CARBON FOOTPRINT FOR HOSTEL CONSTRUCTION USING INDUSTRIALISED BUILDING SYSTEM IN PAUH PUTRA, PERLIS

by

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LIST OF ABBREVIATIONS

GHGs	Greenhouse Gases
CO_2	Carbon Dioxide
tCO_2e	Tonnes Carbon Dioxide Equivalent
IBS	Industrialised Building System
PSP	Prefabricated sandwich panel
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
CIDB	Construction Industry Development Board
ISO	International Organization for Standardization
CIMP	Construction Industry Master Plan
EPD	Environmental Product Declaration
EMSD	Electrical and Mechanical Services
IPCC	Intergovernmental Panel on Climate Change
EIA	Energy Information Administration
WRI	World Resources Institute
WBCSD	World Business Council for Sustainable Development
BSI	British Standard Institution
MMC	Modern Method of Construction
OPC	Ordinary Portland Cement
EPS	Sintered Expanded Polystyrene
CNC	Computer Numerical Control
CFCs	Chlorofluorocarbons
PSM	Single Panel
PDM	Double Panel
FP	Floor Panel
DEFRA	Department for Environmental Food and Rural Affairs

LIST OF SYMBOLS

L	Liter
kW/h	Kilowatt per hour
kg	Kilogram
km	Kilometer
E_i	Embodied carbon emissions due to electricity used
E_q	Purchased electricity quantity from power company
f_i	Embodied emission factor of electricity
CF_{EEM}	Carbon footprint of embodied energy of materials
M_q	Materials quantity
f_e	Embodied emission factor of material
F_c	Fuel mass consumption
t	Operation hour
R_e	Rating of engine
R_c	Fuel mass consumption rate
CF_{EEF}	Carbon footprint of fuel energy of machinery
CO_{2DF}	Carbon dioxide equivalent factor of diesel
CF	Total carbon footprint
˚C	Celsius

JEJAK KARBON UNTUK PEMBINAAN ASRAMA MENGGUNAKAN SISTEM BANGUNAN INDUSTRI DI PAUH PUTRA, PERLIS

ABSTRAK

Pelepasan karbon dioksida (CO_2) daripada sektor pembinaan telah dianggarkan menyumbang hampir 50% daripada jumlah pelepasan global. Mengenal pasti sumber pelepasan tersebut dan memahami fungsi dan hubungannya ke atas aktiviti pembinaan adalah penting untuk mengurangkan krisis global. Penyelidikan yang berterusan telah dimulakan untuk mengurangkan dan membasmi masalah pelepasan karbon, terutamanya dalam industri pembinaan. Kajian ini menilai jejak karbon jentera-jentera utama dan bahan yang digunakan dalam pembinaan sebuah asrama lima tingkat yang melaksanakan kaedah Sistem Bangunan Industri (IBS) di Perlis, Malaysia. Rangka kerja penilaian kitaran hayat (LCA) digunakan dalam menjalankan LCA separa dari pra-reka bentuk kepada fasa pembinaan. LCA dilaksanakan mengikut empat langkah iaitu, definisi matlamat dan skop, analisis inventori, penilaian kesan dan tafsiran. Ia juga digunakan sebagai kaedah untuk menganalisis secara sistematik penilaian alam sekitar. Keputusan menunjukkan bahawa asrama lima tingkat di Pauh Putra, Perlis telah memperoleh skor IBS sebanyak 73.4%. Kawasan tumpuan jejak karbon tidak langsung datang dari kilang pembuatan panel sandwic pasang siap, terutamanya yang dihasilkan oleh mesin dandang. Semasa proses ini, 4.52 tan CO_2e jejak karbon dihasilkan oleh mesin dandang. Ini disebabkan oleh tenaga yang banyak digunakan semasa pemanasan stim dan penggunaan enjin yang berkadar tinggi untuk mesin dandang. Simen melepaskan kira-kira 369.04 tan CO_2e jejak karbon langsung. Titik tumpuan jejak karbon langsung adalah disebabkan oleh penggunaan kuantiti simen yang banyak dalam campuran ‘shotcrete’ dan nilai pengekstrakan-pengeluaran pelepasan CO_2 yang tinggi. Sementara itu, keseluruhan bahan-bahan di tapak pembinaan menghasilkan 65.60% daripada jumlah keseluruhan jejak karbon langsung. Manakala, titik tumpuan jejak karbon langsung oleh bahan bakar jentera di tapak pembinaan kebanyakannya daripada penggalian dan pembinaan superstruktur bangunan yang masing-masing menghasilkan 81.59 tan CO_2e dan 86.76 tan CO_2e. Ini disebabkan oleh penggunaan bahan bakar yang banyak dari kedua-dua jentera dalam aktiviti pembinaan harian. Hasilnya, kajian ini boleh digunakan sebagai salah satu contoh kepada banyak pihak untuk memberikan pemahaman yang memadai mengenai impak pembinaan IBS kepada pelepasan karbon di Malaysia.

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ABSTRACT

Emission of carbon dioxide (CO_2) from construction sector has been estimated to contribute nearly 50% of total global emission. Identifying the sources of emissions and understanding their function and relationship to construction activities are essential if not crucial, in mitigating this global crisis. Sustainability research has been initiated to reduce and eradicate the carbon emissions problem, especially in the construction industry. This study evaluates the carbon footprint of the main machinery and materials used in constructing a five-storey hostel that implemented Industrialised building system (IBS) method in Perlis, Malaysia. A life cycle assessment (LCA) framework is used in conducting a partial LCA from pre-design to construction phase. LCA was performed in accordance with the four-step which is goal and scope definition, inventory analysis, impact assessment and interpretation. It also used as a method to systematically analyse the environment assessment. Results showed that the five-storey hostel in Pauh Putra,Perlis has obtained a total IBS Score of 73.4%. Theindirect carbon footprint hotspots are coming from prefabricated sandwich panels manufacturing factory, especially one which manufactured by boiler machine. During this process, 4.52 tonnes of CO_2e are released by the machines. This is due to the extensive energy used for steam heating and high engine rating for the boiler. Cement releases about 369.04 tonnes CO_2e. Its direct carbon footprint hotspots are caused by the large quantity of cement used in the shotcrete mixture and its high extraction–production CO_2 emission values. Meanwhile, overall onsite materials generated 65.60% of the total carbon footprint. Whereas, the direct carbon footprint hotspots by the fuel machinery at the construction site were heavily from excavator and construction of building superstructure task, which yields 81.59 tonnes CO_2e and 86.76 tonnes CO_2e, respectively. This is mainly due to the extensive use of both types of machinery in the daily construction activities. These results can be used as one of the samples in many problems to determine an adequate understanding the impact of IBS construction to carbon emissions in Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an overview of the research background. The scope covers the current scenario of greenhouse gases (GHGs), especially CO_2 emission in the IBS factory and construction site. Expected finding from this study are carbon footprint emissions and the embodied energy assessment in terms of tonnes CO_2 equivalent (tCO_2e) in construction site from the operation of the machinery usage and the materials used according to life cycle assessment (LCA). This analysis will be used to analyse the total carbon footprint emission, which most significant machinery and materials components contributing to the emissions can be determined. Thus, the outcomes of this study will be useful to guide all parties involved in the construction industry to understand their responsibility towards minimising GHGs emissions at a construction site. Additionally, this will make the construction industry a green industry that contributes towards better environmental development. In this chapter, the problem statement and the research objectives, as well as the organisation of the study are presented.

1.2 Background of study

Global warming has become one of the most important threats to human life since it could modify health of living beings and environment steadiness (Gutierrez et al., 2016). Global warming is caused by greenhouse gas (GHGs), especially CO_2 emissions (hereinafter interchangeably used with carbon emissions), continuously threats the existence of human and ecological environment and has caused a series of global concerns, such as rising sea levels, crop failures, desertification, and pest proliferation. Emissions of CO_2 from fossil fuel combustion, in conjunction with that emitted from cement manufacture, are responsible for more than 75% of the increasein atmospheric CO_2 since the pre-industrial 18th century (Solomon et al., 2007). The construction and occupation of buildings are a substantial contributor to global CO_2 emissions, with almost a quarter of total global CO_2 emissions attributable to the energy used in buildings (Metz et al., 2007). A further 5% can be attributed to the manufacture of cement, a principal construction material (Worrell et al., 2001). Reducing the energy demand and consequential carbon emissions attributed to buildings is clearly an important goal for government climate policy (Monahan and Powell, 2011).

Over the years, the construction industry has been stigmatized as labour intensive, dangerous and polluting. The construction activities rely heavily on in-situ construction methods that involved the use of formworks. The output quality is highly dependent on the skilled and semiskilled workers. The industry also has the highest level of accident injuries and fatalities. Construction activities are also inherently harmful to the environment, creating environmental nuisances such as noise, dust, muddy run-offs, and significant amounts of waste (Bari et al., 2012). The adoption of

Industrialised building system (IBS) is strongly advocated in the Malaysian construction industry to reduce construction time as well as the industry's dependence on foreign labour. IBS should be considered as one of the alternativescontributing to a more sustainable building environment in Malaysia. IBS can be defined in all building components such as the wall, slab, beam, column and staircase are mass-produced, either in the factory or on the factory site under strict quality control and minimal wet site activities (Kassim & Walid, 2012).

The Construction Industry Master Plan (CIMP) 2006-2015 highlighted one of the challenges faced by Malaysian construction industry is the availability of cheap foreign labour encourages labour-intensive construction methods over the use of more innovative methods (CIMP, 2006). This hampers the industry's efforts to increase productivity and quality in the long run. Accordingly, the CIMP has recommended the industry to extend the use of modern construction methods and information technology. Specifically, the use of IBS-related systems may help to ease the pressures of labour requirements while boosting quality and productivity.

Various environmental certification systems are being established such as the Environmental Product Declaration (EPD) and thanks to this trend, the quantifiable impact, such as carbon footprint or energy demand, for instance, can be seen on a product's label and in advertisements in daily life. This raises our awareness about environmental problems and leads the competition in the industry. One of the principle techniques to enable the quantification and comparison of the environmental impacts of a product is life cycle assessment (LCA). LCA is a framework for evaluating the environmental impacts of a product, process or service from cradle to grave and is carried out according to International Standards, ISO 14040 (Monahan & Powell, 2011; Sartori & Hestnes, 2007). LCA also can be defined as a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO, 2006).

Therefore, it is important to study the environmental impact from the industry especially in terms of the energy of building materials throughout their life cycle. The environmental impacts of a building's lifecycle - design, raw material extraction, processing, construction, use, transportation and end of life are considerable, especially when design and construction industries, along with owners, have an increasing interest and responsibility for the environmental impacts of buildings.

1.3 Problem statement

There are a lot of researches that has been done by researchers in foreign countries now in order to understand about the impact of emissions released during the construction process towards the environment. The construction of buildings has a very important impact on the environment, and the construction industry is one of the greatest consumers of resources and raw materials (Yan et al., 2010;Dimoudi & Tompa, 2008). Manufacturing and transporting of building materials, and installing and constructing of buildings consume great quantities of energy and emit large amounts of carbon emissions (Yan et al., 2010). So, as we all know many construction companies that do not take seriously about the surrounding environment. They do not know the volume of CO_2released by the machine and material use at the construction site every day can affect the environment.

Industrialization is a socio-economic process through which a society will change from pre-industrialization into industrialization. IBS is mainly a part of wide modernization process through the development of new technologies and production methods (Zabihi et al., 2012). Construction Industry Development Board of Malaysia (CIDB) defined IBS as low tech solutions and other practices which have already become common and not substituting conventional practices. As such, IBS can be interpreted as an approach or process used in making construction less labour-oriented and fastest as well as fulfilling quality concern (Shamsuddin et al., 2013). The wider adoption of IBS is also encouraged as a means to overcome environmental issues associated with conventional methods. However, the construction industry in Malaysia has low acceptance towards IBS due to the resistance to change and also lack of knowledge in this area, causing the benefits of IBS cannot be leveraged entirely. From a survey done by CIDB in 2003, it was found that the percentage usage of IBS in the local construction industry is only at a mere 15% (Setiani, 2009).

Studies which are related to the environmental impact of IBS construction activity is considered very limited, thus causing difficulties in obtaining data in order to propose a solution related toenvironmental problems. Previous research found that most of the studies that have been conducted are focusing on the carbon footprints on materials used at conventional construction site only (Hammond & Jones, 2008; Zabalza et al., 2011). There was lack of study associated with the carbon footprints with regards to the materials and machinery used at the IBS construction site.

1.4 Objectives

This study uses LCA analysis frameworks to measure the total amount of carbon footprint consumption in the manufacturing factory and construction site activity. The objectives of this study are:

i) To identify IBS Content Scoring System (IBS Score) for five-storey hostel construction building.

ii) To measure the total amount of indirectcarbon footprint in prefabricated sandwich panel (PSP) manufacturing factory in regards to machinery usage.

iii) To measure the total amount of direct carbon footprint for materials and machinery during PSP installation in construction site.

1.5 Significance of study

The significance of this study is to analyse the carbon footprint emissions in the PSP construction site according to the LCA based on the materials and machinery used during the building construction. LCA method is used as a guideline to analyse the total carbon footprint emissions and finally determining the most significant materials and machinery in PSP construction process that contribute to the emissions. The outcomes of this study can be used to help and guide all parties involved in the construction industry to understand their responsibilities towards minimising and finally resolve the problem of the emissions on the construction site.

The data from this study also presents the carbon footprint emission by elements in PSP that will be useful for this research to make our industry adopt PSP into a larger portion of their construction process. Indirectly, these will make construction industry as a green and high tech industry in contributing toward environmental development. So, the implementation of PSP, for utility components are built offsite, has the potential of promoting sustainability deliverables that can be achieved by better control of production environment, minimising construction waste, using efficient building material energy, and stabilising work conditions compared to conventional method of construction.

1.6 Scope of study

Data related to the study was obtained from the PSP factory located in Kamunting, Perak which is PM2 Building System Sdn Bhd and construction site located in University Malaysia Perlis. Summation of the embodied energy of materials and transportation for each category in tCO_2e will be presented, that shows the carbon footprints of the building materials and fuel use by machinery in construction activity. The PM2 Building System Sdn Bhd already have the certificate of its IBS status (Appendix A).The study is carried out at students hostel construction sites located at Pauh Putra, Perlis that utilise Industrialised building system (IBS) construction method. The data collection obtained from this study is including the manufacturing process of PSP at the factory and the construction stages at the site. The transportation of materials for construction including the fuels from their sources to the manufacturing plant is not included in this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will give an overview to carbon footprint emissions on construction site based on the construction project life cycle and discuss on some important aspect such as the meaning of carbon footprints, embodied energy, Life Cycle Assessment (LCA) and the importance of carbon footprints towards sustainable development.

2.2 Industrialised Building System (IBS)

Industrialised Building System(IBS) is a term used in Malaysia for a technique of construction where by components are manufactured in a controlled environment, either at site or off site, placed and assembled into construction works (CIDB, 2013). Worldwide, IBS is also known as pre-fabricated/pre-fab construction, Modern Method of Construction (MMC) and off-site construction.IBS also can be defined as the total integration of all subsystem and components into overall process fully utilising industrialised production, transportation and assembly techniques (Dietz, 1971). The CIDB defines a IBS project as that which uses 70% IBS components (for government projects) or 50% IBS components for private sector project (Chuan & Rosli, 2010).

IBS is a system in which concrete components prefabricated at the site or in the factory are an assembly to form the structure with a minimum in situ construction (Trikha, 1999). IBS is also said as an integrated manufacturing and construction process with the well-planned organisation for efficient management, preparation and control over resources used, activities and results supported by the used of highly developed components. Apart from it, IBS offers minimal wastage, fewer site materials, cleaner and neater environment, controlled quality, and lower total construction costs (Kamar et al., 2009).

On the other hand, a study of the life cycle GHG emission and energy analysis of IBS prefabricated reusable building modules has been conducted and found that a steel-framed prefabricated system resulted in reduced material consumption of up to 78% compared to conventional concrete construction (Aye et al., 2012). Similarly, further highlighting the benefits of prefabricated building systems, it assessed the embodied energy and emission of a construction low energy building using a modern method of construction, known as a prefabricated panelised timber framed system. This system when compared with more traditional methods of construction, resulted in a 34% reduction in embodied carbon (Monahan and Powell, 2011; Omar et al., 2014).

2.2.1 Classification of IBS in Malaysia

IBS is a construction technique whereby building components are manufactured in factories then transported and assembled into a structure with limited on site work. The wider adoption of IBS is also encouraged as a means to overcome environmental issues associated with conventional methods. The advantages of applying IBS include better supervision on maintaining the quality of prefabricated products, reduced overall construction costs, shortened construction time, improved environmental performance due to waste minimization, and better building design and construction integrity (Azmi et al., 2012). There are six main IBS groups identified as being popularly used in Malaysia, namely(MIDF Research, 2014):

i) Precast concrete framing, panel and box systems
ii) Steel formwork system
iii) Steel framing system
iv) Timber framing system
v) Blockwork system
vi) Innovative system

The use of IBS in Malaysia started in 1963. However, although it has been four decades since the introduction of IBS in Malaysia, the application and adoption of this method in the local construction industry, particularly in the private sector, is still relatively low compared to the developed countries. This was despite the perennial problems besetting traditional construction methods which include time delay, cost overrun, and waste generation. The Malaysian government nonetheless sees IBS as the new way forward in the construction industry(Mydin, Sani, & Taib, 2014). The IBS Strategic Plan was launched in 1999 while the IBS Roadmap 2003-2010 was introduced in 2003. Furthermore, the government has mandated that government projects will carry 70% IBS content. The next wave is to convince the private sector to embrace IBS. The main goal of IBS Roadmap 2011- 2015 is to promote private sector to achieve a usage of 50% IBS content. The construction sector was known as a traditional sector that can be characterized as reluctant and even resistant to change. But fortunately, there is a change in paradigm regarding IBS in Malaysia in the past few years(MIDF Research, 2014).

Nonetheless, there are several main barriers in the implementation of IBS in private sector, such as payment method on IBS components, lack of knowledge, high investment cost, concerns on achieving breakeven point, weak level of integration, design process which is still based on conventional practice, shortages of skilled worker, and lack of design standardization. However, we reckon all these barriers not insurmountable. Hence the prospects of IBS construction method in Malaysia are enormous. Moreover, its positive implications on the economy cannot be underestimated. For example, likely savings from government projects as a result of IBS implementation would help to reduce government's development expenditures. IBS can also help to reduce our reliance on mostly foreign unskilled labour and will also improve the industry's image as well as create awareness among local workforce on the benefits of joining the industry. Additionally, in the long-run, the IBS expertise gained will become a trading platform to strengthen the country's comparative advantages and reinforces its economic stature in promoting exports of high value-added products and services(Abedi, Fathi, & Mirasa, 2011).