CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Climate Change

Climate Change refers to any significant change in climate (such as temperature, precipitation or wind) lasting for an extended period (decades or longer) (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 emissions are increasingly becoming one of the major technological, societal, and political challenges that are closely related to energy generation and use (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 well 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 greenhouse gas (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 (GHG) overview

Greenhouse gas (GHG) refers to any gas in the atmosphere that leads to a greenhouse effect, trapping thermal radiation from the sun in the earth's atmosphere. GHGs include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases (US EPA, 2011). Human activities have changed their atmospheric concentrations, that is from the pre-industrial era (i.e., ending about 1750) to 2005, concentrations of these greenhouse gases have increased globally by 36, 148, and 18 percent, respectively (IPCC, 2007).

The principal greenhouse gases 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 (e.g., the manufacture of cement). Carbon dioxide could be removed from the atmosphere (or "sequestered") 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 greenhouse gases that are emitted from a variety of industrial processes. 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 the 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 teragrams (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	Magnesium smelting, 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 to and removed from the atmosphere around the world over time. Figure 2.1 shows Global greenhouse gas emissions. The emissions from CO_2 fossil use accounted for the largest portion (56.6 percent) of the global greenhouse gas emissions in 2004. The second largest source of CO_2 emission is from deforestation and decay of biomass (17.3%) followed by CH_4 (14.3%). Figure 2.2 shows GHGs emissions by sector. The GHGs emission from electricity and heat is the biggest source of GHGs emission accounting for 27%, follows by land-use change and forestry (18%).

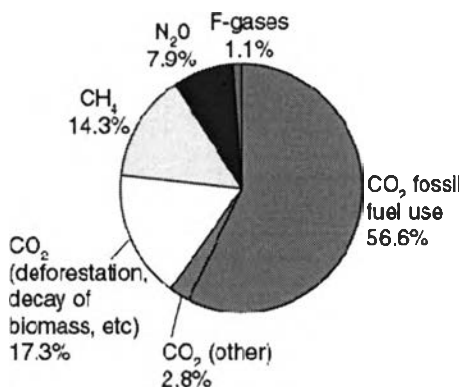

Figure 2.1 Global anthropogenic greenhouse gas emissions in 2004 (IPCC, 2004)

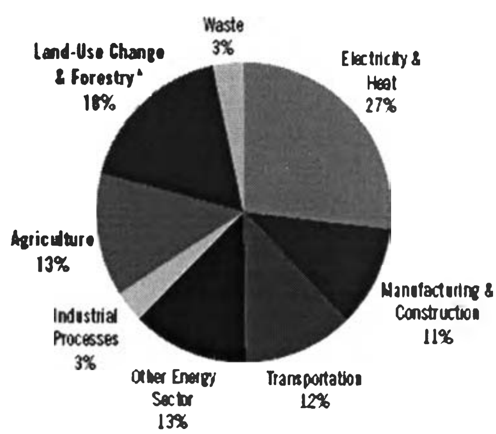

Figure 2.2 Sources of Global Greenhouse Gas Emissions (WRI, 2007)

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 cooling 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 and earlier flowering of trees (IPCC, 2007). The effects of global warming are of concern both for the environment and human life

- 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 greenhouse gas 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 greenhouse gases 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 11^{th} 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).

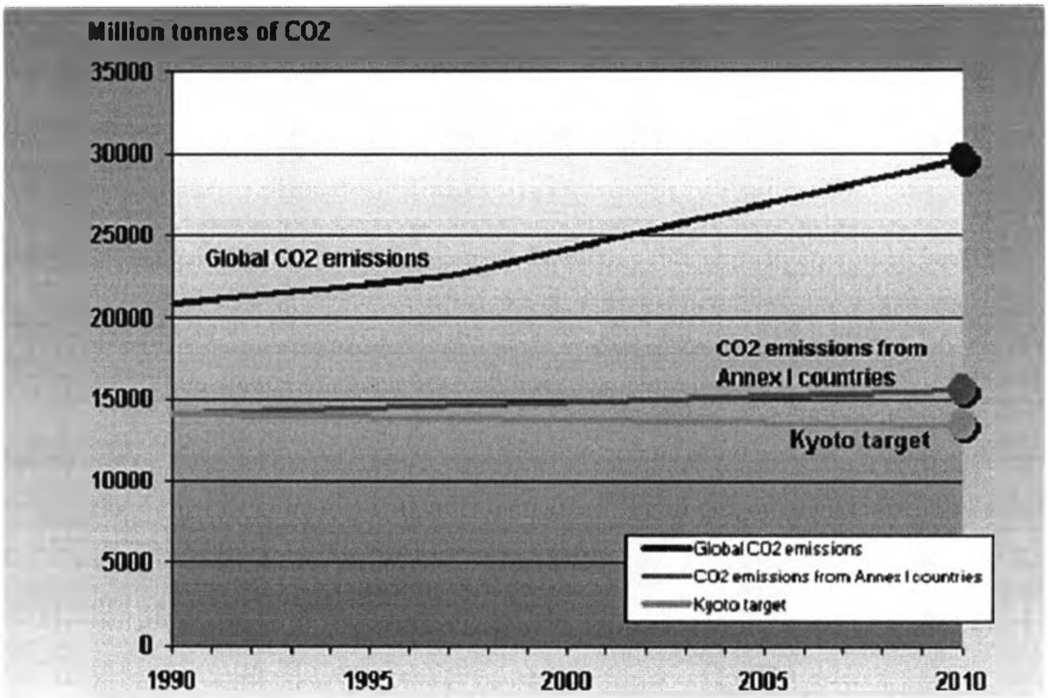

Figure 2.3 Global and Annex I countries' CO_2 emissions (UNEP, 2005)

2.3 Greenhouse Gases evaluation method

The tool can be used as a mechanism to assess and control the emission of greenhouse gases 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)

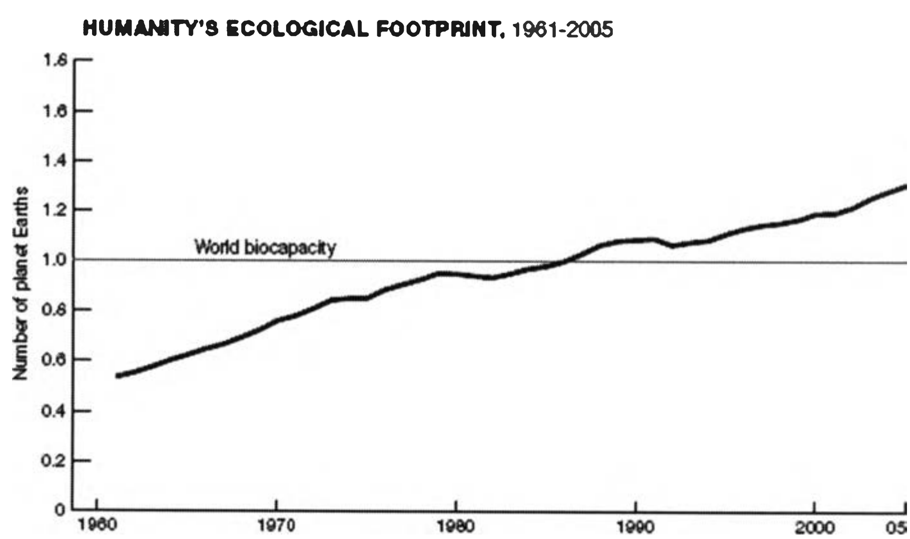

Figure 2.4 Humanity's Ecology Footprint, 1961-2005 (WWF's Living Planet Report 2008)

2.3.2 Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a "cradle-to-grave" approach for assessing industrial systems. "Cradle-to-grave" begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, and ultimate product disposal). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection. The term *life cycle* refers to the major activities in the course of the product's life-span from its manufacture, use, and maintenance, to its final disposal, including the raw material acquisition required for manufacturing the product. Figure 2.5 illustrates the possible life cycle stages that can be considered in an LCA and the typical inputs/outputs measured.

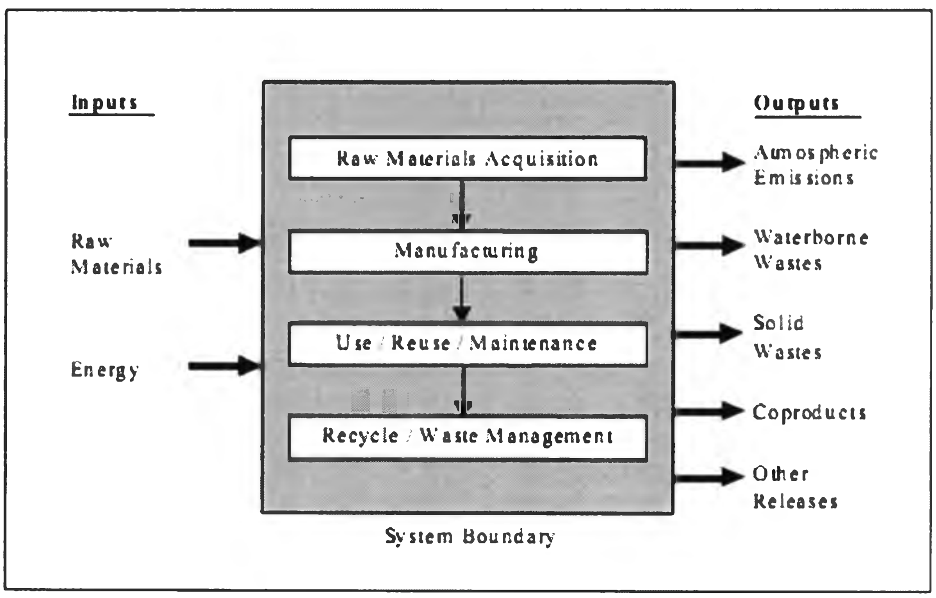

Figure 2.5 Life Cycle Stages (EPA,1993)

LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by...

- Compiling an inventory of relevant energy and material inputs and environmental releases.
- Evaluating the potential environmental impacts associated with identified inputs and releases.
- Interpreting the results to help decision-makers make a more informed decision.

2.3.3 Carbon footprint

A 'carbon footprint' measures the total greenhouse gas 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)

1). The primary footprint 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). The secondary footprint 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 to 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 effects 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 life cycle assessment (LCA). LCA is an 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 consumed along the life cycle of products: 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 life cycle assessment with the analysis limited to emissions that have an effect on climate change. Table 2.3 compare the types of data analyze by LCAs, carbon footprints, and ecological footprints.

Table 2.3 Data analysis of LCAs, carbon footprints and ecological footprints (Bezyrtzi, 2005)

Aspects	Life Cycle Assessment	Carbon Footprint	Ecological Footprint
Material production of building	Yes	No	No
Material transportation of building	Yes	No	No
Material placement of building (design, construction, renovation)	Yes	No	No
Construction of building	Yes	No	Yes
Land required to sequester CO_2 from building construction	No	No	Yes
Maintenance of building	Yes	No	No
Renovation of building	Yes	No	No
Demolition of building	Yes	No	No
Energy consumption (including hot water, equipment)	Yes	Yes	Yes
Land required to sequester CO_2 from domestic energy consumption and water energy use	No	No	Yes
Waste generation through lifetime	No	Yes	No (Debatable)
Waste generation from demolition and decommission phases	Yes	No	No
Waste transportation	Yes	Yes	No
Waste decomposition	Yes	Yes	No (Debatable)
Recycling of materials	No	Yes	Yes
Goods production (consumables)	Yes	No	Yes
Goods production (non-consumables)	Yes	No	No
Land used for goods production (nonconsumables)	Yes	No	Yes
Goods transportation (consumables)	No	Yes	Yes
Goods transportation (and nonconsumables)	No	Yes	No
CO_2 emissions through lifetime	Yes	Yes	Yes
Other emissions (ozone depletion, acidification, nutrification potential)	Yes	No	No (Debatable)
Water pumped /treated (including sewage)	Yes	No	No (Debatable)
Plantation	Yes	Yes	Yes
People's transportation	No	Yes	Yes
Vehicles' manufacture	No	No	Yes
Vehicles' maintenance	No	No	Yes
Land used for transport (roads, car parks)	No	No	Yes
Pasture or crop land area used to produce goods (e.g. food, drinks)	No	No	Yes
Land area required to sequester CO_2 from goods embodied energy	No	No	Yes
Sea area to produce fish	No	No	Yes
Energy used for service delivery	No	No	Yes
Goods' packaging	Yes	No	Yes
Units measurement	Units of J/m2 over buildings life cycle	Units of CO_2 annually	gha or gha/capita annually

2.4 Carbon footprint

2.4.1 Types of carbon footprints

Different types of carbon footprint exist.

1) Individual footprints – The total amount of greenhouse gases (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 food (Figure 2.6).

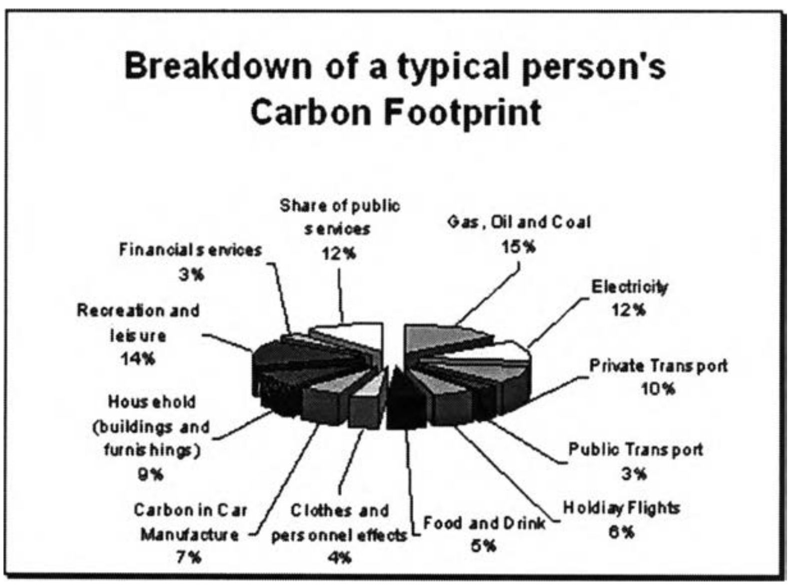

Figure 2.6 Breakdown of a typical person's Carbon Footprint (Carbon Footprint, 2004)

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, computers, printers, copiers, business travel, and commuting are among a number to source of greenhouse gases. The greenhouse gas protocol (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.

3) Product footprints: – 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

1. An organizational/business footprints 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 part 1: Specific with Guidance at the Organization Level for Quantification and Reporting Greenhouse Gas Emissions and Removals - details the principles and requirements for designing, developing, managing and reporting organization or company-level GHG inventories. It includes requirements for determining GHG emission boundaries, quantifying an organization's GHG emissions and removals and identifying specific company actions or activities aimed at improving GHG management. Also detailed are management system requirements and guidance on GHG inventory quality management, reporting, internal auditing and the organization's responsibilities in verification activities1

   - Draft ISO/TR 14069: Carbon Footprint for Organizations

- TGO guideline

2. Product footprints 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:

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) Reduction: Having quantified the emissions, opportunities for reduction can be identified and prioritized, focusing on the areas of greatest savings potential.
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 purposes
    - 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."
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

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.

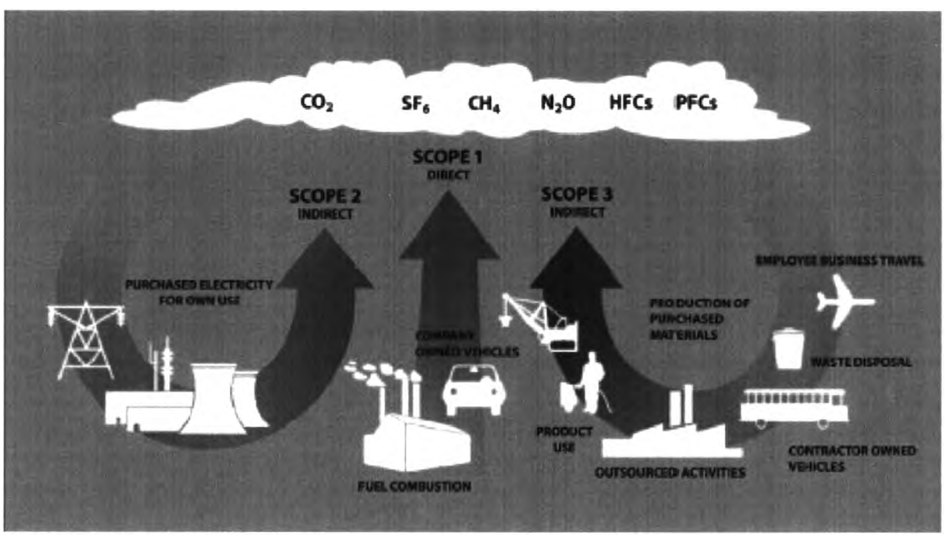

Figure 2.7 Scope of greenhouse emission by sources (GHG protocol, 2004)

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 (ISO 14040/44): (1) the goal and scope, (2) the inventory analysis, (3) the impact assessment, and (4) the interpretation. The assessment steps as following:

1. ***Goal and scope***: 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:

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.

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 greenhouse gas emissions shall be defined according the activities of the organization.

1.3) Proportion of greenhouse gas emissions significantly and the minimum acceptable

The carbon footprint calculation should be has the amount of the greenhouse gas emissions not less than 95% of the total greenhouse gas emissions. Activities having less than 1% of the total greenhouse gas emissions can be cut-off;

however, the total cut-off cannot be more than 5% of the total greenhouse gas emissions. In case of cut-off, the assessment of greenhouse gas emissions from the inputs and outputs shall be scaled up to represent 100% of the total greenhouse gas emissions related with the product unit.

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. ***Inventory Analysis***: 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.

3. ***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.

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 results.

2.4.6 Data sources and data quality

1) Data quality

The data used in the assessment of greenhouse gas 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.
- Source of data: demonstrate the source and reliability of data.
- Uncertainty: take into account the data uncertainty issues.

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 theses 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:

1) Converting the primary and secondary data of inputs/outputs to greenhouse gas emissions by multiplying their loadings with the respective emission factors.
2) Converting the greenhouse gas emissions 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 greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time such as 100 years.

2.5 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).

1) Plant a tree, or a few trees: 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.
2) 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.
3) 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 projects in developing countries.

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

- renewable energy (wind, wave, solar, geothermal, benign hydro, biomass)
- biomass fuels
- waste to energy projects
- recycling
- super efficient vehicles

5) Purchase power from 'green' or renewable energy providers
6) 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).

2.5.1 Energy conservation

Energy conservation is the practice of decreasing the quantity of energy used. It may be achieved through efficient energy use, in which case energy use is decreased while achieving a similar outcome, or by reduced consumption of energy services. Energy conservation may result in increase of financial capital, environmental value, national security, personal security, and human comfort. Individuals and organizations that are direct consumers of energy may want to conserve energy in order to reduce energy costs and promote economic security.

Industrial and commercial users may want to increase efficiency and thus maximize profit. There are many benefits to energy efficiency. Typically, energy conservation measures are quantified in terms of cost savings. However, there is much more to energy conservation than just saving money. Moreover, conserving energy reduces the amount of fossil fuels that are burned, which results in a decrease in air pollutants that cause global warming and acid rain (Arora et al., 1998). This research will be used energy conservation plan and energy management in order to reduce energy usage and cost.

2.5.2 Energy conservation in the building

There are many options available to reduce energy consumption in the building. Guidelines that all staff and students should follow to achieve energy efficiency in the department can be split into three main categories: (1) air conditioning, (2) lighting systems and other electronic equipment, following by (3) green building energy conservation. Moreover, guidelines and savings can be divided into two types: measures that require investment and measures that do not.

1. Air conditioning

The air conditioners are responsible for about 60 percent of all electricity consumed in the building, and there are several types of air conditioning systems in use.

2. Lighting system

The lighting system claims about 25 percent of the building's total electricity consumption.

3. Other electric equipment

Office equipment is responsible for the last 15 percent of total electricity consumed in the buildings. Offices consist of items such as computers, printers, copy machines, and fax machines.

Table 2.4 Energy Use Reduction Strategies

Emission Source	**Reduction Strategies**
Air conditioning	Measures that do not require investment • Turn off when unused for over 1 hr. • Schedule use from 8:30 to 16:30 (and turning it off during lunch breaks 1hr.) • Set the temperature at 25°C Measures requiring investment • Replace old air conditioners with energy-efficient systems for instance ones with Energy Label No.5. This measure can save up to 25 to 35 percent of electricity use. The financial payback period ranges from 3 to 5 years.
Lighting system	Measures that do not require investment • Turn off lights when they are not needed. Measures requiring investment • Replace 36 watt lamps with 18 watt lamp. • Install control equipment.
Other Equipment	Measures that do not require investment • Set the lift to open on only odd or even floors. • Use the sleep mode function when a computer is unused instead of the screensaver. • Turn off and unplug as soon as the user is done. Measures requiring investment • Consider purchasing office equipment that is certified by energy star.

2.6 Literature Reviews

In the literature review consist of carbon footprint of many organizations, especially academic organization which is similar to this study. The criteria to calculation the carbon footprint in the department and comparison with the previous studies are shown in Tables 2.5

Wiedmann and minx (2007) suggest a definition for the term *carbon footprint* in hopes of stimulating an academic debate about the concept and process of carbon footprint assessments. They argue that it is important for a carbon footprint 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 a *climate footprint*. They discuss the appropriateness of two major methodologies, process analysis and found that the input-output analysis is suitable for the meso level because 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.

Barthelmie et al. (2008) developed a Community Carbon Footprint Model (CCFM) that could be used to assess the size and major components of a community's carbon dioxide (CO_2) emissions. The town of Biggar was as the model for creating the first carbon neutral town. The results from this study reveal that one of the biggest challenges with developing a CCFM was collecting the necessary data and scaling them accurately. The CCFM was applied to households within the community of Biggar and a total of 17,402 tones of CO_2 were calculated to have been emitted in the 12 months from June 2006 to June 2007. They found that transport by car generated the highest amounts of carbon dioxide emissions. Detail is provided of the model components and calculations and an assessment is made of the resulting uncertainties. Relevant strategies were suggested for reducing carbon dioxide emissions. In addition, solar and wind resource assessments were undertaken to evaluate the most cost-effective strategies for renewable energy contributions.

GAP, SEI and Eco-Logica (2006) scoped the evidence base for the carbon footprinting of UK school estates. The purpose of this study is to identify a methodology for calculating the carbon emissions associated with schools. The results from an input-output model show that UK schools produce 9.245 million tons of carbon dioxide per annum. This is 1.32% of total UK emissions. Secondary schools produce 4.374 million tons, primary schools 3.681 million tons and other schools 1.190 million tones and 1.296 million tons come from private transport for commuting. Therefore, the total carbon footprint of schools is 10.541 million tons. This amount can be classified into three categories: 2.8 million tons are from direct emissions from school buildings and equipment, 1.4 million tons are from transport emissions from the commuting of staff and pupils to schools, and 6.3 million tons are from the embodied emissions of the goods and services consumed in the schools. From this study, they concluded that a hybrid methodology (bottom-up and top-down) is the best way for calculating the carbon footprint. They found that both the data and an appropriate methodology are available for assessing carbon emissions. Moreover, this study presents information on trends that is likely to influence school carbon emissions over the next five to ten years and present future projects to aid in the proposal of strategy for reducing carbon emissions from the school estates. In addition, they have established that there is good potential for carrying out a future project that will propose a strategy for reducing carbon emissions from the school estates.

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 show 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 was 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 present many possible options for reducing these footprints; for example, utilizing renewable energy sources such as wind energy and solar energy is the fastest way of reducing carbon emissions energy. The use of recycled material 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.

Putt del Pino and Bhatia (2002) calculated the carbon dioxide emissions and presented a step-by-step summary to measure carbon dioxide emissions of an office or organization that will help in the initiation, planning, and implementation of an organizational commitment to reduce carbon dioxide emissions. The examples for each step are clear and easy to understand.

Bezyrtzi (2005) present a carbon footprint of the University of Strathclyde. The Bezyrtzi gathered data in three categories (building data, transportation data, and commuting data) through a questionnaire, the Estates Management Department, and the software itself. The resulting building data showed the energy use in each building. The biggest and oldest building had the highest percentage of carbon dioxide emissions, which can explain the significant amount of gas it consumes. Additionally, this building has a deteriorating underground district heating scheme with excessive heat losses. The transportation data showed air transportation produced the most carbon dioxide emissions. The carbon dioxide from commuting was very low because the majority of students stay on campus. They commute either on foot or by bike, both of which have a zero carbon dioxide factor. On this campus, 52% of the carbon footprint came from the building, while 48% was from transportation. Moreover, a sensitivity analysis was performed on the transportation data in three cases. Following the investigation of the three scenarios, the researcher found that the contribution of transportation to the carbon footprint dropped from 48% to 47%.

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 the university was 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 is 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.

Tilley et al. (2008) reports on the greenhouse gas emission of the University of Maryland, at College Park, for the fiscal year 2002-2008. The greenhouse gas inventory of the College Park campus is 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 sources: (1) purchased energy and on-campus stationary sources, (2) transportation, (3) agriculture, (4) solid waste management, and (5) refrigerants. On-campus is source of emissions account 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 footprinting 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.

Godard and Latty (2008) produced a five-year greenhouse gas emissions inventory for the Hollins University (from2003-2007) 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 emissions (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 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 emissions covered in the study are 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 is 6,245 tons Carbon equivalent of GHG emissions. Transportation of people is considered to be the biggest emitter, which accounts 41% of overall GHG emissions in AIT. The average GHG emission per capita of AIT is 2.08 tC. As a result, energy conservation scenario for energy aspect has high potential in term of reduce GHG emissions, which can reduce GHG emissions up 602 tC. This research aims to motivate AIT to move towards low carbon campus, so it is necessary to have proper policy guidelines and measurement tools.

Keoy et al. (2011) assessed the carbon footprint at 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 comes 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 is main contributor as releases an estimated 150 ton of CO_2 monthly, nearly half the amount is used for the air-conditioning system. The second source is transportation generates 112.7 ton of CO_2 monthly. Moreover, they provide legitimacy to the environmental education programmes that will assist staffs and students in getting the sustainability initiatives. In order to make UCSI University a Green campus, various initiatives and actions are being taken.

Table 2.5 Criteria for calculation of carbon footprint in University

Emission source	Calculation Carbon footprint in University							
	Purdue	**Pennsylvania**	**Hollins**	**Michigan State**	**UCSI**	**Maryland**	**AIT**	**CU (this study)**
▪ Scope 1 Direct								
➢ Combustion of fuel	√	√	√	√		√	√	
➢ University vehicle fleet	√	√	√		√	√	√	
➢ Wastewater								√
▪ Scope 2 Energy Indirect								
➢ Purchased electricity, steam, or heat	√	√	√		√	√	√	√
▪ Scope 3 Other Indirect								
➢ Transportation								
-Research travel	√	√	√	√		√	√	√
-Daily commute	√	√	√	√	√	√	√	√
-Goods							√	
➢ Material usage								
-Permanent Material	√			√				
-Consumable Material	√	√	√	√	√		√	√
➢ Refrigerant		√				√		
➢ Agriculture						√		
➢ Land use	√							
➢ Waste generation								
-Solid waste		√	√			√	√	√
-Wastewater							√	

✓ = Evaluation of carbon footprint