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Yours sincerely,
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CARBON FOOTPRINT ASSESSMENT OF THE CONSTRUCTION MATERIALS AND ENERGY USAGE OF KICT BUILDING IN IIUM

*Shamzani Affendy Mohd Din[1] and Mamadou Lamarana Bah[1]

[1]Kulliyyah of Architecture & Environmental Design, International Islamic University Malaysia.

**E-mail (correspondant email) : shamzani@iium.edu.my*

Abstract

The increasing of carbon emissions in our atmosphere is becoming an environmental issue due to climate change and global warming. The construction industry is one of the biggest carbon dioxide emitter's activities in the world. Statistic shows that in Malaysia, buildings account for about 20 % of GHG production, which comes in third place after transport 27 % and industries 21 %. In 2017, Malaysia ranks 25th in the world in terms of carbon emissions, with 255 $MtCO_2$ of the 36153 $MtCO_2$ world total emissions. In order to minimize the increase in carbon emissions from the construction of the building, several studies have identified some of the effective carbon assessment tools for construction projects such as the Inventory of Carbon & Energy (ICE) developed in the UK, but it is lack of implementation in Malaysia. This study presents an analysis of carbon footprint from an office building (KICT building) to identify and quantify the main sources of carbon emissions and energy consumption of the project and proposes environmentally friendly materials to replace conventional building materials to achieve the implementation of sustainability in Malaysia. In addition, the calculations has shown that the values obtain for electricity consumption is 38,191.4 tons CO_2 for only twelve (12) months of operation, whereas construction materials give values of 8,262.4 tons CO_2, with the difference of 29,929 tons CO_2, which represent in term of percentage 82.2 % and 17.8 % respectively for electricity consumption and construction materials overall. In the other hand, comparing both electricity consumption and construction materials, it is found that during operation at KICT building generate four times more carbon dioxide than embodied carbon from construction materials. One key factor to success is to work in cross function teams where different knowledge and experience cooperate and make the emission reduction even more efficient.

Keywords : Global Warming; Construction Industry; Carbon Footprint; Electricity Consumption; Construction Materials.

CARBON FOOTPRINT ASSESSMENT OF THE CONSTRUCTION MATERIALS AND ENERGY USAGE OF KICT BUILDING IN IIUM

ASSOC. PROF. TS. DR. SHAMZANI AFFENDY BIN MOHD DIN

& MAMADOU LAMARANA BAH

KULLIYYAH OF ARCHITECTURE AND ENVIRONMENTAL DESIGN INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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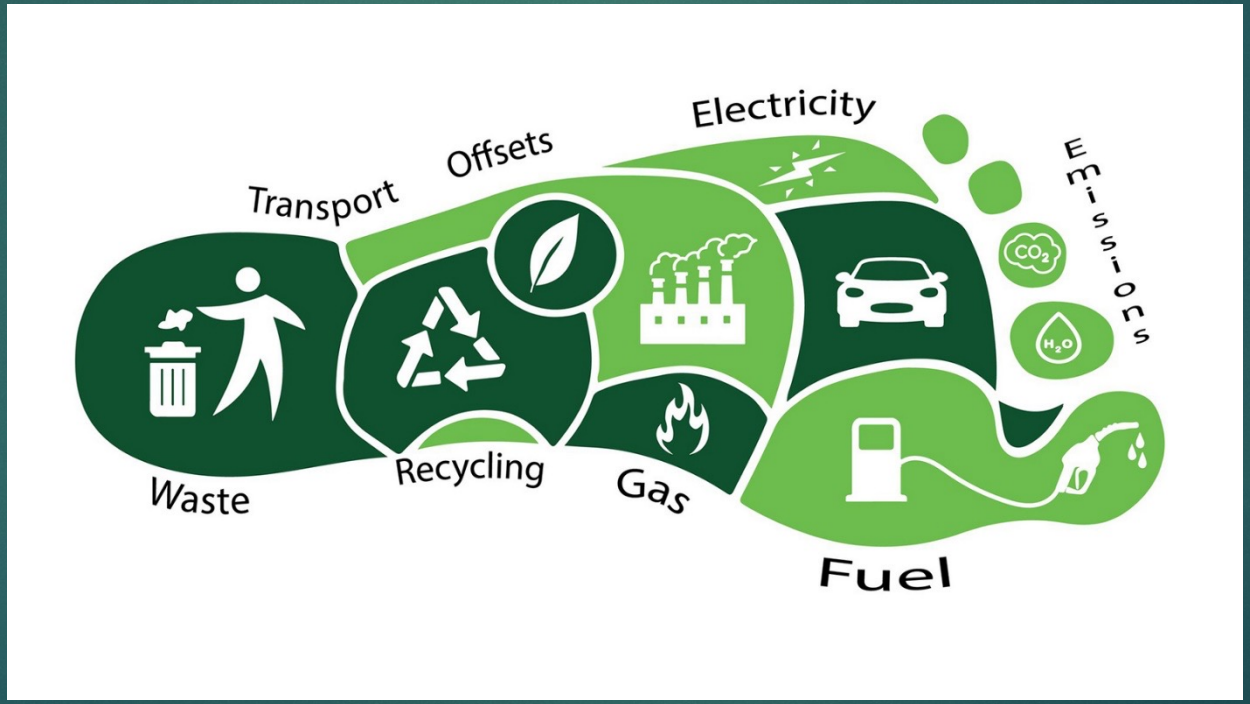
1.0 Background

A carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.



2.0 Aim and objectives

Research Title :

Carbon Footprint Assessment Of The Construction Materials And Energy Usage Of KICT Building In IIUM.

Aim :

The aim of this study is to quantify the carbon footprint and energy consumption associated with the construction materials and operation of KICT, IIUM. Furthermore, the CO_2 emissions from the KICT building operation through energy consumption for a certain period will be determine.

Objectives

i. To identify the CO_2 emission factor for different types of building materials and for different energy sources.

ii. To evaluate the quantity of building materials of KICT building and the amount of electricity consumption from operation, thereby calculating CO_2 emission.

iii. Evaluate critical component of CO_2 emission for a building construction.

iv. To recommend ways to reduce CO_2 from construction materials and building operation.

3.0 Methodology

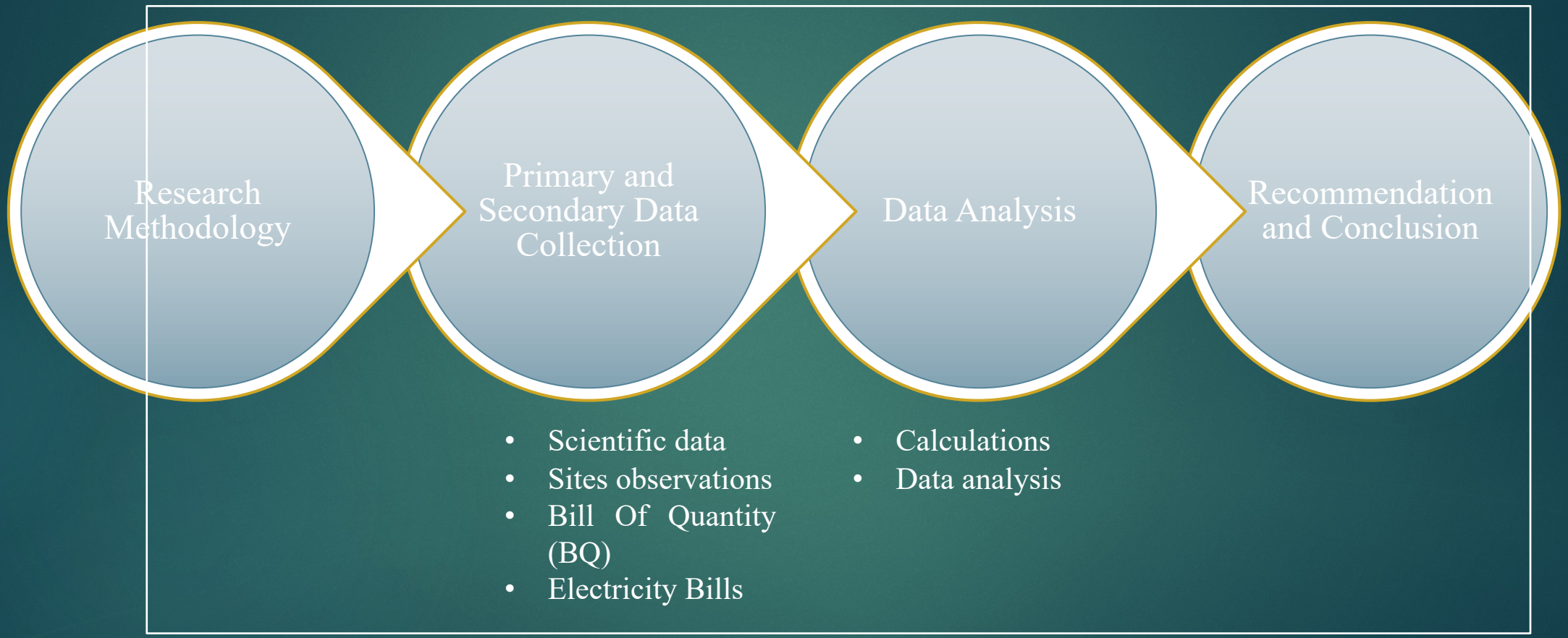


Figure : Research Methodology Structure

3.1 Case study: KICT BUILDING IN IIUM

Location

- KICT building is constructed on the site of the International Islamic University Malaysia (IIUM), Gombak campus in Kuala Lumpur.
- The study will focus on assessment of carbon footprint of construction materials of the building and the energy related and
- Further the carbon related of energy consumption during twelve (12) months of the building operation will be carried out.

3.2 Data collection of used materials

- The construction materials used are collected from the BQ and the drawings, as shown in Table 3.1.
- Materials are classified into concrete, steel, mortar and bricks.
- The various materials used in this selected project are sorted and measured by quantity.

Table 3.1: collected construction materials for CO_2 assessment of KICT building.

Materials	Unit
Concrete	kg
steel	kg
Mortar	kg
Bricks	kg

3.3 Data collection of electricity consumption of KICT building operation

- The methodology used in this research involved consulting the electricity bill as a measure of the energy consumption of the electricity that the KICT building consumed over specific time periods, that is one year, during a 12 months period from June 1, 2018 to May 31, 2019.
- The electricity bills are provided by the Malaysian national energy supplier Tenaga Nasional Berhad (TNB) and include both peaks, months and holidays.
- The quantity of electricity used indirectly shows the total amount of CO_2 emissions resulting from operations in the IIUM KICT building.

3.4 Emission factors for different construction materials

- The different materials found in the inventory process are grouped into the 4 material types as presented in Table 3.2 together with their corresponding emission factors.

Table 3.2: KICT construction materials CO_2 emission factors. Source: Hammond and Jones (2008)

Materials	Emission factor	
Concrete	0.136	$KgCO_2/kg$
Steel	1.99	$KgCO_2/kg$
Mortar	0.2	$KgCO_2/kg$
Bricks	0.21	$KgCO_2/kg$

3.5 Emission factors from electricity consumption in KICT building operation

Electricity consumption from building operation and corresponding emission factor are also illustrated in Table 3.3.

Table 3.3: CO_2 emission factor from electricity consumption in KICT building operation. Source: Abdul-azeez (2017)

Electricity Consumption	Emission factor	
kWh	0.741	kg CO_2/kWh

3.6 Method for Calculating CO_2 emissions

A description of the calculation for emissions in construction project are presented in Figure 3.2.

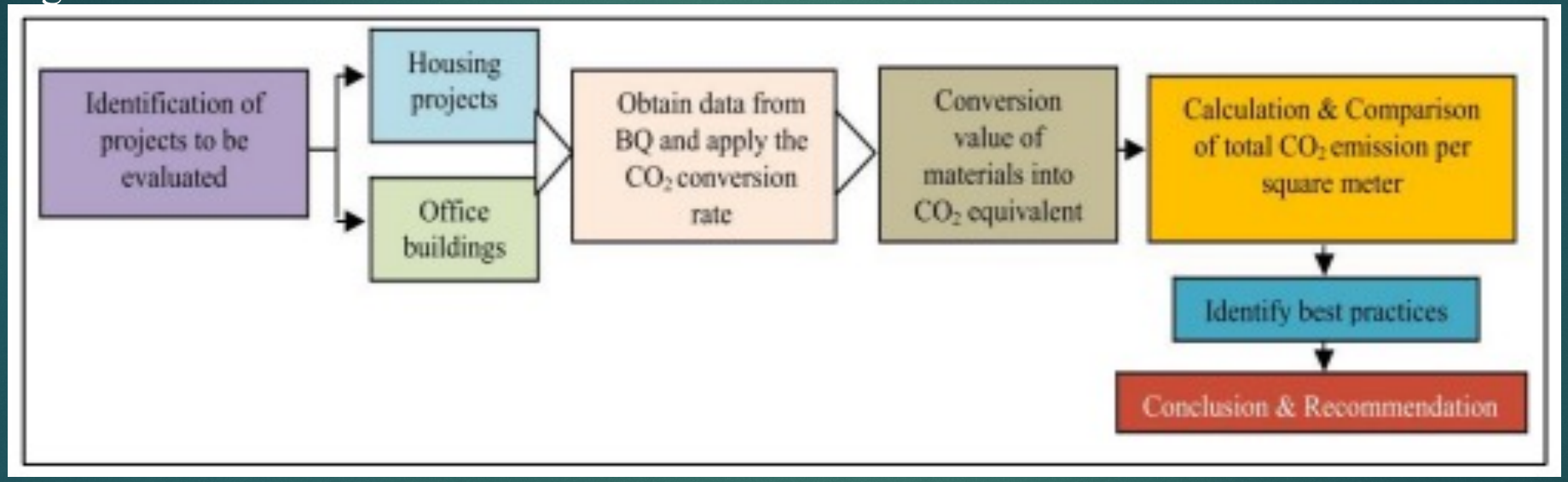


Figure 3.2: A description of the pathway for conducting a carbon footprint for construction. Source: Klufallah et al. (2014)

4.0 Data analysis and findings

4.1 Mass of used construction Materials

The total amount of materials used in KICT building construction and maintenance projects is estimated at 37,208.1 tons as illustrated in Table 4.1.

Table 4.1: The mass of the materials used in the KICT building

MATERIAL	MASS	UNIT	PERCENTAGE	
Concrete	29377.6	Tons	79.0	%
Steel	1497.7	Tons	4.0	%
Mortar	4318.3	Tons	11.6	%
Bricks	2014.5	Tons	5.4	%
TOTAL	**37208.1**	**Tons**	**100**	**%**

- The most consumed material based on the total quantity is concrete alone, with about 29,377.6 tons.
- Mortar is the second most important, with 4,318.3 tons,
- Followed by bricks with about 2,014.5 tons
- And steel with 1,497.7 tons.

The distribution in percentage between materials is shown in Figure 4.1.

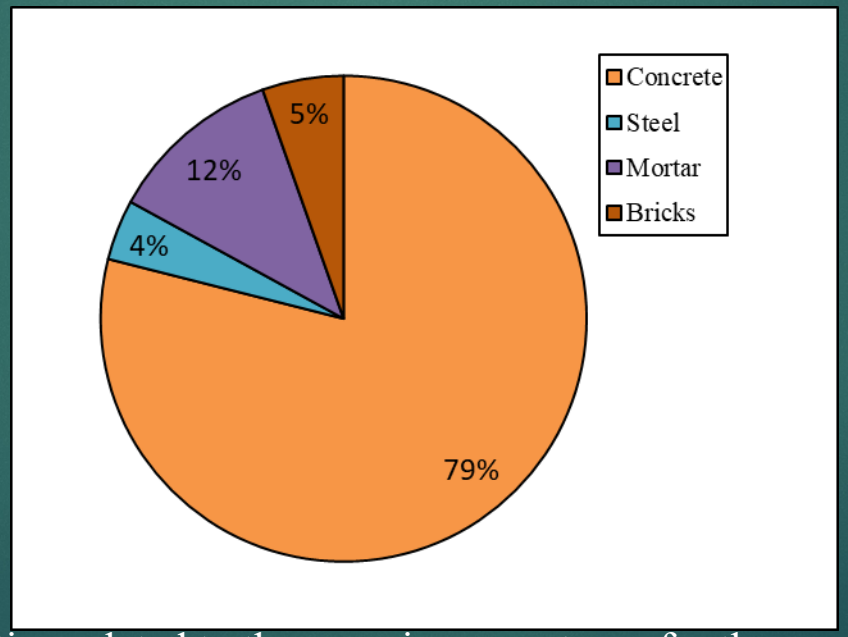


Figure 4.1: The distribution related to the mass in percentages for the used construction materials.

4.2 Amount of electricity consumption from KICT operation

Table 4.2: The electricity bills from 01 June 2018 to 31 May 2019.

Date	Electricity consumption (kWh)	Comment
01-06-2018 to 01-07-2018	4,595,533.00	Semester II Exams period
02-07-2018 to 31-07-2018	3,461,615.00	Short semester
01-08-2018 to 31-08-2018	3,874,808.00	
01-09-2018 to 01-10-2018	3,731,626.00	Semester I
02-10-2018 to 31-10-2018	4,216,748.00	
01-11-2018 to 01-12-2018	4,878,095.00	
02-12-2018 to 31-12-2018	4,689,491.00	
01-01-2019 to 31-01-2019	4,587,640.00	Semester I Exams period
01-02-2019 to 03-03-2019	3,898,166.00	Semester I
04-03-2019 to 31-03-2019	4,053,391.00	
01-04-2019 to 01-05-2019	4,683,543.00	
02-05-2019 to 31-05-2019	4,869,646.00	

- The data are obtained from electricity bills provided by TNB for one year (12 months), from June 8, 2018 to May 31, 2019.
- The electricity bills include both semester and vacation periods to compare electricity consumption during the study and vacation periods.
- Table 4.2 presents the total data collected of 12 months of KICT building operation.

4.3 CO_2 calculations from construction materials

The KICT building construction materials total carbon footprint is about 8,262.4 tonnes of CO_2. In Figure 4.3, the materials contribution to CO_2 emissions in percentages for KICT building construction project.

Table 4.3: CO_2 emissions calculations of KICT building.

MATERIAL	CO_2 EMISSIONS	UNIT	PERCENTAGE	
Concrete	3995.4	Tonnes	48.4	%
Steel	2980.3	Tonnes	36.1	%
Mortar	863.7	Tonnes	10.5	%
Bricks	423.0	Tonnes	5.1	%
TOTAL	8262.4	Tonnes	100	%

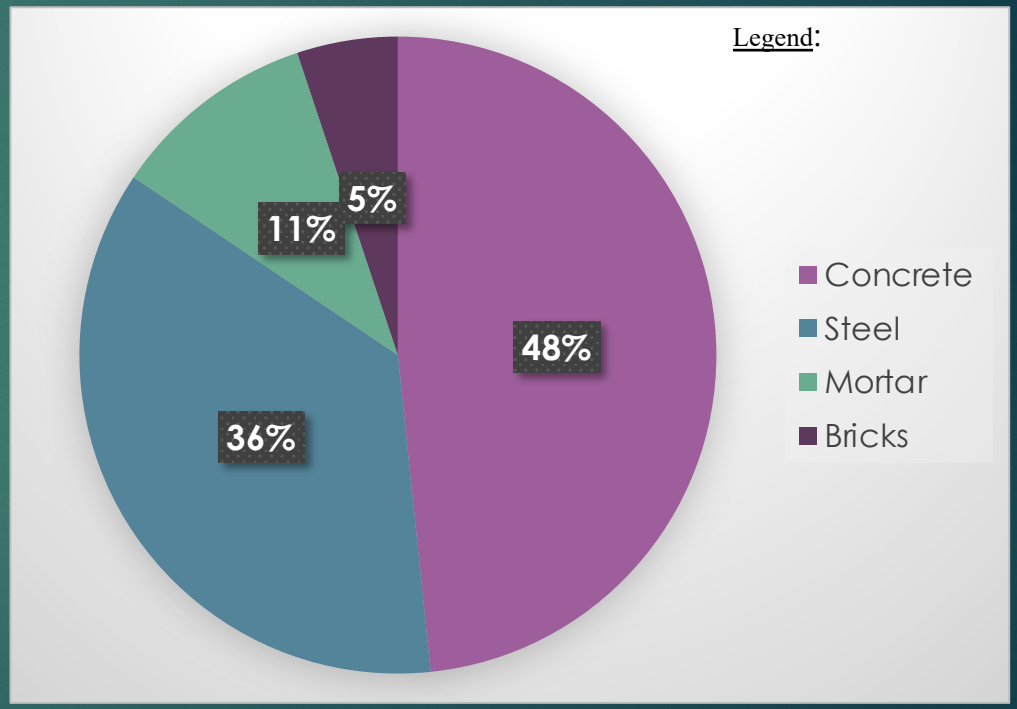


Figure 4.2: Materials contribute in percentage related to CO_2 emissions.

As shown in Figure 4.2, two materials account for a larger share of CO_2 emissions.

- The largest CO_2 emissions from the KICT building construction project are generated by concrete, followed by steel.
- Dimoudi and Tompa (2008) found that the majority of the energy footprint was in structural materials (concrete and reinforcement steel), which accounted for approximately 59 % to 66 % of to the total embodied energy in the building.
- Mortar as well as bricks generate high levels of CO_2 emissions.
- All types of concrete combined, they represent approximately 48.4 % of total CO_2 emissions.
- Steel is another material with high levels of CO_2 emissions, but due to its lower share compared to concrete, generate in this study about 36.1 %.

- However, it has been shown that, according to the quality of the concrete and reinforcement that is used, the carbon embodied in a given concrete structure can vary by as much as 40 % (Ji, Hong, and Park, 2014).
- Syngros *et al.* (2017), obtained an average of 30 % in CO_2 emissions for steel when studying the Embodied CO_2 emissions in building construction materials of Hellenic Dwellings.
- One of the reasons why concrete emits high levels of CO_2 is due to its composition. Concrete is a mixture of inert mineral aggregates such as sand, gravel, crushed stone, and cement.
- Concrete and cement, for example, require a lot of support equipment and emissions generating vehicles.
- Transportation and equipment used for concrete-related activities such as jet cutting and concrete pumps, which account for the majority of diesel and electricity consumption.

4.4 Indirect CO_2 calculation from electricity consumption

$$CO_2 \text{ emitted (kg } CO_2) = (\text{Grid Emission Factor}) \times (\text{kWh})$$

Table 4.4: Electricity consumptions and corresponding CO_2 emissions at the KICT building IIUM.

Date	Electricity consumption (kWh)	CO_2 emitted (kg CO_2)
01-06-2018 to 01-07-2018	4,595,533.00	3,405,289.95
02-07-2018 to 31-07-2018	3,461,615.00	2,565,056.71
01-08-2018 to 31-08-2018	3,874,808.00	2,871,232.73
01-09-2018 to 01-10-2018	3,731,626.00	2,765,134.87
02-10-2018 to 31-10-2018	4,216,748.00	3,124,610.27
01-11-2018 to 01-12-2018	4,878,095.00	3,614,668.39
02-12-2018 to 31-12-2018	4,689,491.00	3,474,912.83
01-01-2019 to 31-01-2019	4,587,640.00	3,399,441.24
01-02-2019 to 03-03-2019	3,898,166.00	2,888,541.01
04-03-2019 to 31-03-2019	4,053,391.00	3,003,562.73
01-04-2019 to 01-05-2019	4,683,543.00	3,470,505.36
02-05-2019 to 31-05-2019	4,869,646.00	3,608,407.69
TOTAL	**51,540,302.00**	**38,191,363.78**

Figure 4.3: Electricity consumptions and corresponding CO_2 emissions at the KICT building from 01 June 2018 to 31 May 2019.

- Electricity consumption, and the related CO_2 emissions for the corresponding 12 months, are illustrated in Figure 4.4.
- Rising electricity consumption in the building also increases CO_2 emissions.
- The highest CO_2 emissions were recorded in semesters I and II, from September to December 2018 and February to June 2019 respectively.
- It also shows that electricity consumption during examination periods is almost identical to that during teaching periods. This indicates that the use of electricity in classrooms for examinations was very important because there were no laboratory activities.

5.0 Conclusion

- The material that contribute the most to CO_2 emissions in this thesis are steel and mortar.
- An extraordinary high amount of steel and large volumes of mortar are used, compared to other materials.
- The work towards environmental protection and emission reduction can be established in a common organisation or tools, as for example the Green Building Index (GBI) or MyCREST and be applied for all building construction activities.
- One reason for emitting CO_2 is because it is related to cost. Fossil fuels are currently cheaper than renewable fuels.
- Malaysian construction industry needs to work towards sustainable consumption in the construction projects.
- One key factor to success is to work in cross function teams where different knowledge and experience cooperate and make the emission reduction even more efficient.
- Also, regulatory information from manufactures and experts are necessary as well as information about emissions related to current and new technologies and materials.

6.0 Recommendations

Different strategies to reduce embodied carbon from buildings. In general, these strategies can be divided into five groups:

- ✓ low carbon emission materials.
- ✓ material minimization and reduction strategies.
- ✓ material reuse and recycling strategies.
- ✓ local procurement and transportation minimization; and
- ✓ construction optimization strategies.
- ✓ The latest progress made in each of these areas is reviewed further.

Thank You

Email : shamzani@iium.edu.my