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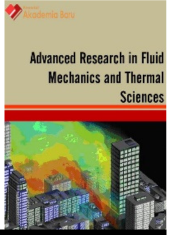

Embodied Energy and CO_2 Analysis of Industrialised Building System (IBS) and Conventional Building System

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Siti Halipah Ibrahim[1,♣], Nadia Zaini[1], Azhaili Baharun[1], Afzan Ahmad Zaini[1], Dona Rose Amer Koesmeri[1], Mohd Nasrun Mohd Nawi[2,*], Faizal Baharum[3]

[1] Department of Civil Engineering, Faculty of Engineering, University Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia
[2] School of Technology Management and Logistic, Universiti Utara Malaysia, Sintok, Kedah, Malaysia
[3] School of Housing, Building and Planning, Universiti Sains Malaysia 11800, Penang, Malaysia

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ABSTRACT

The Malaysian Construction Industry significantly important in development vision of 2020 by reducing 40% of carbon emission. Moreover, the industry has contributed to negative impacts on the environment, not only on consumption of natural resources but also in the consumption of embodied energy and emitting million tons of carbon emission annually. In fact, Malaysia is categorized the 30th in the world's ranking in carbon emission level. Therefore, it is necessary to acknowledge embodied energy and carbon emission amongst other factors in selecting construction method for projects. However, it is lack of studies on the assessment of embodied energy and CO_2 of building projects in Malaysia. The Green Building Index (GBI) has been introduced to guide the construction stakeholders in reducing the level of embodied energy and carbon emission and the impact of buildings on the environment. Industrialized Building System (IBS) has been recommended as one of the alternatives to minimize the usage amount of construction material and reduce the construction time as well as wastage. Nevertheless, the implementation of IBS still remains in doubt because the benefits have not been fully recognized and well defined in the construction industry. This paper presents an analysis of carbon emission from adoption of IBS as construction method in order to identify and quantify the main sources of energy and carbon emission and it proposes environmentally friendly materials as replacements for conventional construction materials to achieve the implementation of sustainability in Malaysia.

Keywords:
Embodied Energy, CO_2 Analysis, Industrialised Building System

1. Introduction

Over the years, the construction industry has been stigmatized as the greatest share of energy consumption, high CO_2 emissions and wasteful resources which gave huge negative impacts towards

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♣ *Corresponding author.*
E-mail address: ihalipah@feng.unimas.my (Siti Halipah Ibrahim)
* *Corresponding author.*
E-mail address: nasrun@uum.edu.my (Mohd Nasrun Mohd Nawi)

environment. According to [1], the construction industry is one of the largest exploiters of natural resources and consume 40% of total global energy. Increasing amount of embodied energy and carbon emission, if left unchecked, will lead to higher rates of water evaporation and higher earth's surface temperature. In fact, more than one third of total energy use and greenhouse gases (GHG) emissions come from Buildings construction both in developed and developing countries[2]. Environmental issues are not only linked to technological or economic activities but also associated with cultural and behavioral aspects as well. Therefore, the major objectives of this paper are to identify and determine the carbon emission of two common types of construction method which are IBS and conventional building system. It provides the amount of embodied energy and carbon emission consume from the manufacturing and construction process of IBS components. Comparative studies between the application of IBS and conventional methods of construction will be conducted. The overall objectives of this study are to quantify the amount of energy consume during manufacturing and construction of different type of IBS components and to assess their benefits in terms of energy consumption.

2. Energy Consumption and Malaysian Construction Industry

According to Tenth Malaysian Plan, Malaysia is part of a larger global community and reported that Malaysia contribute only 0.7% to global CO_2 emission. However, on an emissions intensity level basis, calculated as a ratio of GHGs emission to the country's GDP, Malaysia's emission intensity levels are above the global average in the energy sector as shown in Fig. **1**.

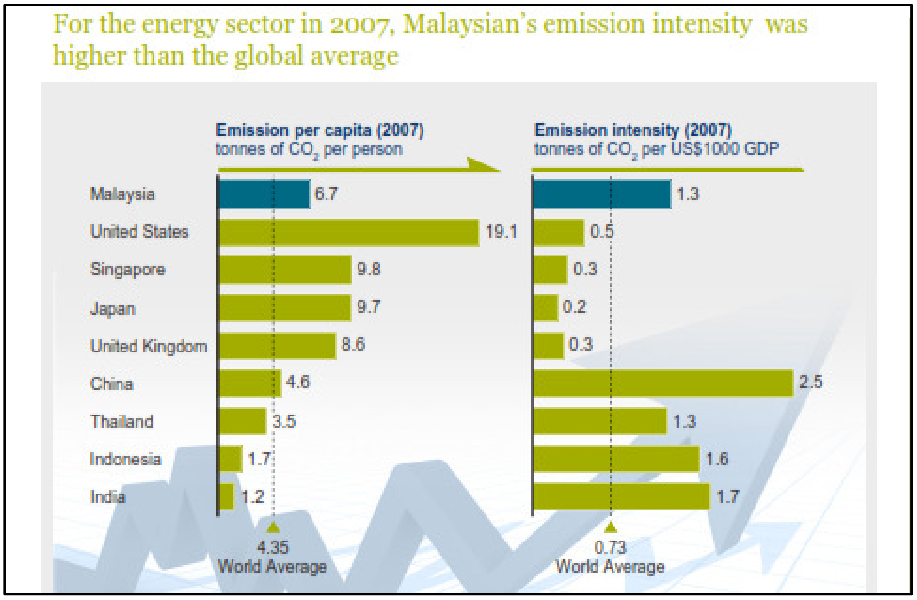

Fig. 1. Global Energy Sector in 2007 (Source: Tenth Malaysian Plan)

The increased concentration of GHG emission will result in global warming and drives to climate change. Among GHGs emissions, embodied energy and carbon dioxide (CO_2) is the most important contribution to global issue due to burning of fossil fuel and extents of land. The construction industries are considered the major contributor to environmental negative impacts. In addition, the construction industry consumes large quantity of environmental resources and it is one of the largest polluters of the environment. Nowadays, environmental awareness in construction field has increased in order to achieve sustainability. There are four sources of embodied energy and carbon emission in construction of buildings, which are; the manufacturing and transportation of building materials, energy consumption of construction equipment, energy consumption of processing resources and disposal of construction waste [3]. However, considerable efforts have concentrated largely on reducing energy used during building operation. Some of the efforts are improved with insulation, reduced air leakage through the house envelope and by heat recovery from ventilation air. These efforts result in minimizing operation energy, but increased in construction materials use and hence increased in energy demands for production [4], [5]. According to Dixit [1], the focus of current research is on minimizing the energy use of the operation phase, while the amount of energy use of the other phases is often neglected. These imply an increase in materials use and hence increased energy demands for production [6]. There is need for the industry to use IBS as a mean for promoting sustainable construction.

3. Industrialised Building System (IBS)

Thousands of similar buildings using IBS are being built each year in Malaysia. But there are some parameters of the design which are of some concern. A major concern which prompted this study is that despite the mass building using this method of construction, no technical evaluation has been done to establish that the technology result in reduction on energy and carbon emission to our country.

A review on the definition of IBS can be viewed from two different perspectives; system and process of construction. Parid in his research defined IBS as a system which uses industrialised techniques either in the production of components or assembly of a building or both [7]. Trikha also classified IBS as a system in which concrete components prefabricated at sites or in factories are assembled to form the structures under strict quality control and minimum in situ construction [8]. From other perspective, Tiong *et al.,* defined IBS as a construction method of a building or other structure where its structural components are either wholly or partly being prefabricated as well as manufactured off-site for assembling and installation at building site [9]. However, CIDB (2010) defined IBS as a construction process that utilises techniques, products, components, or building systems which involve prefabricated components and on-site installation. The components of IBS are manufactured either in a factory, on or off site, positioned, and assembled into place with minimal additional site work [10]. Similarly, Chung and Kadir (2007) defined IBS as a mass production of building components either in a factory or at the site according to the stipulated specifications with standard shapes and dimensions, and transported to the construction site to be re-arranged according to a certain standard to form a building. Kamar *et al.,* [11] defined IBS as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works.

The publication of IBS Roadmap 2011-2015 late of year 2010 was to replace the IBS Roadmap 2003-2010. The objective is to impose higher level intended outcomes in implementing the IBS. The new roadmap will be focusing on private sector adoption of IBS. The government is taking the leading role in persuading the construction industry to adopt a more systematic approach and methodology in construction. To remain focused, it has been narrowed down to four policy objectives; which are quality, efficiency, competency and sustainability. A sustainable IBS industry will contribute to the competitiveness of the construction industry. The aim of new roadmap is to sustain the existing momentum of 70% IBS content for public sector building projects and to increase the existing of IBS content to 50% for private sector building projects by the year 2015.

4. Assessing Sustainability in Malaysia

Green Building Index (GBI) has been developed by the Association of Consulting Engineers Malaysia (ACEM) and Pertubuhan Arkitek Malaysia (PAM) to promote sustainability in the Built Environment. GBI has highlighted that the stakeholder has to integrate building design and its buildability, with careful selection of building materials in relation with the embodied energy and durability of the materials to lower carbon content and better building life cycle. LCA is the most widely used methodology framework to estimate and evaluate environmental impacts throughout the product life cycle from cradle to grave [12]. It is a tool for assessing environmental burdens and environmental impact quantitatively at all the life cycle stages of the target product, ranging from collection of raw materials to the acquisition of materials, the manufacture, consumption stage, disposal and recycling of the product. To achieve sustainability that can provide savings in energy and carbon emission, it is important to raise awareness among developers,architects, engineers, planners, designers, contractors and public about environmental issues.

5. Research Methodology

Data collection in this study has divided into two (2) parts: Part I: Case Studies and Part II: LCA Study. In PART I, case studies involving construction project implement IBS and Conventional system as their construction method. PART II: LCA Studies consists of five (4) stages which demonstrate the application of Life Cycle Analysis (LCA) in building construction. The four (4) stages are:

I. Goal and Scope Definition
II. Life Cycle Inventory (LCI)
III. Life Cycle Impact Assessment (LCIA)
IV. Interpretation of Result

IBS case study, presented as Project A which is situated at Jalan Santubong-Buntal, about 17 km from Kuching City. Project A is a 3-storey administrative block of academic building using precast concrete components with a Gross Floor Area (GFA) of 3,713 square meters, commanding a contract sum of RM 18,391,564.00. Project A was constructed with precast concrete columns, precast concrete beams, precast concrete half slab and precast concrete wall panels. Project B represents a conventional system case study consists of 3-storey administrative block of academic building with a GFA of 4,890 square meters using conventional construction method, commanding a construction cost RM 13,541,820.20 within a construction period of 14 months. The Project B assessment included a brickwall with burn clay bricks, reinforced concrete slab, reinforced concrete column and reinforced concrete beam. Project B was considered as a base case in this study as for comparison study with IBS method. This study adopted this functional unit, 1 m^2, as it supports comparison of different Gross Floor Area (GFA) between three case studies Project A & Project B.

In this paper, the amount of embodied energy and carbon emission for Project A and Project B has been extracted from Bill of Quantities (BQ) in the contract document. In addition, construction drawings used to validate the quantity from BQ. The data and information are then clarified with respondents.

In summary, there are three (3) important elements that need to be quantified, which is quantity of building components, composition of raw materials and transportation during manufacturing and construction phase. All the data required to quantify the total amount of carbon footprint has been extracted out to an electronic format using Carbon Calculator. The carbon calculator measures the greenhouse gas impact of construction activities in term of carbon dioxide equivalent (CO_2E). The conversion to tonnes are the density value, where it can relate the volume and weight for each material. Then the quantity of embodied energy and carbon emission for selected projects has been identified and compared accordingly. Figure explains the research methodology.

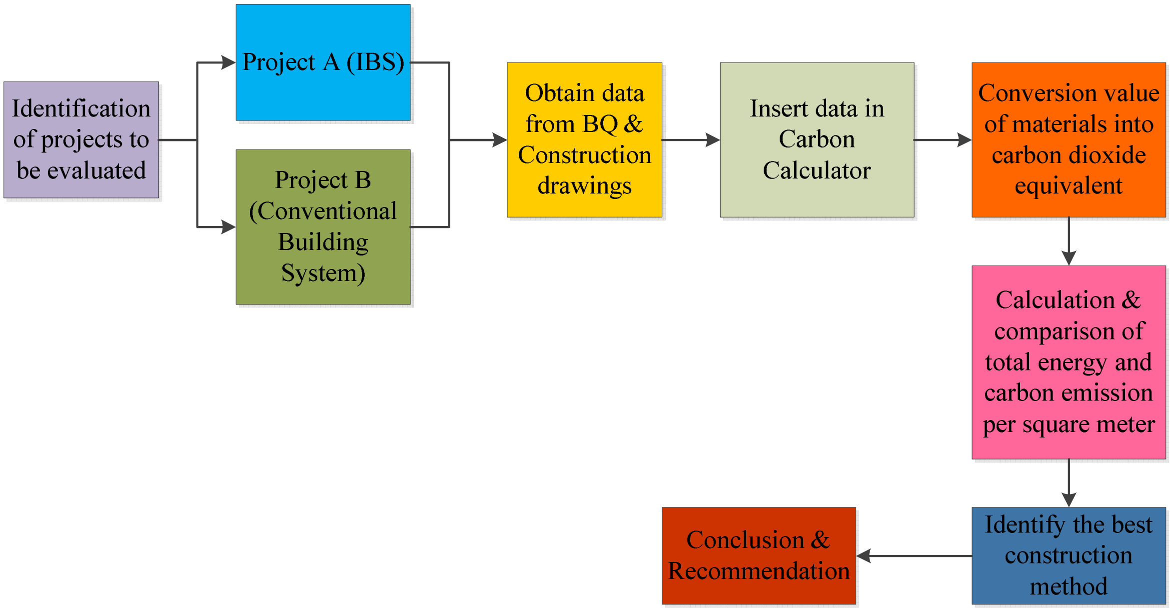

Fig. 2. The flowchart of research methodology

6. Results and Discussions

The quantification of carbon footprint is done by evaluating the selected case studies in Kuching, Sarawak. The data are obtained from the BQ of the projects. In general, there are 3-storey administration block (Project A) adopted IBS as a construction method and 3-storey administration block (Project B) using conventional system to be compared. In **Error! Reference source not found.**, the carbon emission of Project A has been classified into five (5) major selected construction materials. The result shows that steel bar has the highest contributor of carbon equivalent followed by steel wire mesh, portland cement, ready mixed concrete and aggregate.

Table 1
Conversion of the construction materials to CO_2 equivalent (CO_2E) for Project A (IBS)

IBS Building Component	Amount from BQ	Total Volume (m^3)	Construction Material	Density (tonne/ m^3)	Quantity (tonne)	Carbon Emission /tonne of Material	Total CO_2 Emission (Tonnes CO_2E)
Precast Concrete Colume	25		Ready Mixed Concrete	1.90	7905.90	0.14	1106.83
Precast Concrete Beam	119		Portland Cement	1.50	6241.50	0.75	4681.13
Precast Concrete Half Slab	187	4161	Aggregate	2.00	8322.00	0.005	41.61
Precast Concrete Wall Panel	3830		Steel Wire Mesh	7.70	32039.70	1.46	46777.96
			Steel Bar	7.80	32455.80	1.46	47385.47
TOTAL							94163.43

Table 2

Conversion of the construction materials to CO_2 equivalent (CO_2E) for Project B (Conventional System)

Conventional Building Component	Amount from BQ	Total Volume (m^3)	Construction Material	Density (tonne/ m^3)	Quantity (tonne)	Carbon Emission /tonne of Material	Total CO_2 Emission (Tonnes CO_2E)
Reinforced concrete column	206	14,618	Clay Brick	1.90	27,774.20	0.24	6665.81
Reinforced concrete beam	1,560		Damp proof membrane	0.0009	13.16	4.45	58.56
Reinforced concrete slab	1,652		Portland cement	1.50	21,927	0.75	16445.25
Brickwall	11,200		Steel bar	7.8	114,020.40	1.46	166469.78
			Ready Mix Concrete	1.90	27,774.20	0.14	3888.39
TOTAL							193527.79

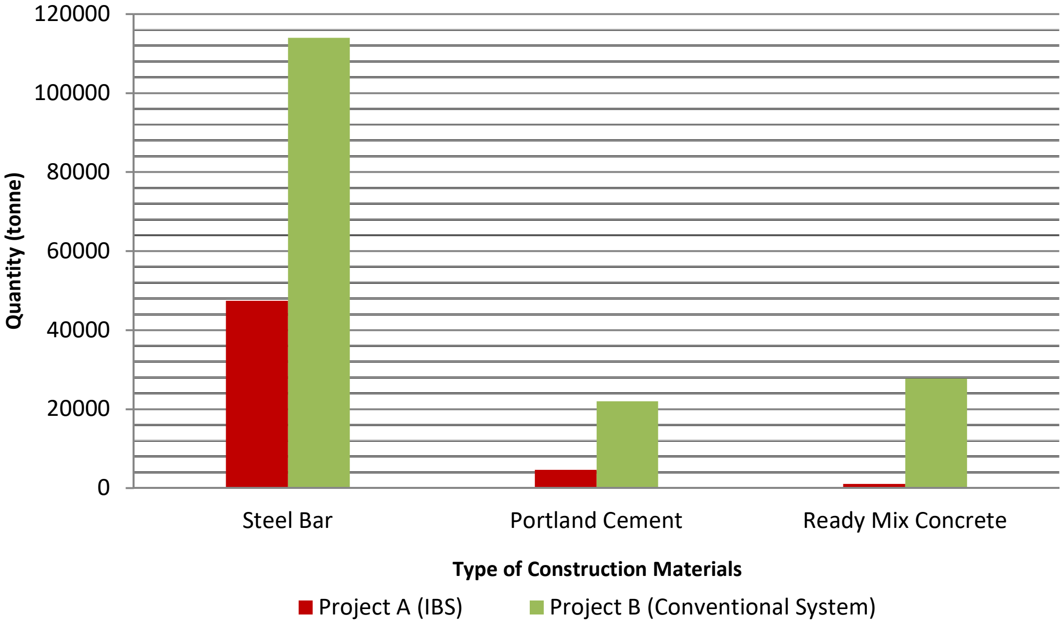

Fig. 3. Carbon emission from materials of Project A and Project B

Error! Reference source not found._classifies the embodied energy and carbon emission of Project B (conventional system) of each material that contributes to the CO_2 equivalent to the project. From Table 2, the result shows that steel bar still the highest contributor of carbon emission followed by Portland cement, clay bricks, ready mixed concrete and damp-proof membrane.

From **Error! Reference source not found.** and **Error! Reference source not found.**, Project A and Project B has three (3) similar type of construction materials that can be compared which are steel bar, portland cement and ready mix concrete. As shown in Fig. **3**, steel has the highest contribution compared to all other materials in both Project A and Project B.

The amount varies of selected materials are dependant on the material used. Therefore, CO_2 equivalent value must be presented as accurately as possible. Table 1 presents the total CO_2E of Project A and Project B per square meter (m^2).

Table 1
The Carbon Equivalent per square meter (CO_2E/m^2) of Project A and Project B

Project	Total CO_2E	Gross Floor Area (GFA) (m^2)	CO_2E per sqm. (CO_2E/m^2)
Project A (IBS)	94163.43	3,713	25.36
Project B (Conventional System)	193527.79	4890	39.58

Fig. **4** shows that the comparison of CO_2E/m^2 between Project A (IBS) and Project B (Conventional System). The values are obtained from Project A is 25.36 CO_2E/m^2, while Project B consume 39.58 CO_2E/m^2, with the average of 32.47 CO_2E/m^2. In terms of reduction percentage by comparing both construction methods, it is found that the IBS construction method has a lower carbon emission compared to Project B using conventional system by 35.93%.

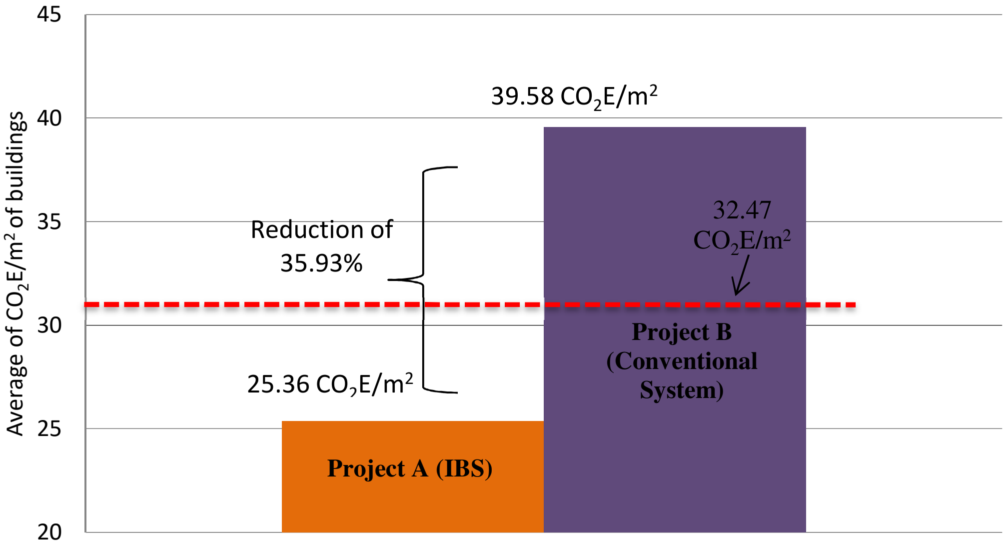

Fig. 4. The average CO_2E per square meter of Project A and Project B

7. Conclusions

In this study, the process-based analysis approach supported by LCA tools, Carbon Calculator was used to compute the amount of embodied energy and carbon emission in terms of CO_2E. This paper studies on two types of academic buildings, but implemented different types of construction methods. The result obtained were converted to per unit m^2 to facilitate comparison. From result and discussion, the average of GHG's emission by type of construction methods is approximately 32.47 CO_2E/m^2 of GHG's emission per square meter. In comparison to this study, Project A (IBS) has consumed 25.36 CO_2E/m^2 compared to Project B (Conventional) approximately 39.58 CO_2E/m^2. The value obtained from the IBS method is less compared to that conventional method by 35.93% reduction in comparison. These values differ because the manufacturing and construction process of IBS more efficiently than conventional method. It can be concluded that for further building construction's practice in terms of type of construction method is recommended to be below red line 32.47 CO_2E/m^2 and any values obtained above the red line is considered not being able to adopt sustainable building practice.

Choosing environmentally friendly materials would absolutely help in minimizing the depletion of natural resources including raw materials such as gravel and sand as well as energy and water used annually in manufacturing & construction process. In addition, it is possible to reduce the amount of steel and concrete to construct the building. This can actually be achieved by using lightweight concrete so that the load carried by structural elements such as main beams, and columns can be reduced significantly.

References

[1] Dixit, Manish Kumar, José L. Fernández-Solís, Sarel Lavy, and Charles H. Culp. "Identification of parameters for embodied energy measurement: A literature review." *Energy and Buildings* 42, no. 8 (2010): 1238-1247.

[2] N. M. Statistic, "CO2 Emission by Country," 2013.

[3] Sahagun, Daniela, and Alice Moncaster. "How much do we spend to save? Calculating the embodied carbon costs of retrofit." (2012).

[4] Winther, Beate Nemeth, and Anne Grete Hestnes. "Solar versus green: the analysis of a Norwegian row house." *Solar energy* 66, no. 6 (1999): 387-393.

[5] Airaksinen, Miimu, and Pellervo Matilainen. "A carbon footprint of an office building." *Energies* 4, no. 8 (2011): 1197-1210.

[6] Dixit, Manish K., Charles H. Culp, and Jose L. Fernández-Solís. "System boundary for embodied energy in buildings: A conceptual model for definition." *Renewable and Sustainable Energy Reviews* 21 (2013): 153-164.

[7] W. Parid, "Global Trends in Research, Development and Construction," in *Proceeding of the International Conference on Industrialized Building System (IBS 2003), CIDB, Malaysia.*, 1997.

[8] D. Trikha, "Industrialized building systems.," in *Prospects in Malaysia Proceedings World Engineering Congress: Malaysia*, 1999.

[9] Yee, Patrick Tiong Liq, Azlan Bin Adnan, Abdul Karim Mirasa, and Ahmad Baharuddin Abdul Rahman. "Performance of IBS precast concrete beam-column connections under earthquake effects: a literature review." *American Journal of Engineering and Applied Sciences* 4, no. 1 (2011): 93-101.

[10] CIDB, "Industrialised Building Systems (IBS) Roadmap 2011 – 2015, Malaysia.," 2010.

[11] Kamar, Kamarul Anuar Mohamad, Zuhairi Abd Hamid, Mohd Khairolden Ghani, Charles Egbu, and Mohammed Arif. "Collaboration initiative on green construction and sustainability through Industrialized Buildings Systems (IBS) in the Malaysian construction industry." *International Journal of Sustainable Construction Engineering and Technology* 1, no. 1 (2010): 119-127.

[12] Haynes, Richard. "Embodied energy calculations within life cycle analysis of residential buildings." *Etet1812. Staging-Cloud. Netregistry* (2010): 1-16.