

Factors Contributing to Carbon Emission in Construction Activity

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ABSTRACT

The construction industry has become one of the world's biggest carbon emitter with the rapid urbanization process and rapid economic growth. It is actually believed that the built environment is a major contributor to a nation's carbon emissions. The carbon emissions connected with the built environment include CO₂ emissions from the built environment's operational stage which is known as operational carbon emissions and carbon emissions from other stages, such as stages of material production and construction. The proportion of carbon emissions embodied in a building is considered to increase in the future from the perspective of the life cycle compared to its operational carbon emissions. This is because more energy conservation technologies have been used to reduce operational energy and its associated emissions. In addition, these energy conservation technologies could boost the rates of renovation of buildings and thus trigger more carbon pollution. This study its further discussing on the factors contributing to carbon emission in construction industry. By using the latest 10 years of publication for extensive literature review methodology perhaps may contribute in enhancing the existing knowledge.

Keywords: *Carbon emission, construction activity, life cycle*

1. INTRODUCTION

The rapid increase in population and economic growth in Malaysia has resulted in the construction of high-rise buildings in urban areas, especially around the area of Klang Valley. Construction practices have a significant impact on energy use, greenhouse gas (GHG) emissions together with the potential for global warming (GWP) [1]. The construction sector, which accounts for a large proportion of emissions, must target an important role in achieving and moving beyond the 40% reduction in CO₂ emissions set by the former Prime Minister Y.A.B Dato's Sri Mohd Najib bin Tun Abdul Razak at COP15, 2009 in Copenhagen, Denmark, in which he proposed to reduce the carbon emissions intensity in Malaysia by at least 40% by 2020 [1]. The Klang Valley is one of Malaysia's major economic areas and is made up of Kuala Lumpur, Putrajaya and surrounding towns and cities in Selangor State, such as Petaling Jaya, Shah Alam, Klang, Gombak, Hulu Langat and Sepang, with a population of about 3.98 million in 2000. During the last decade of the twentieth century, the rapid transformation of the Klang Valley into a wide urban region has brought about many environmental issues, especially carbon pollution. Malaysia's total population reached about 27.90 million in 2009 and according to the Economic Plan Unit (EPU), in 2020, about 80% of Malaysia's population will live in urban core areas such as the Klang Valley. There will have to be major development and improvements in land use in order to meet the demands of population growth. Henceforth the construction industry is much involved in reaching the target of development to meet the needs of the population. This indicates that more

air pollution in the form of Carbon Emission will be present. Thus, it is high time to take an action against Carbon Emission through the construction industry so as to prevent the serious consequences. The main step in overcoming this matter is by testing the level of awareness of the related construction players in the sector. In the light of the above, this research includes the factors and consequences of Carbon Emission in construction sector as well as a study about the level of awareness of construction players concerning the related issue.

Carbon emission has been a serious issue in the construction sector for the past few years, attracting the world's attention [2]. As a major sector with high development and pollution [3], the construction industry accounts for around 36% of global emissions. According to recent studies, China is the world's largest emitter of carbon with its 9.1 billion tons resulting in 27.6 % of the global total in 2016 [4].

Henceforth to address this situation, at the 2009 Copenhagen Conference, China's government initiated a target of 45% reduction in carbon intensity from 2005 to 2020 [5]. On the other hand, according to statistics in Malaysia, the buildings account for about 20% of the output of GHGs compared to transport which represents 27% and 21% for the industries. The building materials used, compose mainly of fossil fuels which thus results in 24% of total carbon comes from the country's building industry [6]. In fact, in both developed and developing countries, buildings are responsible for more than one-third of total energy uses and related GHG emissions in society. As result, despite the fact that the construction sector plays an important role in the economic sector of a country, it however contributes to the emission of greenhouse gas in the atmosphere, leading to severe effects such as global warming and ozone depletion.

Subsequently, there are two types of Carbon Emission in the construction sector which are; direct and indirect emission. Direct carbon emissions are those from on-site construction operations such as construction, maintenance or demolition while indirect carbon emissions are emissions resulting from the supply of construction operations with both products and services such as upstream operations like manufacture of bricks [7]. Those emissions are actually contributed to the atmosphere by various causes. Thus, it is important to highlight those factors leading to an increase in carbon intensity in the atmosphere so as to raise awareness of the construction players in the respective industry.

2. LITERATURE REVIEW

Well the basic emission of carbon in construction sector is the production of building materials followed by energy consumption. Transportation is another major contributor of carbon especially plant machineries through the combustion of fossil fuels. Buildings are actually a major consumption of energy, generated from burning of fuels, for electricity production which therefore released carbon dioxide. Most of these emissions come from fossil fuel combustion to provide heating, cooling and lighting, as well as power & electrical appliances. According to some research in U.S, buildings account for 39% of carbon emission and consume 70% of electricity. By the next 10 years, carbon emissions from buildings are projected to grow faster than any other sector - 1.8% annually by 2030. The consequence is an even greater impact on the environment when considering certain carbon emissions due to construction, such as pollution from the manufacturing and transportation of steel structures and demolition materials and transport associated with urban sprawl. Consequently, buildings last 50 to 100 years and consume energy continuously which then produce Carbon emissions, affecting the climate and provoking global warming.

Figure 1 shows a graphical representation of carbon emissions from different sector of energy consumption in Malaysia. It can thus be seen that over the past years, the carbon emissions have been increasing in the energy sector of Malaysia; accounting for 196 million tons of carbon production in 2012. The main sectors provoking this increase are electricity generation (46%), transportation (22%), manufacturing (19%) and others such as residential and industrial (13%).

Carbon dioxide (CO₂) is a colorless, odorless and non-toxic gas produced by coal combustion and in the breathing of living organisms and is considered a greenhouse gas. Emissions are the release into the atmosphere of greenhouse gases and/or their precursors over a specified area and time period. CO₂ emissions are emissions from fossil fuel burning and cement manufacturing; they include carbon dioxide emitted during heavy, liquid and gas fuel consumption as well as gas flaring. Table 1 show the definition cited from previous researcher.

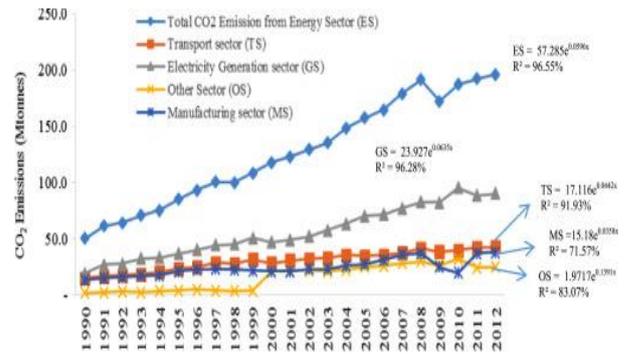


Figure 1 Carbon production representation from energy sub-sectors in Malaysia (1990–2012) (Source: IEA, 2014)

Table 1 Definition cited from previous researchers

No	Definition of Carbon Emissions	Author
1	Production of a greenhouse gas in the atmosphere through construction processes that absorbs as well as emits radiant energy within thermal infrared range	Marc Lallanilla, 2019
2	Release of carbon from the combustion of fossil fuels through a wide range of activities from construction industry	Corinne Le Quéré et al., 2018
3	It is defined as total Carbon released from individuals, events, organizations, and communities	CP Ramesh et al., 2018
4	Carbon dioxide emissions are those resulting from fossil fuel combustion and cement manufacturing which include carbon dioxide generated during solid, fluid, and gas fuel usage, as well as gas flaring.	Makoto et al., 2015
5	Emancipation of a natural gas which is a by-product of combustible and biomass, land-use changes and other industrial procedures	J. Watkins, 2012
6	An estimation of global carbon released to the environment/ atmosphere.	F. Ascui et al., 2012
7	Naturally occurring gas in the Earth's environment together with human actions, such as burning fossil fuels which increase atmospheric concentrations	M. Brander, 2012

	of GHGs, causing worldwide warming and climate change.	
8	It represents a certain quantity of gaseous production relevant to climate change and linked to human production or consumption activities.	T. Wiedmann, 2007
9	Capture and storage of carbon which composed of separation of carbon from industrial and energy-related sources to a long-term atmospheric isolation.	B. Mertz et al., 2005

In a nutshell, Carbon Emission can be summarized as the release of carbon into the atmosphere through human activities in the construction industry such as combustion of fossil fuel and cement production where it is stored thereby increasing the concentration of greenhouse gas emission. Referring to the **Table 2**, it can be deduced that the main factors contributing majorly to Carbon Emission are energy consumption, on-site transportation, cement production, manufacturing of building materials followed by burning of fossil fuel and construction waste disposal. Nevertheless, there are other factors leaking carbon in atmosphere such as mining, plant machineries, off-site transportation, construction works, workers & staff activities.

2.1. Energy Consumption

The rapidly increasing worldwide use of energy has already raised concerns about difficulties in production, exhaustion of energy resources and severe environmental impacts such as depletion of ozone layers, global warming, and climate change [8]. The Inter-National Energy Agency has obtained terrifying information on developments in energy consumption. Recent estimates show that urban areas consume more than 67% of global energy and release more than 70% of global CO₂ emissions [9]. Buildings are a major consumption of energy, generated from burning of fuels, for electricity production which therefore released carbon dioxide. Most of these emissions come from fossil fuel combustion to provide heating, cooling and lighting, as well as power & electrical appliances. According to some research in U.S, buildings account for 39% of carbon emission and consume 70% of electricity. By the next 25 years, CO₂ emissions from buildings are projected to grow faster than any other sector - 1.8% annually by 2030. Consequently, buildings last 50 to 100 years and consume energy continuously which then produce CO₂ emissions, affecting the climate and provoking global warming. Previous research has shown that the energy consumption and emissions of the construction sector are influenced by

building type, type of structure, type of product and source of fuel [10]. Therefore, the construction sector, which encompasses both commercial and public buildings, includes numerous types of buildings like schools, restaurants, hotels, hospitals, museums etc. with a wide range of uses and energy facilities such as HVAC, hot water (DHW), lighting and cooling. **Figure 2** represents a model framework of how energy consumption is affected by the various factors as mentioned above. **Figure 3** is a graphical representation of energy consumption factors in construction industry together with the related carbon emission. It can be deduced that electricity use has so far, the highest intensity of greenhouse gas emission.

2.2 On-Site Transportation

GHG emissions from on-site transportation are actually carbon production from fuel and energy consumption to transport building materials to the sites. Transportation on site during construction process emits carbon pollution in the atmosphere and thus provoking global warming. The diesel used to operate the equipment during construction is to move the building materials to the construction site. The construction phase involves the transport of building materials such as prefabricated concrete, tiles and cement to the site [1]. About 6-8 % of carbon is released due to transportation of materials during an ongoing construction project. Compared to other activities, plant emissions have the highest carbon emissions due to the use of fuels and lubricants such as diesel by plant machineries like excavators, lorries and cranes on site. According to IPCC's statistical and scientific research, it was found that machinery and equipment can emit varying amounts of methane and nitrous oxide that can be classified as stationary, mobile and off-road combustion [11]. Thus, the burning of the fuels and exhausted fumes from the vehicles on site releases carbon in the atmosphere and causes air pollution.

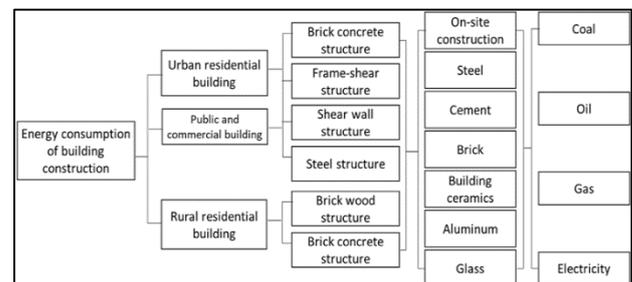


Figure 2 Model framework of energy consumption (Source: Zhang et al., 2019)

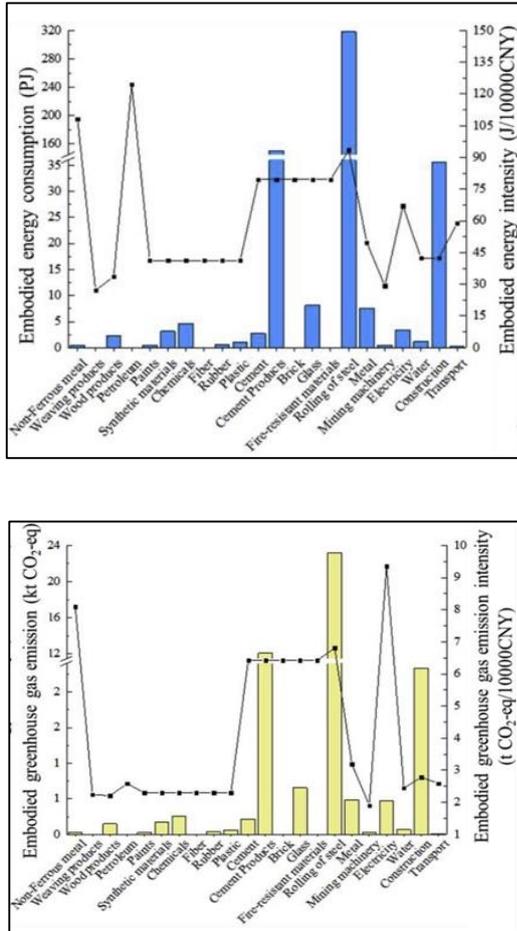


Figure 3 Energy consumption and Carbon emission from construction sector (Source: Li et al., 2019)

2.3 Cement Production

Cement is the basic and most commonly used building material in civil engineering, the quantity of which due to massive and rapid urbanization has increased drastically. One of the most widely carbon emitters is also the cement industry [12]. In 2006, this sector accounted for about 1.8 Gt of CO₂ emissions, about 7% of global anthropogenic CO₂ emissions [13]. The CO₂ emissions from all stages of cement production, includes the preparation of raw materials, the production of clinkers, the combustion of fuel in the kiln and the production of the final cement products [14]. It was found out that the 90% of carbon released from cement plants were generated from clinker production and the rest 10% was emission from the preparation of raw materials as well as the last stage of the production [12] [14]. In the global cement industry, China is the largest producer and emitter of carbon. The cement industry accounts for 14.8% of China's total CO₂ emissions, making it a key sector in which China can help meet its national carbon reduction target of 40-45% [15].

2.4 Manufacture of Building Materials

Construction sector is the world's largest user of materials, and buildings are the world's largest single energy consumption industry [16]. The production of building materials contributes largely to Carbon emissions where nearly 2/3 of all emissions are produced by steel and concrete. The production of these materials is related to the upstream processes such as steel processing and cement manufacturing, which are generated from fossil energy. According to Figure 4 after having ranked all building materials according to their GHG emissions, it can be deduced that steel and concrete are the most used building materials which accounts for approximately 2/3 of overall carbon emissions. Other materials, such as polyamide safety nets and aluminum, despite being light weight (< 0.1%), release a significant amount of GHG (2% - 3%) during the construction stages.

2.5 Combustion of Fossil Fuel

Fossil fuels produce energy when burnt in air or oxygen to provide fuel that can be used directly or converted into electricity. The Industrial Revolution has dramatically increased fossil fuel consumption to the point that rates are widely regarded as unsustainable. Normally there are 9 types of energy sources which are raw coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, natural gas and electricity used in the construction sector. Compared to other types of energy, combustion of coal generates more carbon emissions; henceforth heavier reliance on coal provoke more carbon productions leading to environmental damages [17] [18].

Table 2 Factors contributing to carbon emission

NO	Author	Nissen J et al 2007	GGerilla et al 2007	Upton B et al 2008	Hui Yan, Lei Zhang 2009	H.Yan et al 2010	Purnell 2012	C.Mao et al 2013	J.Hong et al 2015	TJ.Wen et al 2015	X.Zhao et al 2015	B.Lin et al 2016	M. Sandana yolo et al 2018	CP. Ramesh et al 2018	Y.Li et al 2019	Frequency
1	Mining					✓	✓								✓	3
2	Cement Production				✓				✓	✓	✓	✓	✓		✓	7
3	On-site transportation Transportation of materials and equipment	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	11
4	Energy Consumption	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
5	Burning of fossil fuels							✓	✓			✓	✓		✓	5
6	Construction waste disposal		✓			✓		✓	✓					✓		5
7	Manufacture of building materials	✓		✓		✓			✓				✓	✓	✓	7
8	Plant Machineries								✓	✓						2
9	Off-site transportation Transportation of workers					✓			✓		✓					3
10	Construction works Maintenance and Demolishing		✓											✓		2
11	Workers & staff activities								✓							1
12	On and off site water production and discharge								✓	✓						2

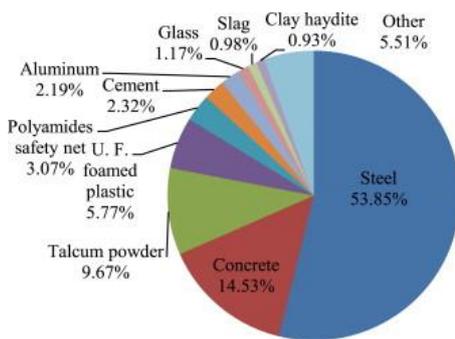


Figure 4 Carbon emissions from different type of building materials (Source: Hong et al., 2015)

2.6 Construction Waste Disposal

Construction waste is defined as a mixture of material surplus resulting from activities in construction industry such as new construction, renovation and demolition of buildings and other structures [19]. Construction wastes are mainly from factors such as site clearance, waste/demolition waste, excavated materials (including contaminated sediments), waste concrete, wooden material, chemical waste, sewage, and domestic waste. The demolition of temporary structures and houses will result in concrete rubble, plastics, metal, glass, surface asphalt and wood. According to some research, concrete / masonry is the highest waste stream during the Foundation which is around 46% and Structural Concrete, 88%, stages. During the Masonry Work and Finishing Stage, wood is found to be the primary contributor at approx. 54%. Henceforth, those waste

management on site emit greenhouse and toxic gases, including methane which is released into the atmosphere, soil and waterways, contributing to the greenhouse effect. Well it is widely recognized that construction industries around the world not only consume massive amounts of natural resources and energy but also generate huge construction and demolition (C&D) waste as mentioned above [20]. China's rapid urbanization has made C&D waste a major source of solid urban waste and accounts for 30% to 40% of total solid municipal waste in China. In addition, 90% of C&D waste was generated from the demolition of buildings which represents up to 200 million tons of demolition waste (DW) generated in China each year [21]. Demolition operations result in the disposal of large building materials, many of which still have a high residual value but remain unrecycled, and this therefore increases energy demand for transport and landfilling which leads to Carbon emission [22]. The transportation and disposal equipment used in the demolition process can have adverse effects on the environment due to waste disposal which induces greenhouse gas emission in different ways [23].

3. METHODOLOGY

There are 19 journal papers been use in finding the suitable literature review to support this research. A descriptive study by using 19 related research papers within 10 years interval from year 2008 to 2018. Which the numbers of papers versus years can be reflect from Figure 5 below. A descriptive study been use for this research to gather all the information to support literature review of this study.

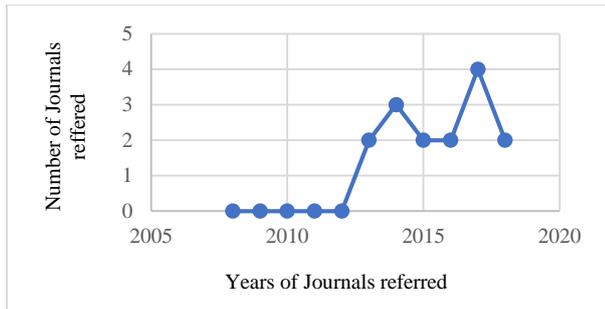


Figure 5 Journal referred

4. CONCLUSION

In the current review, by knowing factor contributing to carbon emission can be really appreciated by the construction player to minimize the harmfulness to the environment while doing construction activity. This is one of the Agenda of Sustainable Development Goal 2030 which to protect the environment. There are a few considerations that construction player should take note while doing construction activity, such as, using low carbon emission for machinery and also transportation. Enforcement from the government and local authority to those whom do not comply with the Environmental Act will be one of the good agenda to publish and to get all the parties whom involve in construction activity are well verse. From the research study, carbon emission may contribute a major harmless to the construction activities from initial stage to the delivery stage. The collaboration and awareness of each parties in construction project are meaningful to minimize the issues has been highlighted. The enforcement from the government as well as from the independent parties like professional bodies to monitor and enforce further action to be taken to minimize the issues. The success it's depending on all parties who involve in the construction project activities from developer, consultant, contractor as well as governing bodies to come as one to have good practices in construction site while delivering the project.

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