.5%, respectively.

[Insert Table 1]

The globalization of trade flows in Hong Kong puts forward the demand for the worldwide embodied energy database, an issue discussed by Chen and Chen (2013). Since studies on the time series are conducted, the purchase power change during the research period should be reflected by the corresponding GDP deflators which are used to adjust price level to the base year. Besides, the currency conversion is considered because of the difference of currency units in different regions.

2.3 Accounting procedure

Based on the IOA-based method, the accounting procedure for embodied energy of Hong Kong's service trade includes the following steps:

- (1) collect the import and export database of external trade services in Hong Kong based on the statistics of Hong Kong Government;
- (2) identify the embodied energy intensity of each trading item from the corresponding regions according to the worldwide embodied energy database; and
- (3) calculate the EEI, EEE and EEB based on the formula in Section 2.1.

3. Results and Discussions

3.1 Embodied energy in imports

3.1.1 Regional analysis

[Insert Figure 1]

Figure 1 shows Hong Kong's embodied energy in service trade import with its major trading partners for the three year period between 2010 and 2012. Analyzed by region, Mainland China is the largest import origin for embodied energy in Hong Kong's service trade with the import volumes of 4.83E+08, 4.36E+08 and 4.35E+08 GJ in 2010, 2011 and 2012, respectively. There is a decreasing trend over these three years. This could be a result of energy efficiency improvement in Mainland China due to through technological advancement in service provision and trade structural adjustment. The second largest import origin is the USA, which is another Hong Kong's important trading partner and it has substantial economic linkages with Hong Kong. Hong Kong has imported embodied energy of 1.78E+08, 1.99E+08 and 1.88E+08 GJ during 2010-2012 from the USA. Then it is followed by the UK with the values of 4.43E+07, 5.03E+07, and 4.71E+07 GJ in these three years; Japan with the values of 4.19E+07, 4.63E+07, and 5.48E+07 GJ and Taiwan with the values of 3.86E+07, 4.57E+07, and 5.08E+07 GJ. These three regions also make a great contribution to the embodied energy import to Hong Kong. Actually, Hong Kong is an important entrepot among Mainland China, Japan and Taiwan, and the trade volume has been growing yearly.

3.1.2 Industrial sector analysis

[Insert Figure 2]

Amongst various service components, the import of Industry Sector 1 (Manufacturing services) contributes most significantly to the overall embodied energy in Hong Kong's service trades, mainly attributed to the import from Mainland China. For imports relating to Sector 3 (Transport), Mainland China, Japan and Taiwan are the main sources to Hong Kong. This is followed by Sector 4 (Travel) and Sector 10 (Other business services), which are all mainly import from Mainland China and the USA.

Although sectoral embodied energy in imports during 2010-2012 shows the same trend, the actual values of sectoral embodied energy vary year by year. The imported embodied energy of Sector 1 (Manufacturing services) decreases from 2.63E+08 GJ in 2010 to 2.23E+08 GJ in 2012. This can be attributed to China's effort and effectiveness to improve energy use efficiency of manufacturing industry. There is an increasing trend for the embodied energy in Sector 3 (Transport), ranging from 1.89E+08 GJ to 2.06E+08 GJ, and finally to 2.11E+08 GJ during the period of 2010-2012. Embodied energy in import of Sector 4 (Travel) sees a fluctuation, which increases from 1.85E+08 GJ in 2010 to 2.04E+08 GJ in 2011, and then drops to 2.01E+08 GJ in 2012.

3.2 Embodied energy in exports

3.2.1 Regional analysis

[Insert Figure 3]

Hong Kong's embodied energy in service trading export with its major trading partners is described in Figure 3. Analyzed by region, Mainland China is also the largest export destination for embodied energy in Hong Kong's service trade and the values are changed from 2.85E+08, 3.41E+08 to 3.64E+08 GJ in 2010, 2011 and 2012, respectively. This presents an increasing trend, which shows Hong Kong's growing competitive advantage to Mainland China. The second largest export destination is Japan with the embodied energy of 1.84E+08, 1.76E+08 and 1.73E+08 GJ during 2010-2012. They are followed by the USA (with the embodied energy of 9.23E+07, 8.65E+07, and 8.84E+07 GJ during 2010-2012), the UK (with the values of 8.27E+07, 8.74E+07, and 7.96E+07 GJ), and Taiwan (with the values of 7.09E+07, 7.09E+07, and 6.62E+07 GJ), which are also the main destinations of exported service trade in Hong Kong. Hong Kong's industrial export to Japan is unrestricted by the import and

many Japan companies have set the regional headquarters in Hong Kong to do the bilateral trade activities.

3.2.2 Industrial analysis

[Insert Figure 4]

Amongst various export service components, Sector 3 (Transport) and Sector 4 (Travel) embody the first and second largest volumes of energy in service trade. The export destinations of Sector 3 (Transport) are Mainland China and Japan. While for Sector 4 (Travel), Mainland China is the main destination in export, which can be attributed to individual visit scheme of the allowance of travelers in Mainland China to visit Hong Kong since 2003. Compared with these two sectors, the other sectors have a relatively little effect on the embodied energy in Hong Kong's export.

The sectoral embodied energy in export shows the winds of change during 2010-2012. The exported embodied energy of Sector 3 (Transport) increases from 4.79E+08 GJ in 2010 to 4.87E+08 GJ in 2011, and then drops to 4.67 E+08 GJ in 2012. There is an increasing trend for the embodied energy in Sector 4 (Travel), ranging from 1.61E+08 GJ to 2.04E+08 GJ, and finally to 2.35E+08 GJ during the period of 2010-2012. This can be explained by the increasing numbers of Mainland visitors to Hong Kong, which has greatly boosted the tourism industry.

3.3 Embodied energy in trade balance

[Insert Figure 5]

[Insert Table 2]

Figure 5 depicts Hong Kong's embodied energy in service trade balance with its major trading partners. Table 2 shows the distributions of EEI, EEE and EEB in Hong

Kong's service trade by region. For these five regions, Hong Kong plays two opposite roles, i.e., the net importer and net exporter. Hong Kong mainly receives net embodied energy import from Mainland China and the USA. Energy embodied in net import from Mainland China shows a decreasing trend with the values of $1.99\text{E}+08$, $9.50\text{E}+07$ and $7.09\text{E}+07$ GJ from 2010 to 2012. By comparison, the value of EEB is less than the values of EEE and EEI, because re-exporting has become a significant component of Hong Kong's trade since the early 1980s, when its large and labor-intensive industries began to move to Mainland China. Hong Kong imports $9.49\text{E}+07$, $1.12\text{E}+08$ and $1.09\text{E}+08$ GJ embodied energy from the USA over the period of 2010-2012. By contrast, Hong Kong supplies net embodied energy export to Japan, the UK and Taiwan. The embodied energy in net export from Hong Kong to Japan shows a downward trend, which drops from $1.42\text{E}+08$, $1.30\text{E}+08$, to $1.18\text{E}+08$ GJ during 2010-2012. Hong Kong is also the net exporter as for the UK with the embodied energy of $4.81\text{E}+07$, $3.63\text{E}+07$ and $4.13\text{E}+07$ GJ. Taiwan is another important main destination of exports of services in Hong Kong and it has exported $3.23\text{E}+07$, $2.52\text{E}+07$ and $1.54\text{E}+07$ GJ embodied energy.

4. Discussions

4.1 Key impact factors of embodied energy of trading service in Hong Kong

With virtually no direct energy consumption, service industries' embodied energy plays a unique role in the urban energy evaluation system. It is important to find that two key factors have great influences on the embodied energy of service industries. Firstly, the change of trade structure will trigger the change of indirect energy consumption in and out the city boundary. Therefore, how to control the import of high-intensity service industry is a very critical problem for Hong Kong as an important free trade zone. Secondly, the energy strategies of major trading partners have close relations with the embodied energy of service industries in the concerned

area. With the urban character of high dependence, the consumed goods/services in Hong Kong greatly depend on the outside world, which will cause the direct energy consumption outside the city boundary. The energy strategies of major trading partners will in turn impact the embodied energy in Hong Kong.

4.2 Policy implications

To alleviate the pressure of energy shortage in Hong Kong, policy makers can look into both aspects of new energy strategy at home and the control of foreign trade. That is, Hong Kong should not only strive to develop its own new energy systems, but also develop trade policies to ensure energy security on the basis of embodied energy accounting in the whole life-cycle production chain. For example, as the largest trade partner, Mainland China has helped alleviate energy pressures for Hong Kong. In return, Hong Kong needs to contribute high-tech and/or financial support to the improvement of energy efficiency in Mainland China, since energy intensities of commodities/services produced in Mainland China have a deeply influence on the embodied energy in Hong Kong by means of international trade. Industrial structure adjustment is also an important way to achieve urban sustainability. Because industrial sectors of Manufacturing services, Transport and Travel contribute most significantly to embodied energy in Hong Kong, they should become the priority areas to target big consumers and facilitate energy reform. Energy labelling programs can also be implemented to shift trading market from economic-interest-orientated to environmental-interest-orientated. This study has provided basic data in support of these programs.

4.3 Limitations of this study

In spite of much effort, it remains that the trading data was incomplete and the analysis did not yield the full results. Many countries in the world have established trading

relations with Hong Kong. However, due to the limited statistics available, this study only analysed Hong Kong's top five trading partners. More trade statistical data needs to be collected in the future for this study to present more complete pictures. Future studies can also delve into issues with closer connections to policy making in Hong Kong such as energy related taxation strategies.

5. Conclusions

As a global free trade centre, Hong Kong's economy is highly dependent on the rest of the world. International trade is the most important economic activity in Hong Kong and involves significant levels of embodied energy. This forms an important part of the equation for sustainable urban development. For the first time, this research presents a systematic assessment of Hong Kong's embodied energy in its service trade based on an input-output modeling of statistical data. The results reveal the temporal trend of Hong Kong's embodied energy in imports, exports and trade balance from the perspectives of region and industry sector. Specific results are as follows:

1) Embodied energy in import - Mainland China and the USA are the two main sources of imports of services in this context. They are followed by the UK, Japan and Taiwan. Industry Sector 1 (Manufacturing services), Sector 3 (Transport), Sector 4 (Travel) and Sector 10 (Other business services) contributed most significantly in this regard.

2) Embodied energy in export - Mainland China and Japan are the two main destinations of exports of services. They are followed by the UK, the USA and Taiwan. Industry Sector 3 (Transport) and Sector 4 (Travel) contribute most significantly in this area of assessment.

3) Embodied energy in trade balance – With five major trading partners, Hong Kong plays two opposite roles according to the embodied energy in trade balance, i.e., net importer and net exporter. Hong Kong mainly receives net embodied energy import from Mainland China and the USA. It supplies most net embodied energy export to Japan, the UK and Taiwan.

To sustain economic growth and deal with urban density, Hong Kong will need to actively respond to the energy challenge due to very limited energy resources of its own. Since Hong Kong's economic structure has changed from manufacture-based to service-based, it's crucial for the government, business and local service industries to learn about the relationship between trade structure, energy transfer and international partners. As an urban open economy, external environment has a great effect on the urban overall embodied energy. Results of this study provide a basic view for the embodied energy transfer situations between Hong Kong and its major trading partners. It will provide a useful reference to future energy related policy making in trading of service, industry sector reform and business partnerships.

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