Carbon emission of global construction sector

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Abstract:

The construction sector delivers the infrastructure and buildings to the society by consumption large amount of unrenewable energy. Consequently, this consumption causes the large emission of CO_2. This paper explores and compares the level of CO_2 emission caused by the construction activities globally by using the world environmental input-output table 2009. It analyses CO_2 emission of construction sector in 40 countries, considering 26 kinds of energy use and non-energy use. Results indicate: 1) the total CO_2 emission of the global construction sector was 5.7 billion tons in 2009, contributing 23% of the total CO_2 emissions produced by the global economics activities. 94% of the total CO_2 from the global construction sector are indirect emission. 2) Gasoline, diesel, other petroleum products and light fuel oil are four main energy sources for direct CO_2 emission of global construction sector. The indirect CO_2 emission mainly stems from hard coal, nature gas, and non-energy use. 3) The emerging economies cause nearly 60% of the global construction sector total CO_2 emission. China is the largest contributor. Moreover, the intensities of construction sector's direct and indirect CO_2 emission in the developing countries are larger than the value in the developed countries. Therefore, promoting the development and use of the low embodied carbon building material and services, the energy efficiency of construction machines, as well as the renewable energy use are identified as three main pivotal opportunities to reduce the carbon emissions of the construction sector.

Key words: Construction sector, Direct carbon emission, Indirect carbon emission, Energy use, Non-energy use

Abbreviations[1]:

ETP15: Energy Technology Perspectives 2015

EU-27: European Union 27 member states

OECD–P: OECD Pacific countries, including Australia, Japan, and South Korea

OME: Other main emerging economies, including Brazil, Indonesia, Mexico, and Turkey

RoW: Rest of the world

WIOD: World input-output database

HCOAL: Hard coal and derivatives

BCOAL: Lignite and derivatives

COKE: Coke

CRUDE: Crude oil and feed stocks

DIESEL: Diesel oil for road transport

GASOLINE: Motor gasoline

JETFUEL: Jet fuel (kerosene and gasoline)

LFO: Light Fuel oil

HFO: Heavy fuel oil

[1] The 26 energy commodities are defined by WIOD, more detailed information see http://www.wiod.org/publications/source_docs/Environmental_Sources.pdf (page 67)

NAPHTA: Naphtha

OTHPETRO: Other petroleum products

NATGAS: Natural gas

OTHGAS: Derived gas

Ren-ENERGY: Renewable energy

Austria: AUT

Belgium: BEL

Bulgaria: BGR

Cyprus: CYP

Czech Republic: CZE

Germany: DEU

Denmark: DNK

Spain: ESP

Estonia: EST

Finland: FIN

France: FRA

United Kingdom: GBR

Greece: GRC

Hungary: HUN

Ireland: IRL

Italia: ITA

Lithuania: LTU

Luxembourg: LUX

Latvia: LVA

Malta: MLT

Netherlands: NLD

Poland: POL

Portugal: PRT

Romania: ROU

Slovak Republic: SVK

Slovenia: SVN

Sweden: SWE

1. Introduction

The built environment, including buildings and infrastructure, is the fundamental component of the economic and social development. Naturally, the built environment involves the large quantities of material and energy consumption. For example, the buildings sector consumes about 40% of primary energy utilization [1]. Life cycle energy consumption of build environment can be divided in two: 1) operational energy - the energy used for the occupation/operation of buildings (including heating/cooling, ventilation, hot water, etc.); 2) embodied energy –the energy used for the construction, maintenance, renovation, and demolition of built environment [2]. For the occupied built environment, the operating energy accounts for about 80% of the total energy use [3]. Therefore, the analysis of the operational energy and its related carbon emission have dominated building energy research for many years when compared to the analysis on the embodied energy. More recently, the significant role of embodied energy and emissions has been recognized [2, 4-23]. This is because of two facts. Firstly, the percentage of operational energy and its related carbon emissions are expected to decrease in the future, due to the implementation of more energy efficient building technologies, more advanced and effective insulation materials, and more energy efficient equipment and appliances [3, 24]. Secondly, for the 'unoccupied' built environment such as road, bridges and other infrastructure, embodied emissions accounts for over 90% of life cycle emission [25-27].

The embodied energy includes 1) direct energy - the energy required for the on-site construction operations (construction, maintenance/renovation, demolition); 2) indirect energy - the energy required to providing products and services for the construction operations. Until now, both the direct and the indirect energy used in the construction sector are mostly from the unrenewable resource. Consequently, with increased attention to issues of sustainable development, many GHG emissions' mitigation policies have targeted the built environment [17, 28-30]. A number of studies have displayed the importance, and potential mitigation policies for carbon emission of the built environment. Studies focusing on the embodied carbon emissions of built environment have two main types. 1) micro level studies mainly using life cycle assessment [2, 6, 10, 27, 31-35], 2) national level studies mainly using input-output analysis, including USA [14], Australia [36], China [18, 37], Ireland [4], Norway [15], etc.. Nevertheless, the literature study leading up to this paper revealed almost no contributions that display the global map of CO_2 emission stemming from the construction sector. The comparison of carbon emission of construction sector globally will help people to identifying the responsibility of climate change mitigation. This observation, obviously, emphasizes the needs to assessing carbon emission of construction projects at the global level. Therefore, this study aims to answer these two questions:

1) What is the level of CO_2 emission produced by the global construction sector?
2) What are the hot spots and improvement opportunities of the global construction sector?

In order to answer these two questions, this study conducts input-output analysis based the world input-output table in 2009[2]. The study considers 40 countries and 26 kinds of energy. It analyses the CO_2 emission produced by energy use and non-energy use for the global construction sector.

The paper is organized as follows. Section 2 outlines the development of models and the source of data. Section 3 explains the main results of the analysis. Section 4 discusses the potential mitigation of construction sector to the global CO_2 emission. Section 5 concludes the findings.

[2] The WIOD has provided world input-output table for 2011. However, the data on energy and carbon are only available until 2009. Therefore, the 2009 situation is discussed here.

2. Method and data

2.1 Input-output model

According to Miller and Blair [38] , the final total emission intensity matrix ‘‘E’’ was calculated by

$$E = S(I - A)^{-1} \tag{1}$$

Where A is the technical coefficient matrix, I is the identity matrix, and S is the satellite matrix. The satellite matrix ‘‘S’’ includes direct CO_2 emission intensity in different energy source and non-energy use. The matrix ‘‘E’’ is the inventory of CO_2 emission by different energy and non-energy source of the construction sector economic output. For the calculations, the world Input-output table (WIOD) is used for matrix A and for the final total output of the construction sector.

2.2 Data

The data used in this study is newly released the world input-output database (WIOD) [39, 40]. It was built on national accounts data, which was developed within the 7th Framework Programme of the European commission. Detailed world input-output tables include 34 sectors in 40 countries and rest of the world (RoW). The main advantages of the WIOD with respect to previously available data sources are: 1) it allows to describe and analyse carbon emission of construction activities at the global level, since the data collection is consistent and fully comparable across countries. 2) Due to the lack of CO_2 emission data for imported products for national input –output table, the default method assumes the same air emission intensity for both the import and domestic products associated to each sector [38, 41]. The WIOD makes it possible to eliminate the disadvantage of such assumption.

The direct CO_2 emission data for this analysis is obtained from two sub-database in WIOD: the CO_2 emission data and the emission relevant energy use data. These two data source are accompanying satellite accounts to the WIOD database [40, 42]. The CO_2 emission (measured as Kilotons) are disaggregated across 26 energy carriers and non-energy use. To measuring of sectorial economic activity, the paper considers the gross output, which is expressed in monetary units in million US$ (2009 current price).

For the sake of simplicity, the paper explains the detailed country results to eight regions: China, the European Union (27 member states, EU-27), India, OECD–Pacific (including Australia, Japan, and South Korea, OECD-P), other main emerging economies (including Brazil, Indonesia, Mexico, and Turkey, OME), Russia, the U.S., and the RoW (rest of the world).

3. Results

This section provides, firstly, an overview over the CO_2 emission of global construction sector, including the main contributors of such emission. Secondly, it displays the detailed information of different regions.

3.1 Global CO_2 emission and relevant energy consumption

The total CO_2 emission of global construction sector is 5.7 billion tons in 2009, equalling to 23% CO_2 emission of the global economics activity. The intensity of total CO_2 emission of global construction sector is 0.67 kilotons/ million US$. This is much larger than the average value of global economics activities (0.22 kilotons/ million US$).

Figure.1 (a, b) and Figure.2 (a, b) illustrate the results for the CO_2 emission and its intensities of construction activities in eight regions. The largest CO_2 emission of the global construction sector have taken place in China. Around 23% direct CO_2 emission, 42% indirect CO_2 emission and 41% total CO_2 emission of world construction activities stem from China. EU-27 is the second largest direct CO_2 emission contributor (18%), and the US is the third one (13%). EU-27 is also the second largest indirect CO_2 emission contributor (10%), and the India is the third one (8%). Most developed countries contribute more direct CO_2 emission than indirect one. As a result, EU-27, India, OECE-P, OME, Russia, US and the RoW contribute to around 10%, 8%, 7%, 4%, 3%, 6% and 20% of the total carbon emission of global construction sector in 2009, respectively. China, India and Russia have larger CO_2 emission intensity than other regions/countries and average world value, especially indirect CO_2 emission intensity. Equally, the intensity of the direct CO_2 emission, the indirect CO_2 emission and the total CO_2 emission of construction sector in EU-27 is lowest one in the world.

Figure.3 (a, b) explores the resources for the CO_2 emission of global construction sector. The four main resources of direct CO_2 emission of the global construction activities are Gasoline (22%), diesel (19%), other petro (OTHPETRO) (18%), and liquid fuel oil (LFO) (17%). There is less than 1% of direct CO_2 emission produced by non-energy resource. The hard coal (HCOAL) is the largest producer of indirect CO_2 emission (48%). 63% of this HCOAL produced indirect global construction sector CO_2 emission is generated in China. Nature gas (NATGAS) is the second largest energy resources of the indirect CO_2 emission of the global construction sector (13%). Equally, 15% of indirect CO_2 emission stem from non-energy use, mainly because of the production of cement. Consequently, the HCOAL, nature gas and non-energy use are three main resource of total CO_2 emission in global construction sector. Results also show that the contribution of renewable resources to the energy use in global construction sector is tiny, with less than 0.1% of direct energy use and less than 6% of total one.

3.2 Regional CO_2 emission and relevant energy consumption

3.2.1 China

Figure.4 (a, b) displays the direct and indirect CO_2 emission of Chinese construction sector in 2009, including the resources of emission. In china, total CO_2 emission of construction sector is nearly 2.4 billion tons, accounting to 38% of national economic activities' CO_2 emission. Comparatively, the total output of Chinese construction sector contributed around 9% of national total economic output. As a result, the intensity of total CO_2 emission of Chinese construction sector (1.7 kilotons/millions US$) is much larger than average value of Chinese economics activities (0.41 kilotons/millions US$). The direct CO_2 emission only represents 3% of the total CO_2 emission of Chinese construction sector. Equally, the intensity of direct CO_2 emission of Chinese construction sector is 0.05 kilotons/millions US$. This indicates that CO_2 embodied in building materials are the dominate part. Moreover, 27% of the inputs to Chinese construction sector is imported products. Main imported goods to Chinese construction sector is equipment and machine from Germany, Japan and South Korea. However, all imported goods to Chinese construction sector only account to 5% total CO_2 emission of this sector. On the other hand, unlike other production in China, there are very few (less than 0.5%) construction products to be exported. This means that most of these huge CO_2 emissions are produced and consumed domestically.

The main energy resources of direct CO_2 emission of Chinese construction sector are OTHPETRO (50%), LFO (18 %), HCOAL (18%) and diesel (8%). Equally, the HCOAL caused 72% indirect emission and 70.1% total one of Chinese construction activities. This ranks that HCOAL is the largest resource of total CO_2 emission of Chinese construction sector. Equally, Second largest contributor are non-energy use, mainly owing to the process of cement production. This also indicate that larger intensity of total CO_2 emission of Chinese construction sector is the result of the coal dependent Chinese energy mix. This finding is different from the previous study done by Chang (2010), which showed that coke is the main energy of carbon emission from Chinese construction sector. This could be the results of different data source and energy classification, because the coke is usually made from the coal.

3.2.2 EU-27

Figure.5 (a, b) and Figure.6 (a, b) indicate the direct and indirect CO_2 emission of EU-27 construction sector in 2009 by countries and resources. In EU-27, the construction sector contributed 7.7% total economics gross output in 2009. The total CO_2 emission of EU-27 construction sector is 579 million tons, accounting to 18% of total CO_2 emission produced by EU-27 economic activities. This is less than Chinese value. On the other side, the contribution of direct CO_2 emission to the total one in the EU-27 construction sector is 10%. This is larger than the one in China (3%). Consequently, the contribution of the indirect CO_2 emission to the total CO_2 emission of construction sector in EU-27 (90%) is less than the value in China (97%). This is mainly because of less new construction in EU-27.

For direct CO_2 emission of EU-27 construction sector, the four main contributors are UK (16%), Germany (14%), France (12%) and Spain (8%). This is reasonable, because these four countries are the four large economics in EU-27. Equally, the four largest contributor to indirect CO_2 emission of EU-27 construction sector are Spain (17%), Germany (13%), Italy (11%) and France (10%). This could be the results of the fact that Spain and Italy contribute 19% and 12% to total no-energy purpose CO_2 emission in EU-27 construction sector, respectively. These values are more than other EU-27 countries. Consequently, Spain (17%), Germany (13%), Italy (11%), France (10%) and UK (9%) are five largest contributor of total CO_2 emission of EU-27 construction sector. However, the largest intensities of direct CO_2 emission of the EU-27 construction sector are Bulgaria (0.1 kilo tons/ million US$), Romania (0.1 kilo tons/ million US$), and Estonia (0.08 kilo tons/ million US$). The largest intensities of indirect are Bulgaria (0.7 kilo tons/ million US$), Spain (0.5 kilo tons/ million US$), and Poland (0.04 kilo tons/ million US$). Obviously, the intensity of direct and indirect CO_2 emission of construction sector in these lower income countries are larger than those higher income countries in EU-27.

Unlike to China, the main resources of direct CO_2 emission of EU-27 construction sector are diesel (33%). and LFO (17%). Moreover, non-energy use (21%), Nature gas (20%) and the HCOAL (19 %) are three main resources of indirect emission of EU-27 construction sector. Different from china, HCOAL is not the dominate resource of carbon emission of construction sector in the EU-27. The electricity (14%), HCOAL (12%), Diesel (9%) and nuclear (8%) are four main energy resources of total CO_2 emission of the EU-27 construction sector. This means that the contribution of renewable energy in EU-27 is larger than the average global value.

3.2.3 India

Figure.7 (a, b) indicates the direct and indirect CO_2 emission of India construction sector in 2009 by resources. In India, the total CO_2 emission of construction sector is 444 million tons, accounting to 30 % of total CO_2 emission stemming from national economic activities. Less than 3% of these 444 million tons CO_2 is produced directly from construction activities. Equally, the Indian construction sector contributes 12% total economics gross output. Consequently, the direct intensity of total CO_2 emission of Indian construction sector (0.04 kilotons/millions US$) is much less than average value of Indian economics activities (0.6 kilotons/millions US$), but the intensity of total CO_2 emission of Indian construction sector (1.5 kilotons/millions US$) is much larger.

Nearly 14% inputs to the India construction sector are imported. Main imported goods to Indian construction sector is metal products from Austria, and Canada. Equally, all imported goods to Indian construction sector only accounts to 6 % total CO_2 emission of this sector. Equally, India do not export the construction products/service.

Similar to EU-27, the main resources of direct CO_2 emission of Indian construction sector are LFO

(44%) and diesel (27%). Similar to China, the HCOAL are the dominate resources of indirect and total CO_2 emission of Indian construction sector. The HCOAL produces 66% indirect CO_2 emission and 64% total one. Equally, the second largest contributor are non-energy use (14%), mainly due to the cement production.

3.2.4 OECD-Pacific

Figure.8 indicates the direct and indirect CO_2 emission of OECD-Pacific construction sector in 2009 by resources and countries. The total CO_2 emission of construction sector in these three OECD-Pacific countries is 407 million tons. 9% of this total CO_2 emission is the direct emission. Similar to EU-27, the construction sector accounts to 8 % of total output of the total regional economics activities. However, the direct and indirect CO_2 emission intensities of OECD-Pacific construction sector are larger than the values in EU-27. As the result the intensity of total CO_2 emission of OECD-Pacific construction sector is nearly 1.5 times value of EU-27 one. Japan are the largest contributor to the direct and indirect CO_2 emission of the OECD-Pacific construction sector, with smallest intensities of indirect CO_2 emission (0.26 kilo tonnes/ million US$). The intensity of direct CO_2 emission of construction sector in Australia is 0.1 kilo tonnes/ million US$, as the smallest one in the OECD-Pacific countries. The construction sector of South Korea, however, has the largest direct and indirect CO_2 emission intensities. This could be the result of the more use of OTHEPETRO and HCOAL in the Korean construction sector.

The main resources of direct CO_2 emission of OECD-Pacific construction sector are LFO (32%), Coke (23%) and diesel (10%). Direct CO_2 emission of Australian construction sector mainly stems from LFO (38%), Gasoline (26%) and diesel (24%). Equally, direct CO_2 emission of Japan construction sector mainly stems from the Coke (32%) and LFO (32%). Similar to Australia and Japan, LFO (28%) is the largest resource for direct CO_2 emission of South Korean construction sector. However, waste are the second largest resource for direct CO_2 emission of South Korean construction sector. This is quite different from all other developed countries.

HCOAL, non-energy use and Nature gas are the three largest contributor to the indirect CO_2 emission of OECD-Pacific construction sector, responsible for 32%, 14% and 13% respectively. Contribution of HCOAL to the indirect CO_2 emission of Japanese construction sector is smaller than other two countries. That is why Japanese construction sector has the lowest to indirect CO_2 emission intensity. The inputs to Australian, Japanese and South Korean construction sector require 8%, 8% and 16% imported goods/service, respectively. One fourth of international inputs to the South Korean construction sector are from China, especially buildings materials. This is another reason that why the construction sector of South Korea has the largest indirect CO_2 emission intensities than other OECD-Pacific countries.

3.2.5 OME

OME (other major emerging economies) includes Brazil, Indonesia, Mexico and Turkey. Figure.9 (a, b) indicates the direct and indirect CO_2 emission of OME construction sector in 2009 by resources and countries. The total CO_2 emission of construction sector in these four emerging economies are 238 million tons, accounting 20% of total CO_2 emission from total regional economic activities. The direct emission contributes 16% of this total CO_2 emission of OME construction sector. This contribution is the largest compared with all other regions and countries in this study. Moreover, the direct and indirect CO_2 emission intensities of OME construction sector are larger than the values in EU-27 and OECD-Pacific. As a result, the intensity of total CO_2 emission of OME construction sector are nearly double value of EU-27 situation.

The largest contributor of direct and indirect CO_2 emission of the OME construction sector is Indonesia. Consequently, Indonesia cause 43% total CO_2 emission in the OME construction sector.

On the other hand, the intensities of direct and indirect CO_2 emission of Turkish construction sector are the largest among in these four countries. The intensity of direct CO_2 emission of Turkish construction sector is also the largest among all these 41 countries in this study. This is the result of larger HCOAL (60%) use directly. Equally, 74% of Indonesian construction sector direct CO_2 emission stem from OTHPETRO. Diesel (75%) is the dominate energy resources to the direct CO_2 emission of Brazilian construction sector. The direct CO_2 emission of Mexican construction sector are mainly caused by the using Gasoline (50%) and diesel (20%). Correspondingly, the main resources of direct CO_2 emission of OME construction sector are OTHPETRO (30%), Gasoline (19%), diesel (17%) and HCOAL (16%). However, due to the large indirect use of HCOAL in the Indonesian construction sector, HCOAL is the largest energy resources to the total CO_2 emission of OME construction sector, with 23.8%. Non-energy and Nature gas use are another two large contributor to the total CO_2 emission of OME construction sector, responsible for 18% and 17% respectively. This is similar to OECD-pacific. Brazilian, Indonesian, Mexican and Turkish construction sector have 8, 18%, 21% and 17.6% input from international trade, respectively. The main imported inputs to Brazilian and Mexican construction sector is USA. Half of the imported inputs to the Mexican construction sector are from USA. China is the main contributor to the imported inputs for the Indonesian construction sector, while Germany is the main contributor to the imported inputs for the Turkish construction sector.

3.2.6 Russia

Figure.10 (a, b) indicates the direct and indirect CO_2 emission of the Russian construction sector in 2009, including the resources of emission. The total CO_2 emission of the Russian construction sector is 194 million tons. Nearly 4 % of this CO_2 emit directly by the Russian construction sector. This is similar to India and China. This also indicate that indirect CO_2 emission are the dominate part. 8% of inputs to Russian construction sector are from imported products/service. Nearly 20% of these imported inputs come from Germany, epically machine. All these international inputs only cause 3% of the total CO_2 emission in the Russian construction sector. Furthermore, the intensity of direct CO_2 emission of Russian construction sector is 0.05 kilotons/millions US$, close to the value in China. Equally, the intensities of indirect and total CO_2 emission of Russian construction sector are some less than the values in China and India.

The main resources of direct CO_2 emission of the Russian construction sector are Gasoline (32%), LFO (26%), Nature gas (24%) and diesel (10%). The use of Nature gas emit 40% indirect CO_2 emission of Russian construction activities. Therefore, the nature gas is the largest resource of total CO_2 emission of the Russian construction sector. Equally, the second largest contributor to this total emission is non-energy use (26%).

3.2.7 USA

Figure.11(a, b) indicates the direct and indirect CO_2 emission of the U.S. construction sector in 2009, including the resources of emission. The total CO_2 emission of the U.S. construction sector is 361 million tons. Similar to EU-27 and OECD- Pacific, the direct CO_2 emission contributes 12% of this total emission. 11% of the inputs to the U.S. construction sector is from imported products/service. Moreover, the imported inputs response to 17% indirect CO_2 emission of the USA construction sector. 31% of these imported indirect CO_2 emission are from China, even there are only 10% of those imported inputs are from China.

The main resources of the direct CO_2 emission of the U.S. construction sector are Gasoline (78%), and diesel (15%). Equally, HCOAL (31%), Nature gas (22%) and non-energy use (17%) are main resources for indirect CO_2 emission of the U.S. construction sector. Correspondingly, HCOAL, Nature gas and Gasoline are three main energy resources to the total CO_2 emission of the U.S.

construction sector.

4. Discussion

Table 1 presents the intensities of carbon emission and emissions related energy of the global construction sector. Obviously, the unrenewable energy use is main source of carbon emissions in construction sector.

4.1 Carbon emission from energy use

The global construction sector creates 315 million tons direct CO_2 emission, representing 5.5% the total CO2 emission of this sector. 99.5% of the direct energy use in the global construction sector are fossil fuel. This fossil fuel is mainly used for the on-site construction operation, specially the operation of construction machines and equipment. It has been shown that emission of CO_2 is increased while the engine of non-road diesel construction equipment is idling [43]. Therefore, the improving of the energy efficiency and optimizing the operation of the construction machines is identified as a room for significantly reducing the direct carbon emission [7, 44, 45].

The findings also clearly indicate that the indirect carbon is the dominate part. The un-renewable energy resource (85%) and non-energy use (14%) are two main producer of this indirect CO_2 emission. Only 6% of the indirect energy use in the global construction sector are renewable energy. Buildings materials is recognized as the most important part for indirect carbon emissions in the construction sector [9, 10]. There is less than 10% imported inputs to construction sector in most countries. However, the imported products from countries with higher carbon intensity result the more carbon embodied in the domestic construction sector. Moreover, the extraction, production and distribution of buildings are operated with the international supply network. Thus, adopting fewer carbon-intensive building materials requires information transparency on embodied carbon at global level.

Apart from the increasing the energy efficiency, energy mix is another important factor of carbon emissions. Therefore, on the view of emission's resources, the policies should emphasize on improving the blend of renewable energy, including renewable power generation and biofuel for heavy construction and transportation equipment. According to the new released IEA energy technology perspective 2015, the carbon intensity of primary energy have to be reduced around 60% by 2050 compared with today [46]. Thus, the policy to encourage the innovation of the low carbon energy is urgent for the mitigation of global warming. This is special for the emerging economies, because they are the main new construction market in the world now. The OECD countries can engage the activities in the emerging economy low carbon initiatives.

Researchers have been striving to devise strategies and policies to mitigating carbon stemming from construction activities [4, 14]. Many developed countries have been prompting the construction sector to change their carbon intensive ways of operations [36, 47]. The results indicate that the emerging economies is the main contributor to the total carbon of the global construction sector, especially China. They have policies on the national carbon mitigation. They also ad but not declare clear action plan on carbon mitigation of construction operations. Worse still, these emerging economies will be keeping as the main part of global construction activities in the foreseen future. In this regard, these emerging economies will work as a tremendously important role of carbon-mitigation on global construction sector.

4.2 Carbon emission from non-energy use

The 14% non-energy use CO_2 emission is mainly owe to the cement production. Cement production is an energy and carbon-intensive process, due to the calcination of limestone and the combustion of fuels. Strategies and potentials toward CO_2 emissions reduction in cement plant include energy saving, carbon separation, as well as utilizing alternative materials [48]. Several studies tried to address the CO_2 emission and energy efficiency issues for different regions of the world [49-55]. However, it looks not enough for 2 degree global warming scenario according to the ETP15 [46]. For example, the recent study in EU cement industry indicated an improvement in the thermal energy efficiency and the CO_2 emissions per tonne of clinker respectively of 11% and 4% in 2030 compared with the level of 2002 in the baseline scenario [52]. CCS (carbon capture and storage) is identified as one of key for the decarbonisation in cement and energy industries [46, 48, 52]. However, there are only 13 large scale CCS projects across five sectors by the end of 2014 [46]. For cement industry, CCS have been pilot tested but not demonstrated at the commercial scale. Policies need to be developed to deal with the various barriers and challenges for CCS, especially in term of economic factors and legislation.

5. Conclusion

Using the input-output analysis on energy related carbon emissions of 41 countries and regions construction sector with the world input-output table 2009, this paper reveals that:

1) 5.7 billion tons CO_2 emission (23% of the global economics activity) embody in the global construction sector in 2009. The indirect CO_2 emission is the dominate part (94%) of this total one. It is not unreasonable to look the construction is one of the global most significant carbon emitting sector.
2) Gasoline, diesel, OTHPETRO and LFO are four main energy sources for direct CO_2 emission of global construction sector. The indirect CO_2 emission mainly stems from HCOAL, Nature gas, and Non-energy use. The renewable resource response to less than 6% of total embodied energy in the global construction sector.

3) The emerging economies cause nearly 60% of the global construction sector total CO_2 emission. China is the largest contributor. Moreover, the intensities of direct and indirect CO_2 emission from construction sector in the developing countries are larger than the value in the developed countries. Turkish construction sector has the largest intensity of direct carbon emissions. Equally, Chinese construction sector has the largest intensity of indirect carbon emissions.

4) Developing and using low embodied carbon building material and services at life cycle perspective, increasing the energy efficiency of construction machines, as well as promoting the renewable energy use are identified as three main pivotal opportunities to reduce the carbon emissions of construction sector. Specially, emerging economies need to make greater efforts to develop, promote and enforce more low-carbon technologies/purchasing in their constructions.

Acknowledgements

The authors also acknowledge the anonymous referees for the constructive suggestions.

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