ESTIMATING THE ENVIRONMENTAL IMPACTS OF CARBON EMISSIONS FROM FUEL CONSUMPTION DURING CONSTRUCTION ACTIVITIES

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
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JANUARY 2015

This project report is dedicated to my wife and my parents without their love and support it could not have been produced.

ACKNOWLEDGEMENT

I wish to acknowledge and thank the following persons for their help and support rendered throughout the period of preparation of this thesis.

My supervisor, Dr, Khairulzan Yahya for his enthusiasm, guidance, constructive discussion and support throughout all stages of this research.

To the staff of the faculty of Civil Engineering and Universiti Teknologi Malaysia for their support and assistance towards my postgraduate studies.

I wish to thank my wife for her love and support and my parents for their kindly support.

Finally I appreciate all of my friends who helped me during this research.

ABSTRACT

Nowadays, there is a great concern about the environmental issues such as global warming. In the construction industry, traditional construction consumed huge amount of fuels and produce a large amount of carbon emissions that affect the environment. The aim of this study is to estimate the environmental impacts on global warming potential (GWP from fuel consumption during building construction activities by plants and machineries. The methodology that is used in this study is Midpoint Life Cycle Impact Assessment (LCIA). GaBi software has been used for the LCIA purposes. The findings revealed that there was a great impact from construction plants and machineries on GWP. Three types of machineries namely tower crane, lorry, and concrete mixer truck have been analysed in this study. Thed concrete mixer truck was found to be the highest contribution of global warming potential with the highest capacity of engine power. Results also shown that the global warming potential value for tower crane JT170-H10 and Potain H30/30C were 2.31E005 kg CO2 Eq and 2.37E005 kg CO2 Eq respectively. Meanwhile GWP for for Nissan lorry, Isuzu lorry and ZZ1257M3641 concrete mixer truck were 2.27E005 kg CO2 Eq, 2.24E005 kg CO2 Eq and 2.74E006 kg CO2 Eq respectively. The total global warming potential for all of these machineries were estimated to be around 3.7E006 kg CO2 Eq. Consequently, the concrete mixer truck were identified to contributed the highest carbon emissions because of the long usage duration and the engine power as well. Followed by the Potain H30/30C and JT170-H10. Moreover, Nissan lorry and Isuzu lorry were found to be the lowest contribution of carbon emissions. It can be concluded that the construction activities should take more consideration on the fuel consumption in order to reduce the GWP. Modern and efficient plants and machineries could help to reduce the fuel consumption and CO_2 emissions.

ABSTRAK

Pada masa kini, terdapat kebimbangan mengenai isu-isu alam sekitar seperti pemanasan global. Di dalam industri pembinaan, cara pembinaan tradisional menggunakan sejumlah besar bahan api dan menghasilkan sejumlah besar pengeluaran karbon yang memberi kesan kepada alam sekitar. Tujuan kajian ini dijalankan adalah untuk menganggarkan kesan alam sekitar dari sudut potensi pemanasan global (GWP) daripada penggunaan bahan api semasa penggunaan jentera dalam aktiviti pembinaan. Metodologi yang digunakan dalam kajian ini adalah Penilaian Kitaran Hayat (LCIA). Untuk melakukan proses LCIA, perisian Gabi yang telah digunakan. Hasil kajian menunjukkan bahawa terdapat kesan yang besar dari penggunaan jentera-jentera berat pembinaan terhadap pemanasan global. Tiga jenis jentera termasuk kren menara, lori, dan lori pembancuh konkrit telah dianalisis dalam kajian ini. Trak penggaul konkrit dikenalpasti mempunyai potensi pemanasan global yang paling tinggi dengan jumlah kuasa enjin yang tinggi. Keputusan kajian menunjukkan, GWP bagi kren menara JT170-H10 dan Potain H30/30C dianggarkan sebanyak 2.31E005 CO2 Eq dan 2.37E005 CO2 Eq setiap satu. Manakala GWP bagi lori Nissan , lori Isuzu dan trak penggaul konkrit ZZ1257M3641 adalah dianggarkan 2.27E005 kg CO2 Eq, 2.24E005 kg CO2 Eq dan 2.74E006 kg CO2 Eq setiap satu. Jumlah potensi pemanasan global untuk semua jentera adalah dianggarakan sebanyak 3.7E006 kg CO2 Eq. Trak penggaul konkrit dikenalpasti sebagai jentera dengan pengeluaran karbon yang paling tinggi. Ini disebabkan oleh tempoh penggunaan yang panjang dan kuasa enjinya yang tinggi. Selain itu, kren menara Potain H30 / 30C dan JT170-H10 turut dikenalpasti sebagai sumber pengeluaran CO2 yang tinggi. Manakala, kedua-dua lori Nissan dan Isuzu didapati menjana jumlah CO2 yang paling rendah daripada kalangan jentera-jentera ini. Kesimpulannya, bagi mengurangkan kesan GWP ditapak bina, sektor pembinaan perlu mengambil lebih pertimbangan tentang jumlah penggunaan bahan api dan selain pemilihan jentera-jentera moden dan efisyen bertujuan bagi penjimatan bahan dan mengurangkan pelepasan CO2.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Housing is one of the most important needs of every human being. Without housing, one would be exposed to adverse effects resulting from vagaries inherent in an environment. Exposure to bad weather would lead to hill health. Housing fosters the development of other industries. The building industry produces buildings for utilities, shops and communal facilities. Housing is also a tool for economic development. Today, it is widely accepted that human activities are contributing to climate change. The Fourth Assessment report of the Intergovernmental Panel on Climate Change (IPCC) estimated that between 1970 and 2004, global greenhouse gas emissions due to human activities rose by 70 percent (IPCC, 2007). While the full implications of climate change are not fully understood, scientific evidence suggests that it is a causal factor in rising sea levels, increased occurrence of severe weather events, food shortages, changing patterns of disease, severe water shortages and the loss of tropical forests. Most experts agree that over the next few decades, the world will undergo potentially dangerous changes in climate, which will have a significant impact on almost every aspect of our environment, economies and societies.

In forty years we need to have reduced our greenhouse gas emissions by at least 50% to avoid the worst-case scenarios of climate change. In eleven years, we

need to have achieved at least a 25% reduction in emissions. In December 2009 the world's nations are gathered in Copenhagen to negotiate an agreement on a new global protocol that will enable humanity to achieve the necessary global targets. The building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy. Furthermore, 41% of the total energy consumption in the U.S. is emitted 38% of greenhouse gas emissions. Given the massive growth in new construction in economies in transition, and the inefficiencies of existing building stock worldwide, if nothing is done, greenhouse gas emissions from buildings will more than double in the next 20 years. Therefore, if targets for greenhouse gas emissions reduction are to be met, it is clear that people must tackle emissions from the building sector. Mitigation of greenhouse gas emissions from buildings must be a cornerstone of every national climate change strategy (USDOE, 2011).

There are many environmental impacts in the way of development, but the one with the highest profile currently is global warming, which demands changes from government, industry and public. Concerns about the local and global environment situation are rising all over the world. Global warming is the consequence of long-term build-up of greenhouses gases (CO2, CH4, N2O, CO, etc.) in the higher level of atmosphere. The emission of these gases is the result of intensive environmentally harmful human activities such as the burning of fossil fuels, deforestation and land use changes (Buchanan and Honey, 1994). This is generally accepted to be the reason that average global temperatures have increased by 0.74 ^{o}C in the last 100 years. Global temperatures are set to rise by a further 1.1 oC in a low emissions scenario, and by 2.4 ^{o}C in a high emissions scenario, by the end of the century. it is necessary to reduce Green House Gases (GHG) emissions by 50% or more in order to stabilize global concentrations by 2100 (Houghton et al., 2001). The Tyndall Centre has suggested that a 70% reduction in CO2 emissions will be required by 2030 to prevent temperature rising by more that 1 ^{o}C (Bows et al., 2006).

Due to the increasing rate of fuel consumption because of the rapid population growth, the scarcity of fossil fuels, and alarming situation of some

environmental issues such as global warming, it is crucial to measure the amount of fuel consumption and its impact on the environmental indicators.

Early studies have proposed the Environmental indicators such as global warming, eutrophication, acidification, and resource depletion. It is important to identify the sources of these indicators. Many sectors such as agriculture, industry, construction, and transportation can be the sources of environmental indicators. Nowadays, the severity of these impacts in different sectors, the rate of negative impacts, and the way that these impacts can be controlled are the major concerns. In recent years, many studies have conducted by different researchers in this area and many breakthroughs have done to control the environmental indicators. To face these problems, the concept of life cycle assessment has introduced. Inside the LCA, there are two different methods include Endpoint and Midpoint. According to Jane C. Bare (2000), midpoints are considered to be a point in the cause-effect chain (environmental mechanism) of a particular impact category. To discuss about the Midpoint LCA, many indicators such as climate change, ozone depletion, acidification, eutrophication, soil erosion, and hydrological change have introduced. Many studies have conducted in this area during the demolition phase of buildings, utilization phase of buildings, and different phases of construction. This study tries to estimate the amount of fuel consumption and released emissions during the building construction activities during the structure and finishing phase of construction and the environmental impacts of them. Furthermore, the process of midpoint life cycle assessment towards finding the effects of emissions from construction plants and machineries on environmental indicators will be done.

1.2 Problem Background

Construction industry is responsible for a large amount of fuel consumption and emissions. According to Beatriz Rossello Batle and Andreu Moia (2009), the use and construction of buildings are responsible for 40% of energy use, 17% of water consumption, 32% of CO_2 emissions and 25% of wood consumption worldwide.

There are many problems with construction activities worldwide. One of the most critical problems in construction is the emissions related to the fuel consumption during construction, which leads to resource depletion. On the other hand, the fuel consumption in construction produces a large amount of emissions such as CO_2, N_2O, and CH_4. Consequently, these emissions lead to midpoint life cycle assessment indicators including climate change, ozone layer depletion, acidification, eutrophication, soil erosion, and hydrological change. Nowadays, global warming is one of the most important concerns worldwide. Green House Gases (GHGs) are generated from human activities like construction and cause the greenhouse effect, which is the reason for Global Warming based on the Intergovernmental Panel on Climate Change (IPCC, 2007). Today, many countries are trying to propose a global program to control the alarming situation of Global Warming in some countries.

When the sunlight enters the atmosphere and warms up the earth's surface, it absorbed by the greenhouse gases. Then these gases reflect the sun radiation one more time in all directions including back to the earth surface. As a result, the surface of earth is warmer in compare with the time that it would be only radiated by sunlight. So, when the greenhouse gases increase, consequently the greenhouse effect and global warming are intensified. "Burning of fossil fuels is part of the reason as to why global warming is caused. Fossil fuels contain high percentages of carbon which includes coal, petroleum and natural gas." said Gurmit Singh, Chairman of the Centre for Environment, Technology and Development Malaysia. Based on Jorgelina C. Pasqualino (2008), the construction sector uses a large amount of energy (for extracting, transporting, processing and assembling of materials) and thus emitting a large amount of carbon dioxide to the atmosphere.

To find a possible solution for environmental indicators like Global Warming many researchers had conducted many studies. Their attempts have reached to Life Cycle Assessment (LCA) methodology, which was applied to evaluate the environmental impacts of the construction phase of several building enclosure combinations, considering the type and amount of materials, their transport to the building site, the energy consumed by the machineries, and the disposal of material and packaging wastes.

1.3 Problem Statement

Since 1751, approximately 337 billion tons of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these emissions have occured since the mid-1970s. The 2007 global fossil-fuel carbon emission estimate, 8365 million metric tons of carbon, represents an all-time high and a 1.7% increase from 2006. Globally, liquid and solid fuels accounted for 76.3% of the emissions from fossil fuel burning and cement production in 2007. Combustion of gas fuels accounted for 18.5% of the total emissions from fossil fuels in 2007 and reflects a gradually increase in global utilization of natural gas. The European Union has agreed upon climate targets to decrease the emissions of greenhouse gases by 20% by 2020 and 50% by 2050 compared with the 1990 level (International Energy Agency, 2009) (United Nations, 2007) (European Commission).

Nowadays there is a growing concern for sustainability. This has led to a change in the otherwise economic approach to resource consumption accounting. In recent years, the tendency has been to use structural optimization criteria to reduce the environmental impact involved in all life cycle stages. Any optimization of design for sustainability should be conducted in accordance with the ISO 14040 standards, which require that an appropriate boundary and scope be set and justified (ISO 1998). Today, many concerns have risen because of environmental issues and especially Climate change and Global warming. Global warming is one of the most important environmental issues. Construction is one of the sectors, which cause global warming by consuming a large amount of fossil fuels and generating a large amount of carbon emissions. The over-dependence on fossil fuels and over-exploitation of earth's natural resources has now become obstructions for sustainable development in many countries. Global energy related emissions of CO_2 are anticipated to rise from 20.9 billion tons in 1990 to 28.8 billion tons in 2007. It is then projected to reach 34.5 billion tons in 2020 and 40.2 billion tons in 2030, an average growth rate of 1.5% per year. Reducing CO_2 emissions is one of the most widely used criteria, since data related to the environmental impact of most

construction materials have been compiled by distinct organizations (Goedkoop and Spriensma, 2001).

During building construction activities, the construction plants and machineries consume a large amount of fossil fuels and consequently, generate a large amount of carbon emissions. Midpoint life cycle assessment is looking for the primary impacts of carbon emissions. Global warming is one of the Midpoint Life Cycle Assessment indicators. According to Jane C. Bare (2000), Midpoint indicators may cause damages to human health and ecosystem at the endpoint if they will not be controlled. Therefore, Endpoint is to find a solution for human health problems or loss of biodiversity while Midpoint is preventing Global warming, Ozone depletion, Acidification, and other indicators to prevent human health and ecosystem impacts.

In this study, the researcher is going to estimate fuel consumption during the construction activities by plants and machineries and its related carbon emissions. Furthermore, the global warming potential would be estimated based on the carbon emissions. Solving or improving environmental problems such as global warming is a duty for human being to have a sustainable world in future. More fuels lead to more carbon emissions and more carbon emissions is the reason for many environmental indicators. One of these indicators is global warming which is a big concern in current century because when the temperature goes up, many disasters can occur. Therefore, it is important to assess the fuel consumption in construction and try to find some ways to reduce the fuel consumption. Therefore, we need some ways to find cleaner fuels or sources of energy. Meanwhile, reducing fuel consumption can be another way to control the Global Warming.

1.4 Aim of the study

Aim of the study is to estimate the Global Warming Potential (GWP) for some construction machineries by using the midpoint life cycle assessment methodology. This estimation is based on the fuel consumption of machineries and the carbon emissions generated from fuel consumption.

1.5 Objectives of the Study

Objectives of the study are as below:

1- To identify the type of construction machineries and their fuel consumption rate

2- To calculate the operation hours of all machineries

3- To estimate the amount of CO_2 emissions equivalent by the operation of the machineries

1.6 Scope of the Study

The scope of the LCA mostly consists of the functional unit, the system boundary, allocation procedures, data requirements and assumptions or limitations. The functional unit of this study was defined as the diesel consumption per 1 hour operation of machineries in the construction of Tropez Residences Towers.

The boundary of this study includes the structure and finishing phases of this project. In order to suit the objectives of the study and based on the system boundary, the study only focus on carbon emissions from operation of machineries. The fuel

used by machineries is diesel. Therefore, this study was focused on LCA of fuel used and GHG emissions based on the structure and finishing of the case study (Tropez Residences Towers in Johor Bahru).

REFERENCES

Baiocchi, G., Minx, J., & Hubacek, K. (2010). The impact of social factors and consumer behavior on carbon dioxide emissions in the United Kingdom. Journal of Industrial Ecology, 14(1), 50-72.

Baumann, H., & Tillman, A. M. (2004). The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application. External organization.

Bovea, M. D., & Gallardo, A. (2006). The influence of impact assessment methods on materials selection for eco-design. Materials & design, 27(3), 209-215.

Cao, S., & Li, C. (2011). The exploration of concepts and methods for low-carbon eco-city planning. Procedia Environmental Sciences, 5, 199-207.

DECC, D. (2011). Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting. London: Department for Environment, Food and Rural Affairs and Department for Energy and Climate Change.

Downie, J., & Stubbs, W. (2013). Evaluation of Australian companies' scope 3 greenhouse gas emissions assessments. Journal of Cleaner Production, 56, 156-163.

Dreyer, L. C., Niemann, A. L., & Hauschild, M. Z. (2003). Comparison of three different LCIA methods: EDIP97, CML2001 and Eco-indicator 99. The International Journal of Life Cycle Assessment, 8(4), 191-200.

Feliciano, M., & Prosperi, D. C. (2011). Planning for low carbon cities: Reflection on the case of Broward County, Florida, USA. Cities, 28(6), 505-516.

Glaeser, E. L., & Kahn, M. E. (2010). The greenness of cities: carbon dioxide emissions and urban development. Journal of Urban Economics, 67(3), 404-418.

Goedkoop, M., & Spriensma, R. (2001). The eco-indicator99: A damage oriented method for life cycle impact assessment: Methodology report.

Grisso, R. D., Kocher, M. F., & Vaughan, D. H. (2004). Predicting tractor fuel consumption. Biological Systems Engineering: Papers and Publications, 164.

Guinée, J. B., & Heijungs, R. (2005). Life cycle assessment. John Wiley & Sons, Inc.

Guinee, J. B., Heijungs, R., Huppes, G., Zamagni, A., Masoni, P., Buonamici, R., ... & Rydberg, T. (2010). Life cycle assessment: past, present, and future†. Environmental science & technology, 45(1), 90-96.

Heijungs, R., Goedkoop, M., Struijs, J., Effting, S., Sevenster, M., & Huppes, G. (2003). Towards a life cycle impact assessment method which comprises category indicators at the midpoint and the endpoint level. Report of the first project phase: Design of the new method VROM report, online: http://www. leidenuniv. nl/cml/ssp/publications/recipe_phase1. pdf.

Hertwich, E. G., & Peters, G. P. (2009). Carbon footprint of nations: A global, trade-linked analysis. Environmental science & technology, 43(16), 6414-6420.

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., & Rosenbaum, R. (2003). IMPACT 2002+: a new life cycle impact assessment methodology. The International Journal of Life Cycle Assessment, 8(6), 324-330.

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., & Rosenbaum, R. (2003). IMPACT 2002+: a new life cycle impact assessment methodology. The International Journal of Life Cycle Assessment, 8(6), 324-330.

Jolliet, O., Müller-Wenk, R., Bare, J., Brent, A., Goedkoop, M., Heijungs, R., ... & Weidema, B. (2004). The LCIA midpoint-damage framework of the

UNEP/SETAC life cycle initiative. The International Journal of Life Cycle Assessment, 9(6), 394-404.

Junhua, Y., & Ying, H. (2011). The Analysis of Correlation between Urban Residents Behavior and Low-carbon Economic Development. Energy Procedia, 5, 1762-1767.

Korjenic, A., & Bednar, T. (2012). Validation and evaluation of total energy use in office buildings: A case study. Automation in Construction, 23, 64-70.

Metz, B. (Ed.). (2007). Climate Change 2007-Mitigation of climate change: Working Group III Contribution to the fourth assessment report of the IPCC (Vol. 4). Cambridge University Press.

Omer, A. M. (2008). Focus on low carbon technologies: The positive solution Renewable and Sustainable Energy Reviews, 12(9), 2331-2357.

Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. Construction and Building Materials, 23(1), 28-39.

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., & Fleming, P. (2013). Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study. Journal of Cleaner Production, 56, 185-198.

Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. Energy and buildings, 40(3), 394-398.

Peters, V. A., & Manley, D. K. (2012). An examination of fuel consumption trends in construction projects. Energy Policy, 50, 496-506.

Robinson, W. S. (2009). Ecological correlations and the behavior of individuals International journal of epidemiology, 38(2), 337-341.

Rosselló-Batle, B., Moià, A., Cladera, A., & Martínez, V. (2010). Energy use, CO< sub> 2</sub> emissions and waste throughout the life cycle of a sample of hotels in the Balearic Islands. Energy and Buildings, 42(4), 547-558.

Sartori, I., & Hestnes, A. G. (2007). Energy use in the life cycle of conventional and low-energy buildings: A review article. Energy and buildings, 39(3), 249-257.

Skea, J., & Nishioka, S. (2008). Policies and practices for a low-carbon society Climate policy, 8(sup1), S5-S16.

Solomon, S. (Ed.). (2007). Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC (Vol. 4). Cambridge University Press.

Suzuki, M., & Oka, T. (1998). Estimation of life cycle energy consumption and CO emission of office buildings in Japan. Energy and Buildings, 28(1), 33-41.

Takase, K., & Suzuki, T. (2011). The Japanese energy sector: current situation, and future paths. Energy Policy, 39(11), 6731-6744.

Wee, K. F., Matsumoto, H., Ho, C. S., & Yu, F. L. (2008). Energy consumption and carbon dioxide emission considerations in the urban planning process in Malaysia.

Xin, Z., & Zhang, Y. (2008). Low carbon economy and low carbon city. Urban Stud, 4, 98-102.