CHAPTER III

METHODOLOGY

3.1 Research plan

This study is to quantify the total greenhouse gas emissions from the Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, and to develop feasible options for reducing the carbon footprint of this product. This chapter describes the methodology to achieve the objectives of this study. The methodology of this study can be divided into seven parts as follows:

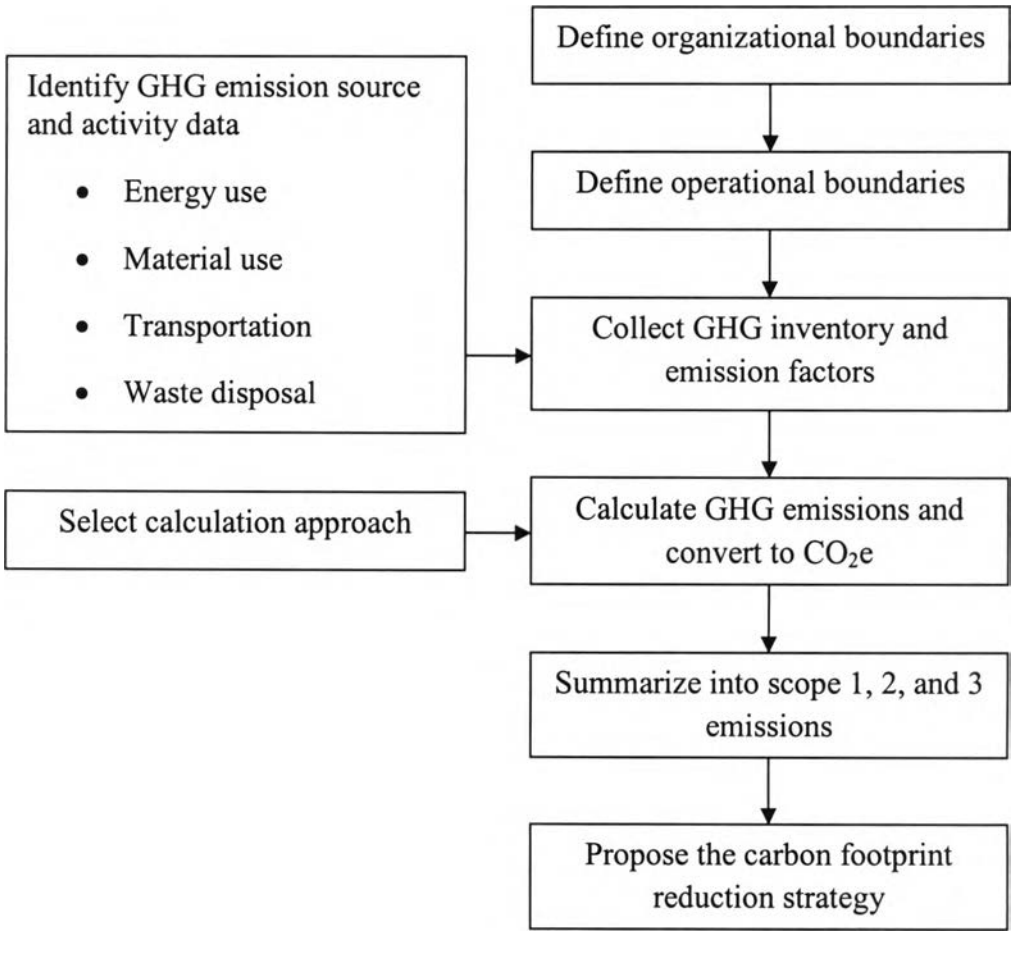

Figure 3.1 Flow diagram of research methodology

3.2 Definition of organizational boundaries

The organization may comprise one or more facilities, so the researcher has to define boundaries in the organization what have any units that is within calculation limits of this project. In this study organizational boundary of the department was set up based on one of the following approaches:

- Control approach: The organization shall be responsible for emissions where it owns or has control over it, which this study set the organizational boundary as control approach as well.

- Equity share approach: The organization shall be responsible for emissions which their does not own or has control over it but share them with other units in that organization.

3.3 Definition of operational boundaries

Each organization will have its operational boundaries that associate with the organization's operations. This step is to identify what any activities in the organization boundary is used to calculate the emissions of GHGs. The scopes for delineating direct and indirect emission sources are classified into 3 scopes as follows:

- Scope 1 - Direct emissions: These are emissions that are owned or controlled by the department.
- Scope 2 - Energy Indirect emissions: These emissions are from activities that occur within the department, but the original sources are owned or controlled by another department such as an emission from generation of purchased electricity, stream, or heat.
- Scope 3 - Other indirect emissions: These emissions cover everything else that is not associated with direct or indirect emissions.

The methodologies for accounting and reporting emissions can refer to the greenhouse gases protocol by the World Resources Institute (WRI) in collaboration

with the World Business Council for Sustainable Development (WBCSD), ISO 14064-1, and TGO guideline. Table 3.1 shows the examples of standard boundaries Scope 1, 2 and 3 emissions as well as the emissions from the department in each scope.

Table 3.1 GHG inventory and the scope of emission boundaries.

(TGO guideline, 2011)

Scope description	**TGO's Standard Boundaries**
Scope 1: Direct emissions that are owned and controlled by the organization.	⊛ Consumption of fuels by vehicles fleet ⊛ Production of physical and chemical emissions ⊛ Leakage of refrigerants and other GHG's (fugitive emissions) ⊛ Use of fire extinguisher ⊛ Use of chemical fertilizer ⊛ Release of GHG's from wastewater operation
Scope 2: Energy indirect emissions that are from the purchase of power	⊛ Purchased electricity
Scope 3: Indirect emissions that are a result of activities related to the organization, but are not owned or controlled by the organization	⊛ Staff commuting ⊛ Travel between the internal organization by owned vehicles ⊛ Air and organization car travel ⊛ Use of chemicals to clean by contract of service ⊛ Use of tap water ⊛ Use of office equipment and consumable material such as paper ⊛ Use of electricity and LPG in cafeteria and shop leased by the organization ⊛ Waste disposal

In order to organize emissions, the main sources of GHG emissions in the department were classified into 3 scopes as defined in table 3.1. In each scope, all data on the sources of GHG emissions were gathered from surveying such as energy use,

material use, transportation and waste. Each category was then analyzed and determined as the following:

Scope 1 Direct emissions:

All the department activities that are relevant to GHGs emission, i.e., vehicles fleet, production of physical and chemical emissions, refrigerator maintenance, use of fire extinguisher chemical fertilizer, and wastewater management were covered in this study.

For the wastewater management. The GHG emissions were attributed to total organically degradable material in the wastewater treatment operation, which is an anaerobic process. It generates CH_4 emission into the atmosphere unless CH_4 is captured.

Scope 2 Energy indirect emissions:

Energy use – The energy use means the electricity that is purchased outside but consumed within the department of Environmental Engineering. GHGs in this category were generated from three main sources that are offices, laboratories, and others as described below:

1) Offices - Ceiling lights, computers, printers, copiers, air conditioners, fans, and refrigerators tend to consume the majority of electricity in most offices.

2) Laboratories - With regard to the energy use of laboratories, it mainly results from the equipment used by students. Most students in this department have several required laboratory subjects. The graduate students also use the laboratories for their experimental research studies.

3) Others - Other sources of emissions are from hallways, classrooms, restrooms, meeting room, and library which also utilize electricity for ceiling lights, fans, air conditioners, computers, copy machines projectors, overheads, and others.

Scope 3 Other indirect emissions:

1. Material use – Every material has "embodied carbon" value associated with it, which is referred to the carbon footprint of a material. Materials can be separated into two types based on their application. Permanent material is a material that has long life and strong structure such as lab equipment, machines, etc. Consumable material is a thing that be used and change regularly such as paper, plastic, glass. Water is also included in this category. This research was aimed to emphasize on only consumable materials as described below:

1) Paper: Paper is a common material used by almost all organizations and some recording data of its use are available. Paper may be a significant source of GHG emissions for organizations, which usually use paper for internal memos, letters, faxes, photocopies. It is usually purchased and measured in a unit of reams.

2) Water use: Water consumption data were typically classified into two types of water use purposes, i.e., water used in the laboratories and in general offices.

2. Transportation – Transportation in this research refers to the daily commuting of the department staff and research travel (both air and ground travel).

1) Research travel: it means the trip on a purpose of research work of the faculty and staff members and a carbon footprint is considered based on combustion of vehicle fuels.

2) Daily commuting: it means a travel to and from work of the faculty and staff members. However, this excludes student's commuting unless it is paid by the department or the students are the departmental employees who must commute to work. Employees are hired to provide a service, while students are recipients of that service. In this study, only emissions that result from the provision of the service were considered.

3. Waste – Waste in this research is emphasized on solid waste. Solid waste from the department is sent to landfill, resulting in the release of GHG emissions from anaerobic decomposition of organic materials in the landfill. The emissions were calculated by the weight of solid waste.

3.4 Collection of GHG inventory

The greenhouse gas inventory covers the department's fiscal year 2009, which was from October, 2008 to September 2009. Data of **Scope 1** on the wastewater treatment plant was obtained from the previous study and the data on the laboratory experiments of **Scope 2** were collected from electricity bills directly obtained from the provider. Scope 2 emissions were calculated using GHG emission factors from the Thailand national LCI database, which is reflective of the Thailand electricity generation mix.

Table 3.2 The department's scope 1 GHG emission sources

Emission Source	**Use**	**Data Source**
Wastewater treatment operation	BOD removed by anaerobic treatment (kg/year)	Laboratory analysis data

Table 3.3 The department's scope 2 GHG emission sources

Emission Source	**Use**	**Data Source**
Purchased Electricity	Electricity use (kWh/year)	Electricity bills

Scope 3 data were collected by surveying and interviewing the lecturers and officials of the department (Table 3.4). All data were then used for carbon emission equivalent calculations.

Table 3.4 The Department's scope 3 GHG emission sources

Emission Source	Data Source
Faculty/staff daily commuting (car)	GHG inventory survey was conducted to compute the daily commuting emissions for all staff
Faculty /staff, academic/research travel (airplane and car)	Air and car travel data collected from the surveys and interviews were extrapolated.
Waste	Solid waste generation rate was collected and measured in terms of kg/year.
Material use	Paper: bill and actual use records Water use: meter record and calculation

A number of activities are normally taken place in a large academic. These activities generate carbon dioxide from various sources. In this study, Chulalongkorn University was selected as a case study of the academic organization. The Department of Environmental Engineering was particularly focused in this research since the department offers two academic activities, i.e., laboratory study and lecturing. Moreover, the department has all complete levels of the study degrees, i.e., doctoral, master, and bachelor study levels.

3.5 Calculation of GHG emissions

The methodology of this study used to quantify the total emissions of greenhouse gases from the department was performed with Microsoft Excel as a calculation tool.

A GHG inventory for the department was generated to identify what data was needed to use GHG-originating activities and emission factor. The two kinds of data to calculate the organization's GHG emissions include "activity data" and "emission factor"

Calculation of the greenhouse gas emissions for the department was separated into energy use, transportation, material use, and waste from the department. The equation (greenhouse gases protocol by the World Resources Institute (WRI) in collaboration with the World Business Council for Sustainable Development (WBCSD), ISO 14064-1, and TGO guideline) for calculating greenhouse gas emissions from all activities in the department is shown in equation (3.1):

Carbon footprint of a given activity (CO_2)	=	Activity data (mass/volume/kWh/km)	x	Emission factor (CO_2e per unit)	(3-1)

where:

carbon footprint of a given activity = sum of all energy use, transportation material use, and waste across all activities multiplied by their emission factors

activity data = all material and energy amount throughout the product's life cycle

emission factor = the amount of greenhouse gases emitted per unit of activity data

The equations for calculation of each source of GHG emissions are shown in Table 3.5

Table 3.5 Equations for calculating the greenhouse gas emissions from all activities

GHG sources	Equations	EF source	Reference
1. Wastewater treatment operation	CH_4 Emissions ($kgCH_4/y$) = EF ($kgCH_4/kgBOD$) x Total organics in wastewater kgBOD) GHG Emissions ($kgCO_2/y$) = CH_4 Emissions ($kgCH_4/y$) x GWP	IPCC (2006) GWP (100-years)	TGO (2011)
2. Energy use (purchase electricity)	GHG emissions ($kgCO_2e/y$) = Electricity (kWh/y) x EF ($kgCO_2e/kWh$)	TGO guideline	TGO (2011)
3. Transportation - Car travel - Air travel (for travel in commercial plane)	GHG emissions ($kgCO_2e/y$) = Distance traveled (km/y) / Fuel economy (mg/L) x EF ($kgCO_2e/L$) GHG emissions ($kgCO_2e/y$) = Distance traveled (pkm/y) x EF ($kgCO_2e/pkm$)	IPCC (2007), PCD (2008) GHG protocol – mobile guide, 2009	TGO (2011) TGO (2011)
4. Material use - Paper - Water use	Weight of paper (kg) = No. ream of paper x Weight of a ream GHG emissions ($kgCO_2e/y$) = Paper (kg/y) x EF ($kgCO_2e/kg$ paper) Water use (m^3) = No. of staff x Water consumption rate x No. of working day GHG emissions ($kgCO_2e/y$) = Water use (m^3/y) x EF ($kgCO_2e/m^3$ water)	SimaPro Metropolitan Waterworks Authority (Thailand)	TGO (2011) TGO (2011)
5. Solid waste	Landfill waste (kg) = No. working day (d) x Landfill waste (kg/d) GHG emissions ($kgCO_2e/y$) = Landfill waste (kg/y) x EF ($kgCO_2e/kg$ landfill waste)	IPCC 2006, Smith et al 2001 and EPA 2008	TGO (2011)

3.6 Evaluation of the important sources of carbon dioxide emissions

Analyses and comparison of the greenhouse gas emissions for each activity were performed in terms of the carbon footprint (kg CO_2 equivalent per product unit) by (GWP_{100}) because the GHG emission sources obtained from the inventory were needed to be comparatively assessed for the degree of each contribution to GHG emissions. In addition, the classified data of all emission sources into scope 1, scope 2, and scope 3 emissions assist in creating the effective way to identify the source of the significant GHG emissions and to reduce the carbon footprint.

3.7 Development of carbon footprint reduction strategies

For minimization of the environmental impacts from carbon dioxide emissions, the measured carbon footprint was used as a key factor to develop alternative options. The feasible options assist the facilities to achieve more energy-use efficiency and to reduce greenhouse gas emissions. This step involved discussion on the impacts of specific energy conservation approaches, identification of processes and equipment where energy can be reduced, assessment of the opportunity and feasibility way to reduce greenhouse gases emission and energy consumption within the organization. Finally, the suitable approach to reduce greenhouse gases emission and energy consumption was assessed in terms of cost-benefit ratio.