AN INTEGRATED ENERGY AND WATER FOOTPRINT FOR OFFICE BUILDING SUSTAINABLE GREEN MANAGEMENT SYSTEM

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To the memory of my father Mr. Caeser O. Eze who did not live to see a day like this; your memory will live forever in this study.

To my Lord and Saviour, Jesus Christ of Nazareth for the gift of life which made this study possible.

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ABSTRACT

Global energy challenges, depletion of natural resources as a result of wastage and environmental issues are some of the problems facing the world today. Buildings and industries, especially in the urban areas and developed countries are the major consumers of energy and resources and a lot of them are into unsustainable consumption. These affect sustainable development. Though, there are a lot of sustainability footprints available in literature, but with some limitations in expressing combined measure of the environmental impacts of energy and water consumptions. This study presents an integrated footprint to express comprehensive environmental information as regards to energy and water. This study would encourage energy and water efficiency, reduce carbon emissions as well as protecting the environment. The system boundary created for this study has two utilities (water and air emission); four sectors (agriculture, transportation, industrial and domestic) and the Impact Assessment framework in which the IPCC Sectoral Approach was used to convert inventories into emissions and an environmental impact score of 0.590 was calculated. This result when benchmarked with a GEO shows that NO1 (the case study) is not environmentally sustainable. It revealed that there is room for improvement. Policymakers can make use of this footprint when making informed decisions/policies related to sustainability and environmental impacts. The environmental awareness of the general public can also be raised through this footprint.

ABSTRAK

Cabaran tenaga global, kekurangan sumber asli akibat pembaziran dan isu-isu alam sekitar adalah beberapa masalah yang dihadapi oleh dunia hari ini. Bangunan dan industri, terutamanya di kawasan bandar dan negara maju pengguna utama tenaga dan sumber dan banyak daripada mereka ke dalam penggunaan tidak lestari. Ini kesan pembangunan Lestari. Walaupun, terdapat banyak jejak kemampanan yang terdapat dalam kesusasteraan, tetapi dengan beberapa had dalam menyatakan ukuran gabungan impak alam sekitar konsumsi tenaga dan air. Kajian ini membentangkan kesan alam sekitar bersepadu untuk menyatakan maklumat yang komprehensif berkenaan kepada tenaga dan air. Kajian ini akan menggalakkan kecekapan tenaga dan air, mengurangkan serta pelepasan karbon melindungi alam sekitar. Sempadan sistem untuk kajian ini telah mencipta dua utiliti (air dan pelepasan udara), empat sektor (pertanian, pengangkutan, industri dan domestik) dan rangka kerja penilaian kesan yang pendekatan IPCC sektoral telah digunakan untuk menukar inventori ke dalam pelepasan dan impak alam sekitar perincian 0,590 dikira. Ini menyebabkan apabila aras dengan GEO menunjukkan bahawa no1 (kajian kes) tidak adalah alam sekitar yang mampan. Ia didedahkan bahawa terdapat ruang untuk penambahbaikan. dasar boleh membuat penggunaan jejak ini diberitahu apabila membuat keputusan / dasar-dasar yang berkaitan dengan kemampanan dan kesan alam sekitar. Kesedaran alam sekitar awam amnya boleh dibangkitkan juga melalui jejak Ini.

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LIST OF SYMBOLS

CH_4	-	Methane
CO_2	-	Carbon (IV) oxide
CO_2-e	-	Carbon (IV) oxide equivalent
Gha	-	Global hectare
H_2O	-	Water
Kg	-	kilogram
kWh	-	kilo Watt hour
m^3/t	-	meter cubic per tonne
m^3/unit	-	meter cubic per unit
m^3/yr	-	meter cubic per year
NOx	-	nitrous oxide
SO2	-	Sulphur dioxide
TJ	-	Terra Joules

LIST OF ABBREVIATION

CF	-	Carbon footprint
CHF	-	Chemical footprint
CML	-	Centre for
EC	-	European commission
EF	-	Ecological footprint
EDP	-	Ecosystem Damage Potential
EDIP	-	Environmental Design of Industrial Products
EPI	-	Environmental Performance Index
EPD2007	-	Environmental Product Declarations
EPS 2000	-	Environmental Priority Strategies in product design
GCMs	-	Green conservation measures
GEO	-	Green Energy Office
GDP	-	Gross Domestic Product
GEM	-	Green Manager
GFN	-	Global footprint Network
GHGs	-	Greenhouse gases
GWP	-	Global warming potential
IPCC	-	Intergovernmental panel on climate change
ISO	-	International Standard Organization
JF	-	Job footprint
KP	-	Kyoto Protocol

LCA	-	Lifecycle Assessment
LCI	-	Lifecycle Inventory
LCIA	-	Lifecycle Impact Assessment
LEO	-	Low Energy Office
NOB	-	Normal Office Building
PPCPS	-	Pharmaceutical and personal care product and services
SEM	-	Sustainable energy management
SETAC	-	Society of Environmental Toxicology and Chemistry
SGMS	-	Sustainable green management system
TNB	-	Tenega Nasional Berhad
TRACI	-	Tool for Reduction and Assessment of Chemical and other Environmental Impacts
UNEP	-	United Nations Environmental Programme
VWC	-	Virtual water concept
WCED	-	World commission on environment and development
WF	-	Water footprint
WFM	-	Water footprint manual
WFN	-	Water footprint Network
WWF	-	World wide fund

CHAPTER 1

INTRODUCTION

1.1 Research Background

The world is today being faced with global energy challenges, depletion of natural resources and environmental issues (e.g. global warming) etc. Bartram (2008) captured this scenario by saying that about a billion people in the developing countries lack safe drinking water and about two billion are without enough water for sanitation. It is really a serious problem facing mankind. On the other hand, consumption does not seem to measure up with production and the earth cannot regenerate in line with the faster consumption and wastage.

Energy sources like coal, oil and gas are expected to last at least 250 years and 50 years respectively (Kruger, 2006). Although, these predictions are unproven but there remain the uncertain future that human race is facing. Energy sources e.g. coal and nuclear according to Harmon and Cowan (2009), present difficult environmental challenges. The Intergovernmental Panel on Climate Change (IPCC, 2007; Hua *et al.*, 2011) reported that global warming is a serious threat to the world and its ecosystem, and the increase in concentrations of carbon emissions in the

atmosphere might be the cause. Tjan *et al*., (2010) supported the claim above by saying that *"the greenhouse gases (CO_2, CH_4, NO_x etc.) emissions from industrial activities have long been known to be the contributors to global warming".* The scenario may continue as the developing nations increase their quest for energy. All these environmental issues and wastage affect sustainable development. Before a meaningful development can be achieved, sustainability has to be maintained and sustained.

The concept of sustainable development since 1980 is based on the three pillars: Social, Economic and Environmental as shown in Fig. 1.1 (Moldan *et al.,* 2012). A development is sustainable when it meets today's needs without affecting the ability of the future generations to meet their own needs (WCED, 1987). Of the three pillars of sustainability, more attention was given to environmental sustainability in this study.

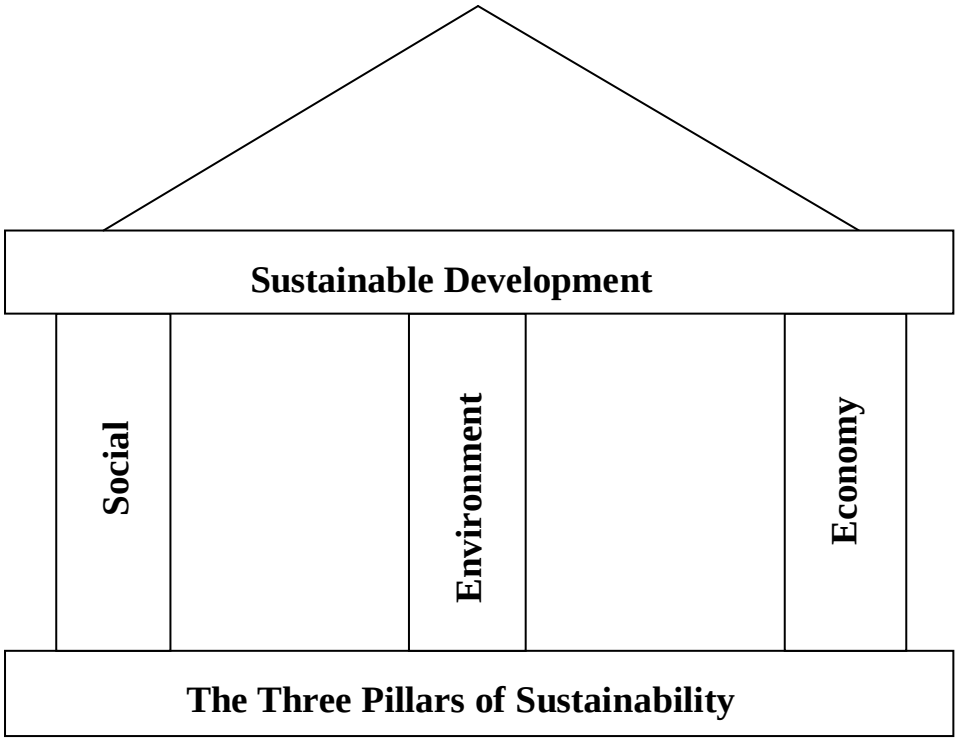

Figure 1.1 The pillars of sustainability (UN, 2002)

Environmental sustainability seeks the improvement in human wellbeing by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans (Goodland, 1995). In this regard, environmental sustainability emerged as a critical policy focus across the world because of awareness on pollution control and natural resources management challenges as being demanded by governments (EPI Yale, 2010).

Buildings and industries, especially in the urban areas and developed countries are the major consumers of energy and resources (Dall'O' *et al.*, 2012). In order to reduce the energy consumption, minimize carbon emissions, maintain sustainability and protect the environment, it is important and necessary to be prudent in the resource consumptions of these buildings. For this to be achieved, it is imperative to draw a line between sustainable and unsustainable consumptions. With this achieved, then what needs to be done either to improve or maintain the consumption pattern will be determined.

However, one of the methods to address some of these environmental problems facing mankind today lies on the proposed new concept known as Sustainable Green Management System (SGMS) via energy and water integrated footprint. This footprint takes into account in its assessment the environmental burden caused by energy and water related activities of an office building. It distinguishes between sustainable and unsustainable consumption patterns.

Sustainable Green Management System (SGMS) is defined as the combination of environmental thinking, awareness and sustainability in the management of energy and resources of a building. The approach of SGMS is quite different from the traditional Sustainable Energy Management (SEM) because of the

word “green” which is known for sustainability. SEM in the other hand lacks the combination of energy and water efficiency. The main difference between SEM and SGMS is that, SGMS is going to measure sustainability of a building with the help of the proposed energy and water integrated footprint.

A footprint for a given material/resource (e.g. carbon or water) according to UNEP/SETAC (2009) describes how human activities can introduce different kinds of burdens and impacts on a global sustainability. Hoekstra (2009) defined it as a quantitative measurement which describes the allocation of natural resources by human. From these two definitions, it is clear that a given footprint determines the resources allocated and the environmental burden arising from the use of these resources by human beings.

1.2 Problem Statement

With the depletion of natural resources as a result of wastage, the high energy and water consumptions by industries and buildings (especially in the cities), though, there are a lot of sustainability footprints available in literature, but with some limitations in expressing a combined measure of the environmental impacts of energy and water consumptions.

This study as proposed investigated the possibility of having an integrated footprint to express comprehensive environmental information in relation to energy and water. This footprint would help to protect the environment, and also encourage energy and water efficiency.

1.3 Objective

The objective of this study is to develop an integrated footprint that can express comprehensive environmental information as regards to energy and water consumption of an office building. An indicator that will be useful for the purposes listed below:

a) To develop an integrated footprint that can express environmental impacts of water and energy consumption.
b) To identify activities that can cause environmental harm and the impact category with the greatest environmental impacts.
c) To provide policymakers quantitative tool to make informed decisions/on policies related to sustainability and environmental effects.

1.4 Significance of the Research

Large buildings and facilities typically consume large amount of utilities and face challenges to make efficient use of resources and maintain good air quality as well as working environment. It is important to have an overall indicator to be used as a benchmark to quantitatively measure the greenness of a building and the environmental impacts associated with it. This indicator is important for the following reasons:

a. To increase the awareness on the need for efficient use of resources (e.g. energy and water).
b. To help in combating environmental effects through carbon emission reduction.
c. To reveal the environmental impact of tap water consumption.

d. This study can also be very useful to academia and sustainability practitioners/researchers.

1.5 Scope of Research

The scopes of this research are limited as follows:

a) To study on how to integrate the environmental impacts of energy and water to get a footprint.
b) The study of the existing mechanisms used to develop major footprints including carbon, water and ecological footprints and also LCA.
c) The use of NO1, Chemical Engineering Department, Universiti Teknologi Malaysia (UTM) as case study for energy and water data collection for a period of one year (2012).

1.6 Thesis Structure

This study is made up of five chapters as summarized below:

Chapter 1: Introduction

This gives the brief introduction to the study, which includes the research background, problem statement, objectives, scope and significance of the research.

Chapter 2: Literature Review

This discussed several topics related to this research. The topics reviewed are Carbon footprint, Water footprint, and Ecological footprint. It also includes their methodologies, strengths and weaknesses, applications etc. LCA and some LCIA methods were also discussed.

Chapter 3: Methodology

This chapter discussed the methodology used in this study, like the system boundary of the footprint, the assumptions taken, data collection and analysis etc.

Chapter 4: Results and Discussion

The results were presented in this chapter. Environmental impacts of energy and water were revealed as well as environmental effects e.g. global warming, acidification etc.

Chapter 5: Conclusion and Recommendation

This is the last chapter and hence the summary of this research work. It concludes on the creation of this integrated footprint with a single point score calculated. It also contains recommendations for future work.

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