CHAPTER II
BACKGROUND AND LITERATURE REVIEW

2.1 Climate Change

Climate Change refers to any significant change in climate (i.e. temperature, precipitation or wind) lasting for an extended period (decades or longer than decades) (IPCC, 2007). It is caused by human-induced emissions of carbon dioxide which are currently 30 % higher than those in pre-industrial times. The phenomenon alters rainfall patterns, intensifies storms and causes sea level rise. Issues of global warming and greenhouse gas (GHG) emissions are increasingly becoming one of the major technological, societal, and political challenges that are closely related to energy generation and used (Fawcett, Hurst and Boardman, 2002). In recent years, the world has realized the importance of climate change because of this problem affect to the balance of the world's climate, change of the seasons and ecosystems as el as affect to the human being and animals, and since the problem is even more intense. In response to this threat governments around the world are setting targets to reduce GHG levels. The reliability of the data from which such targets are set, and which emission reduction claims are based on, is vital.

2.2 The Greenhouse Gas Protocol Initiative (GHG Protocol)

The Greenhouse Gas Protocol Initiative (the GHG Protocol) has been developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) and is currently broadly applied for carbon footprint assessment all over the world (Greenhouse Gas Protocol, 2010). The GHG Protocol is particularly popular in USA where it is officially recognized as a primary GHG emission accounting and reporting tool for organizations. It provides estimates of the carbon footprint for a number of business sectors, including services. The process or activity specific GHG emission factors utilized by the GHG Protocol have been retrieved from a range of carbon inventories where the US Environment Protection Agency (EPA), Intergovernmental Panel on Climate Change (IPCC) and the UK's Department for the Environment, Food and Rural Affairs (DEFRA) represent the major data donors (Greenhouse Gas Protocol, 2010).

The principal GHG covered by the Kyoto Protocol enter the atmosphere because of human activities. They are as follow (EPA, 2011):

- **Carbon Dioxide (CO_2):** Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (such as the manufacture of cement). Carbon dioxide could be removed from the atmosphere when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4):** Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic substances.
- **Nitrous Oxide (N_2O):** Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated Gases**: Synthetic, powerful GHG that are emitted from a variety of industrial processed. Fluorinated gases are sometimes used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons). These gases are typically emitted in smaller quantities, but their potential causes them their name: high global warming potential gases ("high GWP gases")

2.2.1 Global Warming Potentials (GWP)

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects are caused by absorbing radiation. Indirect effects are caused when the substance affect other greenhouse gases. The IPCC developed he global warming potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas as shown in Table 2.1. The GWP of a greenhouse gas is the ratio comparing 1 kilogram (kg) of a substance relative to 1 kg of a CO_2, and GWP emissions are measured in tetragrams (or million metric tons) of CO_2 equivalent (Tg CO_2e). For example, methane has a much greater greenhouse effect than carbon dioxide, but carbon dioxide exists in greater quantities in the atmosphere than methane. Therefore, most climate change mitigation focuses on CO_2 emissions, and it is commonly referred to as carbon (Brewer, 2008).

Table 2.1 Global warming potentials of some greenhouse gases (IPCC, 2007)

Species	**Chemical Formula**	**GWP_{100}**
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbons	HFCs	124-14800
Sulphur hexafluoride	SF_6	22800
Perfluorocarbons	PFCs	7390-12200

2.2.2 Source of Greenhouse Gases

The sources of GHG come from various sectors including transportation, industrial processes, and power generation for residential consumption, agriculture and deforestation. Table 2.2 shows sources of GHGs emission.

Table 2.2 Source of GHGs. (Carbon Trust, 2007)

Species	**Source of GHGs**
Carbon dioxide	Fuels for Energy, Transport, and Manufacturing Processes
Methane	Waste (Landfills, natural activity)
Nitrous oxide	Chemical manufacturing and agriculture
Hydrofluorocarbons	Refrigerants, chemical manufacturing, foams and aerosols
Sulphur hexafluoride	High voltage switchgear, electronics manufacturing
Perfluorocarbons	Aluminum manufacturing, electronics manufacturing

The concentrations of greenhouse gases are affected by the total amount of greenhouse gases emitted and removed from the atmosphere around the world over time. Figure 2.1 shows Global CO_2 emissions by Country. The emission from China was the largest contributor of any country (23 %) of the total emissions. The U.S. also significantly contributed to CO_2 emissions (19 %) of global emissions. Figure 2.2 shows GHGs emission by source. The GHGs emission from energy supply was biggest source of GHGs emission (26 %), follows by industry (19 %).

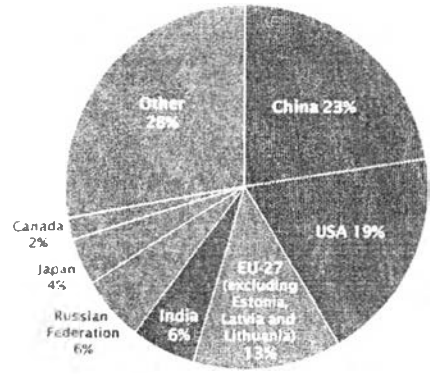

Figure 2.1 Global CO_2 emissions by country in 2008 (National CO_2 Emissions, 1751-2008).

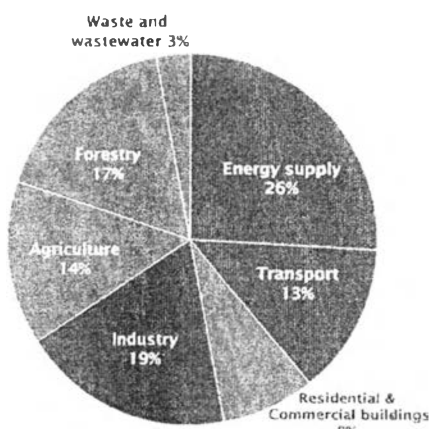

Figure 2.2 Global greenhouse gas emissions by Source (IPCC, 2007).

2.2.3 The Environmental Impacts due to Climate Change

Many elements of human society and the environment are sensitive to climate variability and change. Human health, agriculture, natural ecosystems, coastal areas, and heating and cooking requirements are examples of climate-sensitive systems. Rising average temperatures are already affecting the environment. Some observed changes include the shrinking of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of growing seasons, shifts in plant and animal ranges ad earlier flowering of trees (IPCC, 2007). The effects of global warming are of concern both for the environment and human life as follows:

- Rising sea levels lead to more coastal erosion, flooding during storms, and permanent inundation.
- Increased droughts lead to increased incidences of wildfires.
- Climate change severely stresses many forests, wetlands, alpine regions, and other natural ecosystems.
- Impacts on human health result as mosquitoes and other disease-carrying insects and rodents spread diseases over larger geographical regions.
- Increased temperature, water stress, and sea-levels rise in low-lying areas such as Bangladesh and the Mississippi River delta have disrupted agriculture production.

2.2.4 United Nations Framework Convention on Climate Change

An international agreement launched in 1992 to address the climate change issue, the United Nation Framework Convention on Climate Change (UNFCCC), was ratified by 188 countries. They committed to reducing GHGs emissions by the year 2000, to levels lower than the ones of the year 1990. However, a more detailed policy, requiring higher emission reductions, was found to be necessary, leading to the establishment of the Kyoto Protocol (DEFRA, 2005b).

The countries that agreed to comply with the UNFCCC have to collect and share their GHGs records and their policies at a national level. These countries have to evolve strategies to achieve the targets posed by the Convention, to adapt to the expected consequences, and to become familiar with the climate change effects through collaboration. Another responsibility resulting from the agreement is to provide financial and technological support to developing countries.

2.2.5 The Kyoto Protocol

The Kyoto Protocol was agreed on December 11th 1997, to improve countries efforts to address the climate change. In order to become law, the Protocol had to be ratified by no less than 55 countries. By 1999, it was signed by 84 governments (UNFCCC, 2005). The Annex I countries, which were responsible for 55 % of CO_2 emissions in 1990, as shown in Figure 2.3, setting their targets to reduce the overall emissions by 5.2 % and CO_2 emissions by 13.7 % against the 1990's benchmark. These targets have to be met by 2012 (DEFRA, 2005b).

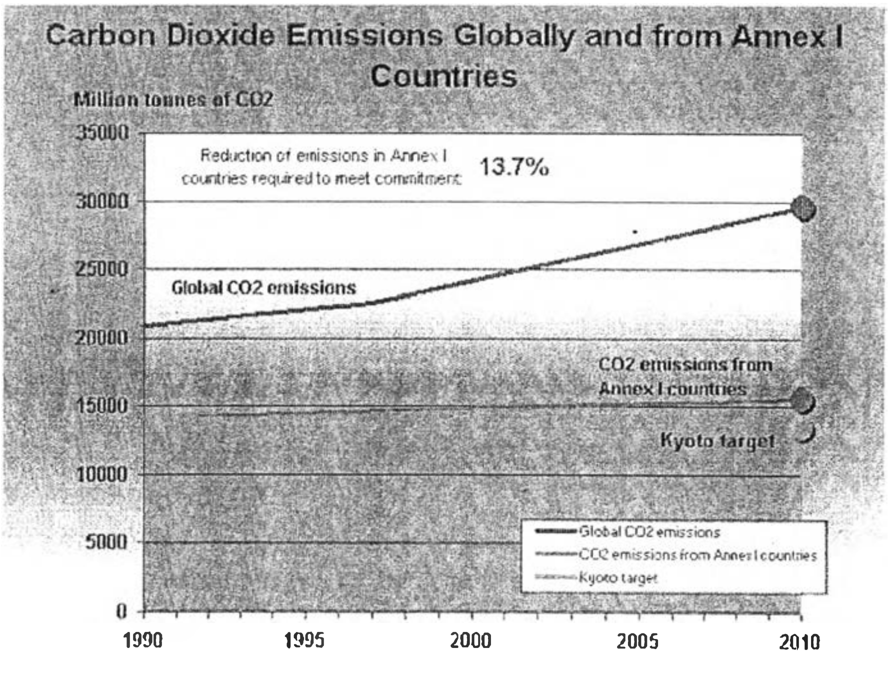

Figure 2.3 Global and Annex I countries' CO_2 emissions (UNEP, 2005).

2.3 Greenhouse Gases Evaluation Method

The tool can be used as a mechanism to assess and control the emission of GHGs have a wide range of Ecology footprint, LCA, CF, etc., which are described in detail the way in the next section.

2.3.1 Ecological Footprint

The ecological footprint is a measure of the consumption of renewable natural resources by a human population. A country's Ecological Footprint is the total area of productive land or sea required to produce all the crops, meat, seafood, wood and fiber it consumes, to sustain its energy consumption and to give space for its infrastructure. The Ecological Footprint can be compared with the biologically productive capacity of the land and sea available to that country's population. To calculate the number of hectares available per capita, one adds up the biologically productive land per capita world-wide of arable land, pasture, forest, built-up land and sea space, excluding room for the 30 million fellow species with whom humanity shares this planet. At least 12 percent of the ecological capacity, representing all ecosystem types, should be preserved for biodiversity protection. Accepting 12 percent as the "magic" number for biodiversity preservation, one can calculate that from the approximately 2 hectares per capita of biologically productive area that exists on our planet, only 1.8 hectares per capita are available for human use.

Since the late 1980s, the Ecological Footprint has exceeded Earth's capacity by about 30 %. Also, the Living Planet Index that measures trend in the Earth's biology diversity fell by nearly 35 % between 1970 and 2005. United Nations projections of slow, steady growth of economies and populations suggested that humanity's demand on nature will be twice the productive capacity in 2050. (Figure 2.4)

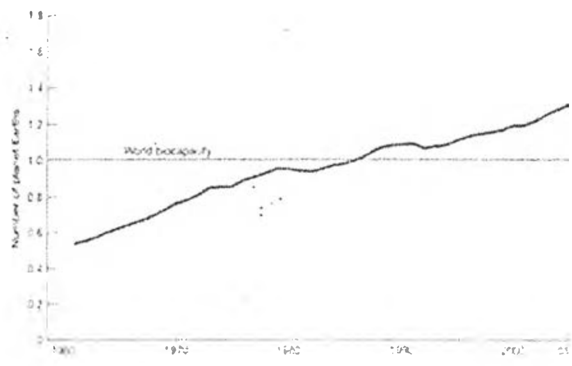

Figure 2.4 Humanity's ecology footprint, 1961-2005 (WWF's Living Planet Report 2008).

2.3.2 Carbon Footprint

A 'carbon footprint' measures the total GHG emissions caused directly and indirectly by a person, organization, event or product, and is typically given in tons of CO_2-equivalent (CO_2e) per year.

The carbon footprint is made up of the sum of two parts, the primary footprint and the secondary footprint (Carbon Footprint, 2004).

2.3.2.1 The Primary Footprint

It is a measure of the direct emissions of CO_2 from the burning of fossil fuels including the emissions from domestic energy consumption and transportation (e.g., by car and plane) such as those associated with their manufacture and eventual breakdown.

2.3.2.2 The Secondary Footprint

It is a measure of the indirect CO_2 emissions from the whole lifecycle of products which is associated with their manufacture and eventual breakdown. It is calculated using a method called life cycle assessment (LCA). This method is used analyze the cumulative environmental impacts of a process or product through all the stages of its life. It takes into account energy inputs and emission outputs throughout the whole production chain from exploration and extraction of raw materials to processing, transport and final use.

To reduce the effect of climate change, carbon output could be reducing by reducing GHG production as following step:

- Calculate a carbon footprint to understand the amount of carbon dioxide emissions
- Measure the carbon footprint against peers (e.g., similar company size or for individuals, a national average)
- Determine the ideal carbon footprint
- Identify the source of the most significant carbon dioxide emissions
- Reduce carbon dioxide emissions by starting with the most significant sources

The carbon footprint originates concept and name from the ecology footprint, and is a sub-set of the data covered by a more complete LCA. LCA is and internationally standardized method (ISO 14040, ISO 14044), while the carbon footprint is a more recent standard from the International Organization for standardization, ISO 14064. LCA is used for the evaluation of the environmental burdens and resources consume along the life cycle of product: from the extraction of raw materials, the manufacture of goods, and their use by final consumers or for the provision of a service, recycling, energy recovery and ultimate disposal. For the corporate carbon methodology of based on WBCSD methodology, it focus on only emissions created by its corporate, not entire-life. One of the key impact categories considered in an LCA is climate change, typically using the IPCC characterization factors for CO_2 equivalents. Hence, a carbon footprint is a LCA with the analysis limited to emissions that have an effect on climate change.

2.4 Carbon Footprint

2.4.1 Types of Carbon Footprints

2.4.1.1 Individual Footprints

The total amount of GHG (CO_2e) produced to directly or indirectly support activities of each person over a year. In the medium and long term, the carbon footprint must be reduced to less than 2,000 kg (CO_2e) per year and per person. This is the maximum allowance for a sustainable living. Individual footprints consist of activities in daily life such as driving a car, flying on vacation, heating a house, and buying goods and foods

2.4.1.2 Organizational/Business Footprints

An organization (office) or business contributes to climate change, and even if its impact is relatively small, it should be taken into consideration and managed properly. Lighting, heating and cooling, computer, printers, copiers, business travel, and commuting are among a number to source of GHG. The GHG protocol and ISO 14064 part 1 can be referred to for methodologies for accounting and reporting an office's emissions. According to GHGs emissions that impact to environment, all part of the world need to concern about this problem. Academic organization is also one of place which consists of many people with various activities; therefore it is suitable for a model to study measurement of GHGs emissions in the organization.

2.4.1.3 Product Footprint

Product assessments involve quantifying all the emissions associated with a product. Product footprints can be from "cradle to customer", which includes all emissions from the extraction of the raw materials, processing, manufacturing, and delivery to retailers/customers, or "cradle to grave" (also known as "whole of – life"), which includes all emissions sources for "cradle to customer", and those associated with consumer use and the final disposal of the product.

2.4.2 Standard and Guidance

2.4.2.1 An Organization/Business Footprints

It involves quantifying the direct and indirect emissions associated with an organization.

- The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (1st ed. and revised ed.)

- ISO 14064-65 series of standards (ISO, 2006). These are fully consistent and compatible to the standards adopted by the GHG Protocol (Hodgson and Gore, 2007).
- ISO 14064-1: 2006, Greenhouse Gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.
- ISO 14064-3: 2006, Greenhouse Gases - Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions.
- ISO/PDTR 14069: 2011, Greenhouse Gases - Quantification and reporting for GHG emissions for organizations - Guidance for the application of ISO 14064-1 (working draft 3) (TGO, 2013).

2.4.2.2 Product Footprints

It involve quantifying all the emissions associated with a product

- ISO 14067
- Publicly Available Specification 2050 (PAS 2050)

2.4.3 Benefits of Calculating the Carbon Footprint

The carbon footprint is calculated for these reasons:

2.4.3.1 Management:

Carbon footprints can be used as effective tools for ongoing energy and environmental management. It is generally enough to understand and quantify the key emissions sources through a basic process.

2.4.3.2 Reduction:

Having quantified the emissions, opportunities for reduction can be identified and prioritized, focusing on the areas of greatest savings potential.

2.4.3.3 Reporting and Dissemination:

Organizations increasingly want to calculate their carbon footprint in detail for public disclosure in a variety of contexts:

- For CSR or marketing purposed

- To fulfill requests from business or retail customers, or from investors
- To ascertain what level of emissions they need to offset in order to become "carbon neutral"

2.4.3.4 Offset Strategies:

Carbon offsets (or carbon credits) can be used for compliance as well as for voluntary purposes. In the compliance market, offsets are acquired by organizations and governments to comply with their emissions reduction targets set under the Kyoto Protocol or other compliance initiatives.

2.4.4 Greenhouse Gases Assessment Method

2.4.4.1 Scope for Greenhouse Gas Accounting

The Greenhouse Gas Protocol Corporate Standard (World Resource Institute and World Business Council for Sustainable Development, 2004) defines the scope for delineating direct and indirect emission sources into 3 scopes are as follows:

- Scope 1: Direct GHG emissions occur from sources that are owned or controlled by the company; for example, emissions from combustion in production process.
- Scope 2: Energy indirect GHG emissions account for greenhouse gas emission from the generation of purchased electricity, steam, or heat consumed by the company
- Scope 3: Other indirect GHG emissions are the results of the activities of the company, but occur from sources not owned or controlled by the company; for example, transportation of purchased material and fuels.

From 3 scopes, we can describe to clearly understand in Figure 2.5.

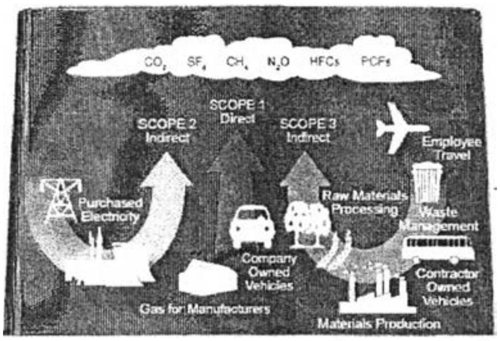

Figure 2.5 Scope of greenhouse gas emission by sources (WRI, 2006).

2.4.4.2 Tier Method (IPCC)

Three tier methods are provided depending on the availability of data because of the emissions vary with feedstock used, process and used. The choice of method depends on national's situation and IPCC guideline gives the decision tree in order to guideline how to use three tier methods.

- Tier 1: method is simple method by using default factors and equation that provided in the IPCC guideline.
- Tier 2: method is similar with Tier 1, but the factors are based on country or region-specific data. So, this method may have more stratification and can account for abatement.
- Tier 3: method is an advanced method, more complex and detailed modeling approaches – results compatible with Tier 1 and 2.

2.4.5 Methodological Framework

The assessment of the carbon footprint should be based on the four phases of LCA phases as shown in Figure 2.6. The LCA process is a systematic, phased approach and consists of four major steps (Roy *et al., 2009*).

2.4.5.1 Goal and Scope Definition

2.4.5.2 Life Cycle Inventory

2.4.5.3 Life Cycle Impact Assessment

2.4.5.4 Interpretation.

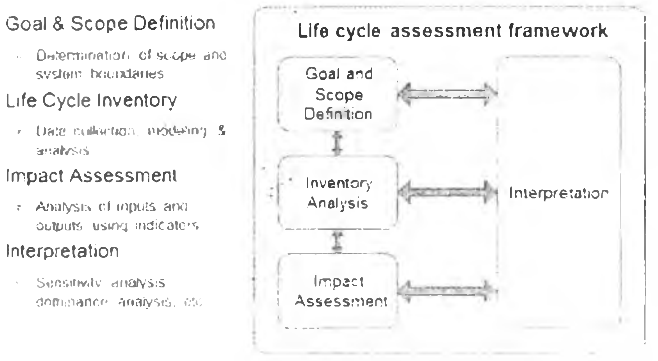

Figure 2.6 The four major steps of the LCA concept.

2.4.5.1 Goal and Scope Definition:

The goal of carbon footprint must be clearly defined following by the objectives of the result application; for example, the carbon footprint of organization for assessment of GHG emissions over time. The scope should define as the following aspects:

2.4.5.1.1 Functional Unit

Based on ISO 14040/44, the functional unit is to provide a reference to which the input and output data are normalized (in a mathematical sense). Therefore the functional unit should be explicitly set and can be measured.

Therefore, the carbon footprint of product must be expressed in terms of CO_2 equivalent per unit.

2.4.5.1.2 System Boundary

The system boundary should provide the information about the scope of the assessment, product system and unit process including associated inputs and outputs. The scope of the assessment of the GHG emission shall be defined according the activities of the organization.

2.4.5.1.3 Proportion of GHG Emissions Significantly and the Minimum Acceptable.

The carbon footprint calculation should be has the amount of the GHG emissions not less than 95 % of the total GHG emissions. Activities having less than 1 % of the total GHG emissions can be cut-off; however, the total cut-off cannot be more than 5 % of the total greenhouse gas emission. In case of cut-off, the assessment of GHG emissions from the inputs and outputs shall be scaled up to represent 100 % of the total GHG emissions related with the product unit.

2.4.5.1.4 Substitute Data for GHG Emission Factors of Inputs.

If the emission factor of some inputs and outputs cannot found, the emission factors of substances having similar physical and chemical properties can be used. In case of inputs or outputs cannot identify or find their emission factor for calculating, the highest emission factor of inputs or outputs can be used instead.

2.4.5.2 Life Cycle Inventory:

In this second phase, identified Identify energy, water, and material usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges) are quantified.

2.4.5.3 Life Cycle Impact Assessment:

This third phase, involve the identification of the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.

2.4.5.4 Interpretation:

In this final phase, the results of the inventory analysis and impact assessment are evaluated to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the result.

2.4.6 Data Sources and Data Quality

2.4.6.1 Data Quality

The data used in the assessment of GHG emissions shall be taken into account in terms of the data quality are as follows:

- Time-related coverage: consider data age and average data from annual production.

- Geographical coverage: consider data collected from different geographical locations according to the objective of carbon footprint study.
- Technology coverage: specify whether specific or mixed technology.
- Precision: consider variation in data depending of type of database, if available.
- Completeness: completeness of inputs and outputs based on direct measurements or estimation.
- Representativeness: consider time, geography and technology based on the actual situation with justification.
- Consistency: perform qualitative assessment by considering if the database development are similar or not.
- Reproducibility: enable the reproducibility of results by another person using similar methods.
- Sources of data: demonstrate the source and reliability of data
- Uncertainty: take into account the data uncertainty issues.

2.4.6.2 Data Type (TGO, 2011)

The types of data used for calculating carbon footprint are as follows:

a) Primary data

The primary data that used for calculating carbon footprint includes all direct activities under control of the organizations and manufacturers such as energy and raw material use, transport of raw materials, etc.

b) Secondary data

The secondary data can be used when the primary data cannot be accessible such as upstream emissions, activities outside the control of implementing organization. The secondary data sources shall be based on these sources are as follows:

- National LCI database
- Peer-reviewed journal, technical report, or these in the context of Thailand

- Databases available in LCA software
- Publications from international organizations (e.g. UN, FAO. etc.)

2.4.7 Calculation of Carbon Footprint (TGO, 2011)

The calculation of a carbon footprint is performed using the following steps:

2.4.7.1 Converting the Primary and Secondary Data

The primary and secondary data of inputs/outputs to GHG emissions by multiplying their loading with the respective emission factors.

2.4.7.2 Converting the GHG Emissions

Converting into CO_2e by multiplying the individual GHGs emission figures by the relevant global warming potential (GWP).

The GWP is a ratio of the warming that would result from the emission of one kilogram of a GHG to that from the emission of one kilogram of CO_2 over a fixed period of time such as 100 years.

2.5 Thailand Greenhouse Gas Management Organization: TGO (Public Organization)

Thailand signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and ratified the Convention in March 1995. Realizing the seriousness of climate change as a global threat, the country has been contributing to international efforts to address climate change issues, as a Non-Annex I country. In February 1999, Thailand signed the Kyoto Protocol, and ratified it on 28th August 2002. As a Non-Annex I country, Thailand promotes the implementation of Clean Development Mechanisms (CDM) under the Kyoto Protocol in order to encourage clean and environmental friendly technologies for greenhouse gas reduction in the country, as well as to promote the country's capability by developing sustainable business practices. Ministry of Natural Resources and Environment (MNRE), as a result of the Cabinet Resolution, is the responsible agency for the implementation of the UNFCCC and the Kyoto Protocol in Thailand. In 2007, MNRE redesigned the institutional framework for Thailand's implementation to the UNFCCC and the Kyoto Protocol Thailand Greenhouse Gas Management Organization (Public Organization), or TGO (Fig 2.7), is the newly established autonomous governmental organization with a specific purpose as an implementing agency on greenhouse gas (GHG) emission reduction in Thailand, promoting: low carbon activities; investment and marketing on GHG emission reductions; establishing GHG information centre; reviewing CDM projects for approval; providing capacity development and outreach for CDM stakeholders and promote low carbon activities, and particularly performing its role as the Designated National Authority for CDM (DNA-CDM) office in Thailand (TGO, 2013).

Figure 2.7 Thailand Greenhouse Gas Management Organization (TGO).
[*www.tgo.or.th/*].

TGO and the National Metal and Materials Technology Center have developed a carbon footprint calculation in order to award the Carbon Footprint for products made in Thailand (Figure 2.8). The carbon footprint takes into account the quantity of greenhouse gas emissions from each production unit for the whole life cycle (cradle to grave) of a particular product. The Carbon Footprint is the result of a calculation the carbon dioxide equivalent of the emissions originated from the extraction of raw materials, transportation and manufacturing all the way to waste management at the end of the product's life.

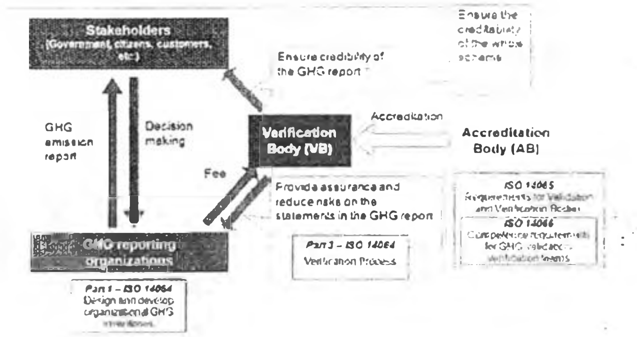

Figure 2.8 Registration process.

2.5.1 TGO's Objectives and Duties

- Analyzing and screening the CDM projects for issuance of the Letter of Approval (LoA) and monitoring the projects;
- Promoting CDM projects and the CER Market;
- To be the National Information Clearing House of Greenhouse Gas;
- Management of all information regarding the approved CDM projects and CERs' value;
- Enhancing the capacity building of the government and private sectors on greenhouse gas management;
- Promoting public outreach regarding greenhouse gases;
- Promoting and supporting all activities related to climate change mitigation (Organization, 2013).

2.6 Carbon Footprint Reduction

The mitigation of carbon footprints through the development of alternative projects, such as solar or wind energy or reforestation, represents alternatives for reducing a carbon footprint. This process, and carbon offsetting, enable people and organization to reduce their carbon footprint. There are several ways of off-setting a carbon footprint (zero carbon footprint, 2006).

- Plant a tree, or a few trees: "breathe in" carbon dioxide and "breathe out" oxygen. This process is called "carbon sequestration" Tree planting is one of the most common form of carbon offset. Trees absorb carbon dioxide and produce oxygen and wood, both of which are very useful for humans and other animals.

- Carbon dioxide credits: Buy purchasing carbon credits and not using them; they are retired so no other person or organization can buy them – thus offsetting a carbon footprint. This stops other people, organizations and countries using them.

- Invest or donate to companies/ organizations, which are researching and developing renewable and sustainable technologies: This option is becoming more common by supplying technologies, such as low energy light bulbs to worthwhile project in developing countries.

- Invest in Sustainable Technology Development: There are many sustainable technologies which are worth supporting either through donations or investment. These include:

- Renewable energy (e.g., wind, wave, solar, etc.)
- Biomass fuels
- Waste to energy projects
- Recycling
- Super-efficient vehicles

- Purchase power from 'green' or renewable energy providers

- Select products from companies who have responsible environmental policies, or who offset the carbon footprint on the products purchase.

The ultimate goal when reducing a carbon footprint is to achieve carbon neutrality. Carbon neutral is defined as having zero net carbon emissions. Organizations can reduce emissions by using renewable energy sources, purchasing carbon offsets and recycled materials, or simply reducing energy and material use. Individuals must reduce their own footprint for an organization to be successful in this goal. Changes in daily habits leading to the consumption of less energy and lower emissions from transportation by using alternate modes and carpooling are the most significant contributions most individuals can make (Douglass, 2008).

2.7 Literature Reviews

The literature reviews consist of carbon footprints of many organizations, especially academic organization. The criteria to calculation the carbon footprint in the organizations and comparison with the previous studies are shown in Table 2.3.

Wiedmann and Minx (2007) suggested a definition for the terms of carbon footprint in hopes of stimulating an academic debate about the concept and process of carbon footprint assessments. They argued that it is important for a carbon foot-print to include all direct as well as indirect CO_2 emissions, that a mass unit of measurement should be used, and that other greenhouse gases should not be included otherwise the indicator should be termed as a climate footprint. They discuss the appropriateness of two major methodologies and process analysis. Their study found that the input – output analysis is suitable for the meso level since it can provide comprehensive and robust carbon footprint assessments of production and consumption activities, as an appropriate solution for the assessment of micro – systems is Hybrid – EIO – LCA approach, where life cycle assessments are combined with input – output analysis.

Douglass (2008) reported the carbon footprint of the Department of Mechanical Engineering at Michigan State University to reduce the negative impact on the environment in that area. The organization's carbon footprint contains data from three categories, (1) energy consumption, (2) material use, and (3) transportation, and was a composite of the carbon footprints produced from the three categories. This study showed that energy use occurring as a direct result of the department' s research teaching and outreach activities was found to generate 442 tC annually. Permanent and consumable materials purchased by the department in a typical year were found to be the source of 7 tC. Transportation, including business travel, commuting by employees and the college racing teams were responsible for 108 tC annually. The department has a total annual carbon footprint of 557 ± 53 tC. This is approximately 2.73 tC per employee, and energy use was the largest contributor to the carbon footprint of the department. Furthermore, this study also presents many possible options for reducing these footprints; for example, utilizing renewable energy sources such as wind energy and solar energy, which were the fastest way of reducing carbon emissions energy. The use of recycled materials can reduce the embodied energy of paper. As a part of reducing transportation emission, reducing the number of vehicles traveling each day is a simple and viable method.

Broughton *et al.* (2007) studied the potential for carbon neutrality at Purdue University. A guideline prepared by 29 students and 6 instructors was formulated to reduce the emissions over time to the point of carbon neutrality (zero net carbon emissions). Annual carbon emissions were evaluated and were divided into six different sectors: on – campus energy, off – campus energy, transportation, permanent materials, consumable materials, and land use. On – campus energy, consisting of electricity, steam heating, and chilled water cooling, provided by Purdue University' s Wade Utility Plant, represented the largest portion at over 50 % of Perdue University's overall emissions. After determining the carbon footprint, they also developed plans and strategies to reduce the university's net carbon emissions and thereby bring Purdue closer to their goal of true carbon neutrality. The plans and strategies were managed into three groups, energy supply, institutional consumption, and individual consumption through which they provided a diversity of viable options to reduce Purdue University's carbon impact.

Braham *et al.* (2007) presented the first greenhouse gas inventory, or carbon footprint for the main campus of the University of Pennsylvania. The propose of their report was to analyze the sources of these emissions at the university. The total carbon footprint of the University of Pennsylvania, including projection to 2020, which was generated into six parts – solid waste, Transportation, On – campus Stationary, Purchased Steam, and Wind power Electricity Offset. The single largest source of greenhouse gas emissions was the purchased utility energies used for the environmental conditioning and electrical supply of campus buildings, both steam and electricity, which account for 90 % of the carbon footprint, as shown in Figure 2.9.

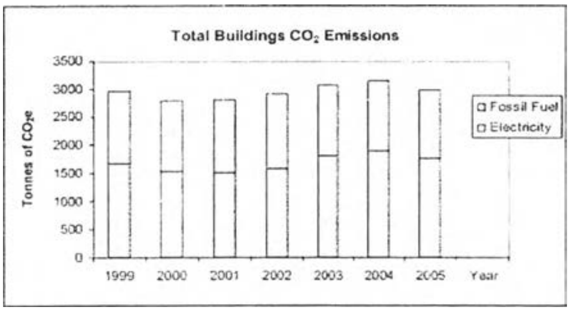

Figure 2.9 The annual CO_2 contribution (Braham *et al.* 2007).

Tilley *et al.* (2008) reported on the greenhouse gas emissions of the University of Maryland, at College Park, for the fiscal year 2002-2008. The greenhouse gas inventory of the College Park campus was intended to provide a baseline for the development and implementation of future GHG emission reduction strategies and track progress toward the long – term goal of carbon neutrality. The results were presented in five categories of GHG emission source: (1) purchased energy and on – campus stationary sources, (2) transportation, (3) agriculture, (4) solid waste management, and (5) refrigerants. On – campus was source of emissions accounting for 41 % of the total emissions of the university. Transportation and purchased electricity also accounted for high amounts of GHG emissions, at 31 % and 23 % respectively.

Bunn (2008) carried out a carbon footprint study of three primary schools: one school was built over 100 years ago (Leigh Primary School), second school was built in the 1970s (Michael Faraday School), and the third was a new school designed to the largest building standard (Kingsmead Primary School). The aim of this research was to find out which had the most sustainable low energy performance. He focused on carbon dioxide emissions from two categories: energy consumption (i.e., electricity and gas) and water consumption. Leigh Primary School was the most revealing of the three. Its carbon footprint per square meter was almost identical to Kingsmead Primary School even if Leigh Primary School was less than half the size of Kingsmead and also had half the number of pupils. This was so because Kingsmead Primary School had a bio – fuel boiler, solar water heating, photovoltaics, and rainwater recovery system. These should at least offset some of energy used for catering.

Gorgard and Latty (2008) produced a five – year greenhouse gas emissions inventory for the Hollins University (from 2003 - 2007) in an effort to make it carbon neutral. Each annual carbon footprint combined the greenhouse gas emissions from purchased electricity, on – campus generated steam and chilled water, commuting, air travel, waste generation, and agriculture. The results show that 15,991 short tons of carbon dioxide equivalent emission (tCO_2e) were produced in 2002/2003. The amount increased annually by approximately 4 % each year through to 2005/2006 where it reached a high of 18,143.5 tCO_2e. In 2006/2007 it decreased by 0.3 % to 18,086 tCO_2e. The bulk of the greenhouse gas production comes from the consumption of electricity (approximately 67 % of the footprint) and the generation of steamed/chilled water (approximately 27 % of the footprint). In this research, they also calculated the offset of the university. The offset was 1.35 % (245 tCO_2e) of greenhouse gas output by protection of forested campus property and approximately 0.2-1 % through recycling. As the greenhouse gas output was reduced, the value of carbon offsets increased.

Lamkitcha (2011) presented the application of the Bilan Carbone Model to mitigate greenhouse gas emission in AIT campus in the year of 2009 by propose scenarios for GHG reduction according best practice for all emission sources. The sources of GHG emission covered in the study were energy, excluding energy, material and product purchased (input), transportation of goods (freights), transportation of people (travel), solid waste and wastewater (direct waste), and property. From the results, GHG emissions of AIT campus was 6,245 tons Carbon equivalent of GHG emissions. Transportation of people was considered to be the biggest emitter, which accounts 41 % of overall GHG emissions in AIT, as shown in Figure 2.10. The average GHG emission per capita of AIT was 2.08 tC. As a result, energy conservation scenario for energy aspect had high potential in terms of reduce GHG emissions, which can reduce GHG emissions up 602tC. This research aims to motivate AIT to move towards low carbon campus, so it is necessary to have proper policy guidelines and measurement tools.

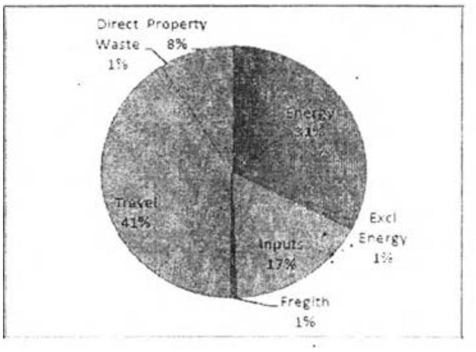

Figure 2.10 Share of GHG emission by source in AIT campus.

Keoy *et al.* (2011) assessed the carbon footprint a UCSI university and Proposed Green Campus Initiative Framework in year 2008. The carbon footprint calculation and proposed framework presented in this paper aims to encourage other higher Education Institutions in Malaysia to implement the GCI. In order to reduce the environmental impact at UCSI University, the measurement of the CO_2 emission was a very important starting point. The CO_2 emission at UCSI University come mainly from the use of electricity, fuel, paper and water because these four resources cause a significant environmental impact that required attention. The result show electricity was main contributor as releases an estimated 150 ton of CO_2 monthly, nearly half the amount was used for the air – conditioning system, as shown in Figure 2.11. The second source was transportation generates 112.7 ton of CO_2 monthly. Moreover, they provide legitimacy to the environmental education programs that could assist staffs and students in getting the sustainability initiatives. In order to make UCSI University a Green campus, various initiatives and actions were being taken.

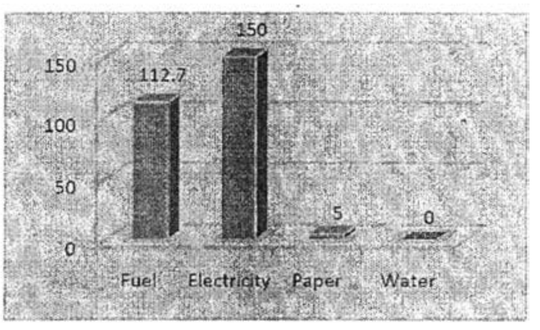

Figure 2.11 UCSI University 's monthly CO2 emission (Keoy *et al.*, 2011).

Boonjira (2011) presented the major sources of GHG emissions were classified into four main categories, which were energy use, materials use, transportation, and waste (wastewater treatment and solid waste disposal). The aim of this research was to evaluate the GHG emissions of the Department of Environmental Engineering, Chulalongkorn University and to develop alternative options for reduction of the GHG emissions using the Life Cycle Assessment Methodology as a key factor. The result showed that the total carbon footprint of the department based on year 2009 was 138.6 tCO_2e/yr and the average carbon footprint per person was 1.08 ton carbon (tC) (permanent staff=35). From the calculation, energy consumption was considered as the biggest source of CO_2 emission that generated 85.2 tCO_2e annually. It accounted for 61.5 % of the overall GHG emissions. The second source emissions produced from transportation, waste and materials use were 43.3, 9.5 and 0.6 tCO_2e annually or 31.3 %, 6.8 % and 0.4 %, respectively. The implementation option for the reduction of carbon footprint was energy conservation within building. The strategies included the use of appliance with high energy efficiency such as air conditioning and lighting as well as turning off air conditioning, lighting lamps and lab equipment when they were not in use. For the waste and materials use, 3R (reduce, reuse, and recycle) was considered to be the powerful strategy that should be promoted to decrease the GHG emissions. The possible GHG reduction option recommended to the department was to replace lamps in the department; T-5 lamps to replace the T-8 lamps. Figure 2.12 and 2.13 show the proportion of the carbon footprint from each emission source and Calculation of carbon footprint of scope 2 and scope 3 (Boonjira, 2011).

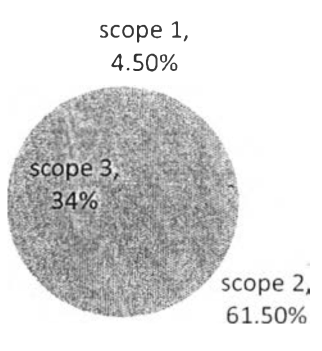

Figure 2.12 The proportion of the carbon footprint from each emission source (Boonjira, 2011).

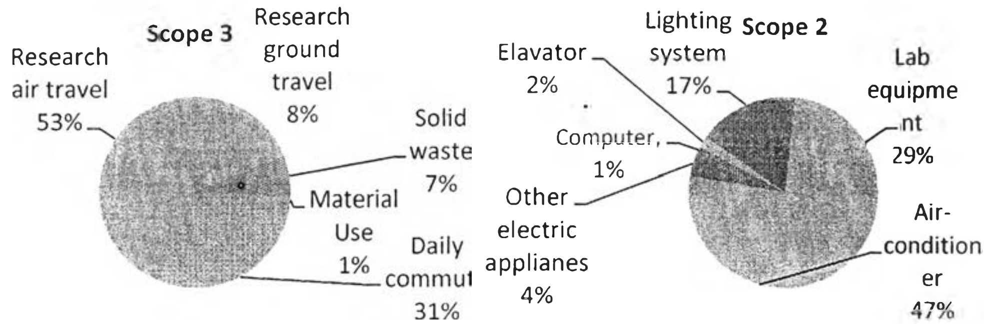

Figure 2.13 Calculation of carbon footprint of scope 2 and scope 3. (Boonjira, 2011)

Sayam *et al.* (2013) reported the importance of measuring the amount of greenhouse gases or Carbon Footprint from the activities of the Faculty of Environment and Resource Studies, Mahidol University with data collection of greenhouse gase sources such as electricity, quantity of wastewater and garbage, and amount of fuels used etc. The results showed that GHGs emission from Faculty of Environment and Resource Studies was equal to 1,091.85 tonCO_2e, as shown in Figure 2.14. Sources that are emited the most greenhouse gases were the uses of electric energy, followed by the generation of solid waste. Thus, power consumption and the amount of waste generated should be reduced with the use of current energy-saving technologies or energy saving campaigns to reduce the power consumption of students and staff including waste classification to facilitate recycling.

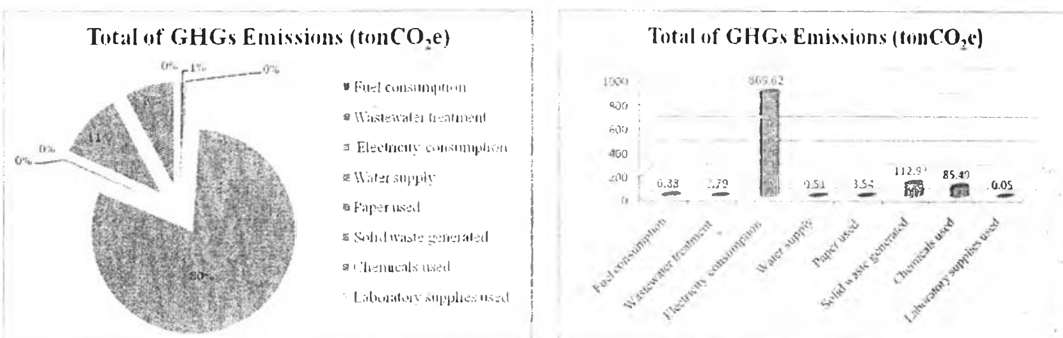

Figure 2.14 The amount of greenhouse gases and percentage of greenhouse gases emissions of each activity (Sayam *et al.*, 2013).

Joseph (2013) assessed the hotel operations, in particular, resulting in significant GHG emissions. Given the limited in-depth findings about the emissions from hotels of different classes, a study was conducted to probe into the carbon footprints of three typical hotels in Hong Kong. Through face-to-face meetings, detailed and reliable data under scopes 1 to 3 of the GHG Protocol (i.e. stationary and mobile sources of fuel combustions, electricity purchased, paper waste) were collected for analysis. The emission levels, when normalized by number of guestrooms, were different from those normalized by floor area. The use of purchased electricity was the dominant contributor to the emissions; emissions from the uses of portable liquefied petroleum gas and emergency operation of power generator were negligible. Reference levels of emissions due to staff daily travels were determined.

Table 2.3 Criteria for calculation of carbon footprint in organization

Emission source	Calculation Carbon Footprint in Organization									
	University of									Hotel in Hongkong
	Purdue	Pennsylvania	Hollins	Michigan State	UCSI	Maryland	AIT	CU	MU	
Scope 1 direct										
* Combustion of fuel	✓	✓	✓	✓		✓	✓			
* Vehicle fleet	✓	✓	✓		✓	✓	✓		✓	✓
Scope 2 Indirect										
*Purchased electricity, steam, or heat	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Scope 3 other Indirect										
*Transportation										
-Research travel	✓	✓	✓	✓		✓	✓	✓	✓	
-Staff travel										✓
-Daily commute	✓	✓	✓	✓	✓	✓	✓	✓	✓	
-Goods							✓			

Table 2.3 Criteria for calculation of carbon footprint in organization (Con`t.)

Emission Source	Calculation Carbon Footprint in Organization									
	University of									Hotel in Hongkong
	Purdue	Pennsylvania	Hollins.	Michigan State	UCSI	Maryland	AIT	CU	MU	
*Material usage										
-Permanent Material	/			/						
-Consumable Material	/	/	/	/	/		/	/	/	/
* Refrigerant		/				/				/
* Agriculture						/				
* Land use	/									/
* Waste generation										
-Solid waste		/	/			/	/	/	/	/
- Wastewater							/	/	/	/