**Chapter 1**

# Introduction

## 1.1 Background

Historically, the atmospheric carbon dioxide ($CO_2$) concentration has shown considerable fluctuations. Over the last 600,000 years, the concentration varied between 180 parts per million (ppm) and 380 ppm as shown in Figure 1.1 below

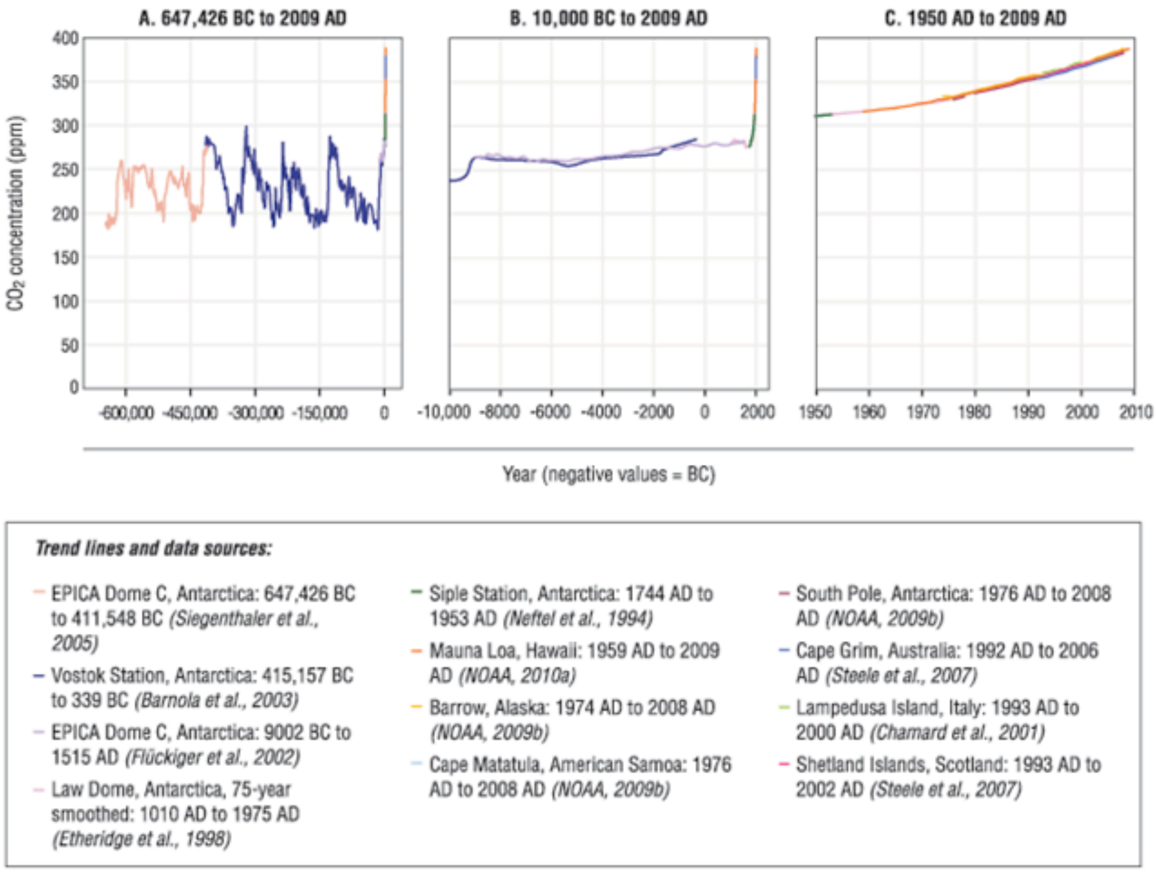


Figure 1.1: Reconstructed record of atmospheric $CO_2$ concentrations over the last 600,000 years.(Source: EPA, 2011)

Figure 1.1 shows that atmospheric $CO_2$ concentration has increased considerably since the beginning of the industrial era, i.e. from 1800. After that atmospheric $CO_2$ concentration has increased very rapidly to the present level to 380 ppm. Between year 1800 and 2010 the atmospheric $CO_2$ concentration has increased by about 100 ppm, which is about 35%, of the atmospheric $CO_2$ concentration.

Greenhouse Gases (GHGs) including $CO_2$ emissions from human activities i.e. energy sector, agricultural sector, industrial sector, transportation, deforestation, including mineral and environmental degeneration in other ways, are the major cause of global warming which make many impacts on human being. Thus, mitigation of GHGs emission both local and international level,through cooperation of every related segment i.e. agricultural and industrial sector as producer, including everyone as a consumer, is very important.

Selection of goods and services which have less GHGs emission is the way that makes consumer’s participation in GHGs emission management.Introduction of market mechanisms could encourage producers to reduce GHGs emissions of their products. Evaluation of carbon footprint of products and services which means the amount of GHGs emission of the whole production cycle from raw material extraction, transportation, manufacturing, usability, and waste disposal,will help customer to have information before selecting goods or services and may encourage the production of the goods and services which environment friendly.

Evaluation of carbon footprint evaluation also will increase the market potential of Thai products in the world market. Due to carbon footprint has been adopted in many countries such as England, France, Canada, Germany, USA, Japan, Korea, and etc. Moreover, if Thailand has an exact system to collect and manage the GHGs emission mitigation, it will help in negotiation in international conference to set the solution for solving global warming.

## 1.2 Rationale of the study

$CO_2$ concentration in atmosphere cannot be reduced in a short period of time. Thus, reduction of $CO_2$ concentration in atmosphere should be started with small scale such as house, village, and municipality.So that people realize the urgent need for reducing $CO_2$ concentration in atmosphere. If everyone concern about GHGs emission, the world's GHGs emission will reduce automatically.

GHGs accounting is the first step which can help in assessing the threats and opportunities associated with the climate change. Also, from the point of view of Corporate Social Responsibility, it has become vital for organizations to assess, monitor & reduce their GHG emissions so as to continue progressing in a sustainable and eco-friendly manner.

## 1.3 Objective of the study

The main objective of the study is to estimate the GHG emission from the activities carried out by selected two municipalities in Thailand, i.e. Chiang Mai and Nonthaburi.

The specific objectives of the study are:

- To identify and estimate the emission factors that needed to use in the study.
- To estimate the GHG emissions due to related activities of two municipalities in Thailand by using the Bilan Carbone tool.
- Compare the major sectors which have caused the most emission.

## 1.4 Scope and Limitation of the study

This study mainly estimates theGHGs emission, using the Bilan Carbon tool.

In many situations, it is not possible to directly measure emissions of greenhouse gases resulting from a given action. The only method to proceed is to estimate the emissions by obtaining them from other data and the "Bilancarbone" method was specifically developed to help achieve this in a reasonable time, through a combination of calculation and observations.

The flood in Thailand during October 2011 has damaged many infrastructures in Chiang Mai municipality and that may affect the sources of essential information and related data. Hence, some data or information, not available has been assumed.

## Chapter 2
## Literature Review

This chapter reviews the literatures and the other sources which related to the study, such as, tools used for GHG inventory and their comparison, Bilan Carbone tool, low carbon initiative for city, emission factors.

### 2.1. Tools used for GHG inventory and their comparison

The anthropogenicGHG emissions were considered as the major cause of global warming and climate change. At the World Economic Forum in 2000, climate changes were voted as the most important challenge. Concern over climate change has led to varied responses like voluntary actions from association to regulations at national level. Conducting an inventory of GHGs emissions is a vital initial step to develop response actions to mitigate climate change. A GHGs inventory brings to identify the threats and opportunities of operating in a carbon constrained economy and thus creating the right actions. At an operational level, information on GHGs emissions may be useful to take decisions regarding the selection of typeof product, materials used, technologies operated and sources of energy (Kolsepatil, 2011).

Sometimes GHGs emissions cannot be measured physically and this would not be practically possible for various activities like production, transportation and consumer use over the life cycle of a product. So, various GHGs accounting tools were developed to estimate the GHGs emissions on the basis of activity data, which can be obtained relatively easily. A few of the GHGs accounting tools have been described briefly below (Kolsepatil, 2011)

1. **$CO_2$Grobbilanz**

The rationale for developing the $CO_2$Grobbilanz was to take account of the GHG emissions generated by cities and to learn more about the different reduction measures that could be taken in consequence. The $CO_2$Grobbilanz can be used in two modes, a standard mode and an expert mode which is more detailed. The standard mode of the $CO_2$Grobbilanz has been used in around 70 communities, the expert mode has been used in around 35 communities and the EMSIG tool has been used in 15 communities. The $CO_2$Grobbilanz takes account of three gases: $CO_2$, methane and nitrous oxide. The $CO_2$Grobbilanz is simple to use and allows also relatively small communities such as villages with only 1000 inhabitants to compile an inventory.The tool proposes various measures for reduction of emissions, along with evaluation of the emissions. Only territories coming under the Austrian Climate Alliance can use this tool. (Bader and Bleischwitz, 2009)

2. **ECO2Region**

The tool is intended to provide municipalities and regions with a basis to establish their CO2 profile and assess their local and regional climate strategies. It is based on software called ECO-Region smart specifically developed by the Swiss company Eco speed for computing local CO2 and energy balances. It can be ordered online and used immediately as an internet service. After a small amount of data has been entered, ECORegion calculates a first initial balance, using default values from a database built on national statistical data with some computing added. The computations use factors like fleet average consumption, emission factors, etc. The UNFCCC national inventories are also used. Users have to enter the number of inhabitants in their municipality and the number of employees in the different branches. From that, a first initial balance based on default values is produced. As a next step, national statistics can be replaced with local or regional data, starting with the number of registered vehicles in the municipality, the energy consumption of pipeline bound energy, other sources of energy and the local energy production**.**(FEDARENE, 2011).

### 3. Greenhouse Gas Regional Inventory Protocol (GRIP)

Greenhouse Gas Regional Inventory Protocol (GRIP) has been in existence for several years, in its infancy much work was undertaken to understand the various methods and approaches used by others to form inventories, this included a comprehensive understanding of the IPCC's inventory methodology for submission to the UNFCCC. The reporting standard for national inventory approaches. It was this understanding that led to the GRIP inventory methodology. (Bader and Bleischwitz, 2009)

GRIP was designed to bring discussions on energy futures together. It empowers coherent discussions across the energy system, so that debates on transport can take place in combination with those on electricity generation and domestic heating, through views and visions being quantified in real time in a clear and effective way. (GRIP, 2011)

### 4. CO2 Calculator

The Danish National Environmental Research Institute (NEERI) and the private firm COWI developed the ‘CO2 Calculator’ in 2008. This tool has been developed as per the requirements of Danish territories. The emission factors for Danish conditions are updated annually. The tool takes into account emissions of only three GHGs, i.e. $CO_2$, $CH_4$ and $N_2O$. The IPCC third assessment report is used as a source for the GWP values. Transparency is one of the strengths of the CO2 Calculator. There are four guidance documents available along with the tool, describing the methodology used, data collection and assumptions made. Though most of the activities producing emissions are considered, emissions from use of the product have not been included in this tool. (Bader and Bleischwitz, 2009)

### 5. Project 2 Degrees

Microsoft had trouble solving the problems with its Vista operating system, so what its chances of fixing climate change. The global software firm has created an online tool called Project 2 Degrees for cities across the world to monitor their greenhouse gas (GHG) emissions and, the hope is, and then does something about them.

While Bill Gates' company have tailored an online carbon accounting tool for cities, businesses are increasingly turning on to the benefits and need to track their own GHGs, opening up an area for enterprise software companies to provide the best tools for the job. This tool considers all the six major GHGs and the GWP values are available from the second, third and fourth IPCC assessment reports. The tool has pre- loaded emission factors from IPCC. The information of the methodology used for this tool is available on the project webpage. This tool is available for estimations for cities and local authorities and does not have a dedicated section for industrial activities.(Bader and Bleischwitz, 2009)

## 6. GHGs protocol calculation tool

The calculations tools are electronic Excel spreadsheets with accompanying step-by-step guidance documents. A guidance document includes:

- An overview of the protocol with information on the sector, sources, and processes that it covers
- One or more approaches for determining CO2 and other GHG emissions, e.g., direct measurement, mass balance, etc.;
- Guidance on collecting activity data and selecting appropriate emission factors;
- Likely emissions sources and the scopes they fall under (specific to a particular sector)
- Additional information, such as quality control practices and program specific information.

The spreadsheets help carry out any necessary emissions calculations.

These tools were developed in partnership with industry experts and represent best practice quantification methodologies. The calculation tools are available on the GHG Protocol website and are meant to complement the Protocol and make calculations easier, but their use is not mandatory. (GHGs protocol, 2011)

## 7. Bilan Carbone

The 'Bilan Carbone' tool was developed by the French Environment and Energy Management Agency (ADEME) in 2003.The "Bilan Carbone" is an evolutionary and accessible tool for a great number: To meet the diversity of actors and approaches, the "Bilan Carbone" exists already in 3 modules: companies, communities and territories.

This tool takes in to account not only the six GHGs identified by the Kyoto Protocol, but also chlorofluorocarbons (CFCs) and water vapor. For instance, water vapor emitted by planes is accounted for in this tool. The GWP values are updated from the fourth IPCC assessment report in 2007. Pre-loaded emission factors exist for the French conditions and are updated regularly. The tool considers all the direct and indirect activities that emit GHGs. The guidance documents provide in depth information about the calculation of emission factors, the methodology used and the use of the tool. The Bilan Carbone tool is thus very transparent and this enables faster adaptation of the tool for different locations and requirements. (ADEME, 2011)

Table 2.1 shows comparison of various GHG inventory assessment tools.The best tool to useassess of GHGs inventory, all major GHGs are included in the inventory and the global warming potential values are updated, and the IPCC Assessment report from wherein the global warming potential values are incorporated and whether the allocation of emission due to electricity can be done from the point of use or the point of generation.It shows that Bilan Carbone takes into account not only all the six GHGs considered in Kyoto Protocol but in addition includes other GHGs such as CFCs and water in the assessment of the GHG inventory. The global warming potential values used for the calculations in the Bilan Carbone are from the latest IPCC Fourth Assessment Report (2007) while the most of the other tools considered use global warming potential values from earlier IPCC reports.

Table 2.1: Comparison of various GHG inventory assessment tools

| Factors considered | Name of the GHG inventory tool | | | | | |
|---|---|---|---|---|---|---|
| | CO2 Grobbilanz | ECO2 Region | GRIP | Bilan Carbone | CO2 Calculator | Project 2 degrees |
| GHGs included in the inventory | | | | | | |
| Carbon Dioxide | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Methane | ✓ | (✓)* | ✓ | ✓ | ✓ | ✓ |
| Nitrous Oxide | ✓ | (✓)* | ✓ | ✓ | ✓ | ✓ |
| Sulphur Hexafluoride | | (✓)* | ✓ | ✓ | | ✓ |
| Hydrofluorocarbons | | (✓)* | ✓ | ✓ | | ✓ |
| Perfluorocarbons | | (✓)* | ✓ | ✓ | | ✓ |
| Other GHGs | | | | ✓ | | |
| Global warming potential (GWP) values used | | | | | | |
| IPCC Second Assessment Report (1995) | | ✓ | ✓ | | | ✓ |
| IPCC Third Assessment Report (2001) | ✓ | | | | ✓ | (✓)** |
| IPCC Fourth Assessment Report (2007) | | | | ✓ | | (✓)** |
| Allocation of electricity emissions | | | | | | |
| Point of use | ✓ | (✓)*** | ✓ | ✓ | | ✓ |
| Point of generation | | ✓ | | ✓ | ✓ | ✓ |

(Source: Bader and Bleischwitz, 2009)

**2.2.Bilan Carbone Tool**

The Bilan Carbone™ was developed in 2003 by the French Environment and Energy Management Agency (ADEME), as specified earlier. The Bilan Carbone is a very popular methodology used by more than 500 companies in Europe to calculate the GHG emissions. The estimation of the GHG emissions is conducted under the guidelines of the Kyoto protocolby converting from C equivalent to $CO_2$ equivalent emissions. The Bilan Carbone method can be separated into three scopes. These are internal scope, intermediate scope, and overall approach (Figure 2.1). This program can estimate GHG emissions for the whole life cycle of the entity or the project such as raw materia, land, energy use. The available documents obtained along with this tool are Worksheet user's guide, Methodology guide, and Emission factor guide.(ADEME, 2011)

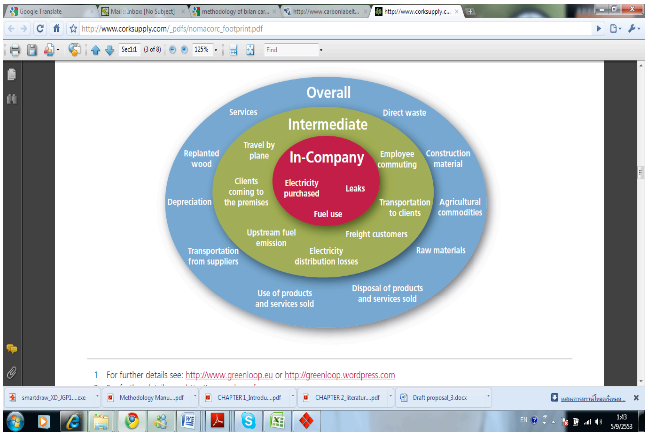

Figure2.:Bilan carbone evaluation scope (Source: ADEME, 2010)

This tool aims to:

• Calculate the greenhouse gas emissions generated by an activity.
• Arrange these emissions in a hierarchy according to their impact.
• Measure the global impact of the activity.

The main component of the tool is a ready-to use Excel spreadsheet that calculates the emissions caused by all the processes necessary for the existence of a given activity using documented emission factors.(ADEME, 2011)

**2.2.1. Objective of Bilan Carbon**

The first objective of the method, naturally, is to have a relatively exhaustive image of all the greenhouse gas emissions for an activity, an area, a development project, etc insofar as the entity that carries out this assessment has sufficiently detailed and exhaustive activity data to fill in the Bilan Carbone spreadsheets. The broader the scope of the assessment, the easier it will be to highlight all the sources on which it is possible to intervene in order to reduce their overall effect on climate change.

Because the site of origin of emissions does not have an influence on their effect on the climate, succeeding in obtaining a reduction directly at one's own site, or provoking it "elsewhere" as a result of your own decision (example: deciding to change your haulage contractor in order to benefit from better-filled and fuel-saving lorries) will have the same effect on the system's overall emissions. Therefore, the field of application for the method which first comes to mind is that of an environmental management tool which participates in a voluntary approach without any real time constraint.

But, it is possible to allude to much deeper changes with this approach. In effect, knowledge now available on the functioning of the climate machine has shown that worldwide emissions of fossil fuel $CO_2$ must be reduced by a factor of two to three by 2050 in order for gas to stop being accumulated in the atmosphere. A logic of sustainable development, in which all people have the right to the same emissions potential, implies a reduction by four or more in French emissions – the reason for the "factor 4" scenario announced by France.

A truly sustainable activity, therefore, should be part of a world which would comply with this constraint and this, generally, poses questions which go well beyond simple emission reduction percentage points - the objective by 2050 is to reduce them by 75%.

Furthermore, information available about hydrocarbon resources allows us to affirm that, if this halving of worldwide emissions of fossil $CO_2$ "one day" is not achieved voluntarily, it will be achieved involuntarily. It is obvious that such a conclusion leads to many questions about the present-day functioning of any organisation (company or local authority) and the Bilan Carbone is often a useful first step for planning for this restricted future. The strength of the method is to put its user in a quantitative approach to an exogenous and non-negotiable constraint which will apply in a global manner.

Because of this, apart from the environmental benefit (future, of course) associated with all voluntary reductions in greenhouse gas emissions, the Bilan Carbone becomes a tool for reducing an activity's dependency on fossil energies, and, thus, makes it possible to decrease economic fragility in the event of an increase in the cost of hydrocarbons, a likelihood which will be difficult to ignore. (ADEME, 2011)

### 2.2.2. Advantages of Bilan Carbon

Bilan Carbone is compatible to ISO-14064 guidelines and the scopes for GHG accounting are similar to those of GHG Protocol. These guidelines are often followed by companies, which makes Bilan Carbone a useful tool for corporate GHG accounting. The detailed documentation and the user interface based on Microsoft Excel enable complete transparency regarding the equations used for calculations, making Bilan Carbone a very adaptable tool. The detailed documentation is useful not only for evaluating GHG emissions but also helps in formulating detailed actions for emission reduction in some cases.(ADEME, 2011)

### 2.2.3. Step to approach Bilan Carbon and details

I. GHGs approach
II. Definition of the scope of the study
III. Data collection
IV. Result exploitation
V. Reduction actions for implementation
VI. Launching reduction actions

The details of each step are described below:

*2.2.3.1. GHGs approach*

The estimation of GHG emission has two types. They are business to consume (B2C) and business to business (B2B). The business to consume (B2C) starts at upstream to downstream but the business to business (B2B) will start from upstream to outgoing produce.

This study will consider the following processes:

1. Manufacture of all types of material used.
2. Production of all types of energy used.
3. The combustion process.
4. Chemical reaction.
5. Leakage of cooling liquids and gases.
6. Performance.
7. All types of transportation involved.

*2.2.3.2. Definition of the scope of the study*

A visit to site is needed before to start anything in order to define the site boundary of the organization. During this site visit, the staff who has access to the data and resources will be identified and how extensive should be determined.During this phase, the parameters to take into account are determined, such as:

- Direct and indirect energy use (e.g. electricity, gas and air conditioning);
- IT (e.g. Internet use, emails sent);
- Transport use for goods (e.g. foods, theater materials) and for staff, theater company, public;
- Input material (e.g. plastic, paper, glass, food);
- Capital Assets (e.g. building, parking, IT, vehicle fleet);
- Direct and indirect wastes produced.

Moreover, this phase is crucial to decide whether to diagnose the GHG emissions over one year, or one month only and then the data can be extrapolated to obtain the calculation into the most common unit for a carbon footprint: Tone of Carbon dioxide ($CO_2$) equivalent per year. Secondly, choose option whether cover the integral organization activities, or only the operation part, or the production part. Finally, make a decision of how extensive the organization wants to assess its carbon footprint. Either carries out a Quick Scan or an extensive carbon footprint. The date of this visit can be combined with the precious phase: Awareness campaign to greenhouse gases/climate change. (ADEME, 2011)

*2.2.3.3. Data collection*

Design a questionnaire tailored made according to the requirements of the organization. To carry out the carbon footprint calculation phase, many data and information are required. It is a complex and laborious task to collect data since it is necessary to track the root of the material for instance. However, this phase depends on the site boundary defined into the previous phase. The carbon footprint could be a Quick Scan or exhaustive. (ADEME, 2011)

*2.2.3.4. Result exploitation*

In this step, there is the first result of the global carbon footprint of the organization. It is important to analyze the uncertainties accumulated over the process.Study the outcome and draft a report, explaining the findings and including suggestions on potential objectives of greenhouse gas emissions reduction (e.g. Reduce 30% of the GHG emissions by 2015 compared to 2000 emissions level). It is fundamental to involve the “Carbon Footprint Leader”, key managers, and staff during the definition of the emissions reductions objectives and potential of cutting energy cost. Also, the report can contain economic simulations which aim to anticipate the economic and social impacts of the fossil fuels declining. These simulations consist in estimating the dependency of the organization to fossil fuels (i.e. oil, gas, coal) and the cost of this dependence to the organization. In other words, this assessment provides a clear overview on how extensive the company relies on fossil fuels, how this trend might influence the energy bill of the company over the time and what risks the organization can encounter if it does make any change. (ADEME, 2011)

*2.2.3.5. Reduction actions for implementation*

Define the action plan to cut energy cost and reduce greenhouse gas emissions on a short, long and very long term based on the objectives defined during the results analysis and global assessment (i.e. phase 4 ), the data collection and various exchanges between the organization and us. The proposed action plan can be classified into three categories:

a) Immediate actions to cut energy cost and reduce GHGs emissions without requiring investment.
b) Priority actions to undertake on a short term and have a high potential for reducing emissions;
c) Strategic actions, involving a marked change in the activity.

From the first and second type of action plan categories are crucial; it is really important that businesses pick the low-hanging fruit. Focusing on energy efficiency is just one such example - put a small amount in and see huge savings in the long-term; providing suggestions on various aspects from changing individual behavior in the short term to strategic developments of the company activities over the longer term. It is therefore important that these suggestions are shared, fully explain and discussed to the “Carbon Footprint Leader” (Identified at the first phase) and key staff (if possible), for them to understand the overall insight of each suggestion. In addition to these suggestions, a complete list of energy saving measures with ashort payback period (so called “no regret options”) can be included. Also, offering a high level overview ofoptions for generation of renewable energy on-site. (ADEME, 2011)

*2.2.3.6. Launching reduction actions*

Support the company to launch their reduction action plan and to communicate their objectives to the outside world with a workshop.

**2.2.4. Principle of emission factor**

For estimating the GHG emissions due to the various activities of the municipality, it is not feasible to carry out a direct physical measurement of GHGs emitted by using gas analyzers or similar instruments. The common methodology for estimating GHG emissions is by using the principle of emission factor and the relevant activity data to estimate the emissions. The GHG inventory calculation in the Bilan Carbone tool is also done by using the emission factor and the relevant activity data. Equation 2.1 shows the calculation of GHG emissions by using the emission factor principle.

$E_A = EF_A \times D_A$ Equation 2.1

Where,

$E_A$= GHG emissions resulting from activity A
$EF_A$= emission factor for activity A
$D_A$= data for activity A

The emission factor for a particular activity is estimated from the energy use and the direct emissions of GHGs resulting from the activity. The emission factor is measured usually in terms of kg of C eq. or kg of $CO_2$ eq. per unit of activity data. As the emission factor is dependent on the energy use and the direct GHG emissions, they tend to vary over locations or even for specific cases. For example, the emission factor per kWh of electricity used would vary over different regions due to the varying energy mix, characteristics of fuel used and the efficiency of electricity generation for the different regions. The emission factor per km travelled would vary over the world, depending on the fuel characteristics, the engine characteristics for the vehicle, the driving and traffic patterns prevalent. For accurately estimating a GHG inventory, it is thus important to use the emission factor specific to the location. (TGO, 2011)

**2.3.Example of using Bilan Carbon for cities**

**2.3.1. Blanche school complex case study**

For this the City of Paris has chosen seven representative sites of the city's heritage. Here, they summarized the results for the site of the school at $9^{th}$ Blanche Street which is situated in the 9th district. The school group is in an old building (built in 1879) of Jules Ferry style. That is to say, with high ceilings, large wooden windows, etc. The canteen food is prepared at the place. This school group includes a kindergarten school and an elementary school. (ADEME, 2005)

The school has the following members:

Table 2.2: School's member (Total 584 people) (Source: ADEME, 2005)

| | Children | Adults | Surface |
|---|---|---|---|
| Kindergarten | 161 | 21 | 1915 m² |
| Elementary school | 375 | 36 | |
| School complex | 536 | 48 | |

*2.3.1.1. Bilan Carbon method*

The overall impact is made up of emissions that come directly from school (e.g. emissions from the combustion of gas or oil in a boiler) and emissions that take place elsewhere, but are related to processes for activity. It will include emissions from transportation taken by the activity, whether to get teachers to work in the morning or those related to production and delivery. (ADEME, 2005)

The Bilan Carbone proposes to review all physical flows that affect the activity and correspond them accordingly to their greenhouse gas emissions they generate. Then these emissions are aggregated section by section. In vast majority of cases, it is not possible to directly measure emissions of greenhouse gases resulting from a given action. Indeed, it is common to measure the concentration of greenhouse gases in the air, only exceptionally emissions are subjected to direct measurements. The only method to proceed is only to estimate the emissions by obtaining them from other data and the Bilan Carbone method was specifically developed to help achieve this in a reasonable time, through a combination of calculation and observations. The figures that convert the data observed in the school for the emission of greenhouse gases, are expressed in carbon3 equivalent, are called emission factor. As most of the approach is based on average emission factors, this method has the primary purpose of providing orders of magnitude. However, this does not prevent to draw practical conclusions if one wishes to take actions because, often, some sections are easy to estimate due to its predominance in the group. (ADEME, 2005)

*2.3.1.2. Implement step*

Here is the procedure followed for realizing Bilan Carbone:

- Launching of Bilan Carbone project.
- Presentation of questionnaire by 2AD to the school principal and the DPA
- (Directorate of heritage and architecture) and DASCO (business management school).
- Collecting data from resource person
- Meeting to get the collected data.
- Analysis of the data.
- Reporting the results.

*2.3.1.3. Result of the study*

I. Internal energy usage

They consider here all the electricity consumption and the consumption of fuel. They purchase of electricity from EDF, purchase gas from Gaz De France and purchase steam from the CPCU (Compagnie Parisienne de Chauffage Urbain), as the building is heated with steam. (ADEME, 2005)

Table 2.3: Emissions recorded from the purchase of energy. (Source: ADEME, 2005)

| Origin | Consumption (kWh) | kg. C equ Pre kWh | kg. equ carbon |
|---|---|---|---|
| Heating (CPCU) | 321000 | 42 | 13482 |
| Canteen electricity | 65000 | 23 | 1435 |
| School electricity | 100000 | 23 | 2300 |
| Natural (Canteen) | 6215 | 64 | 398 |

The sections permit to construct the following diagram:

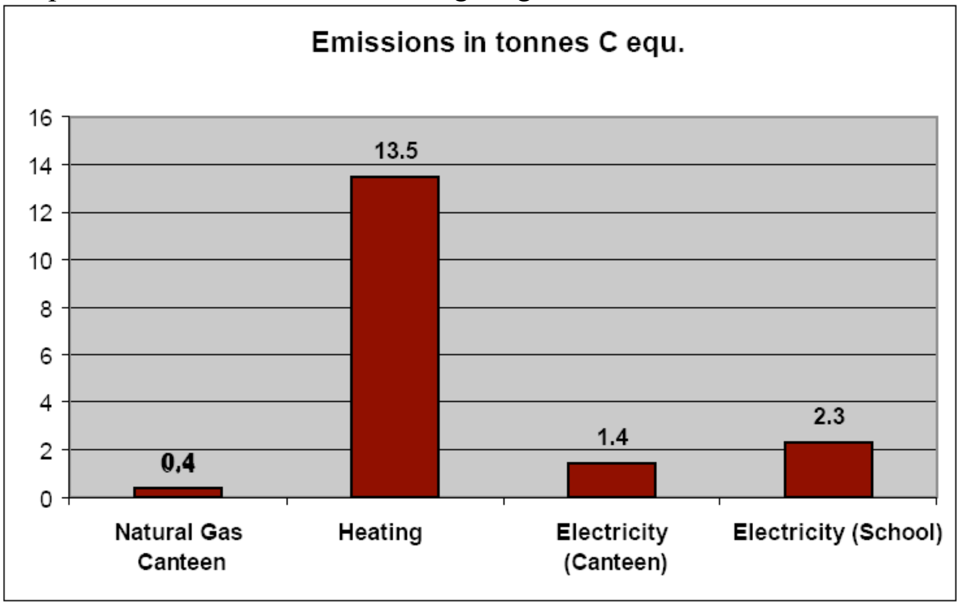


Figure 2.2: Internal energy emissions (Source: ADEME, 2005)

II. Transport

Displacement home - school

The school has considered here the travel between home of students to school and school staff. Here is a table summarizing the results:

Table 2.4: Medium of commuting between home-school(Source: ADEME, 2005)

| | | Metro | Light travel (Bicycle, by walk…) | Car |
|---|---|---|---|---|
| Kindergarten | Students | 161 | | 0 |
| | Staff | 11 | 1 | 0 |
| Elementary school | Students | 14 | 260 | 1 |
| | Staff | 21 | 3 | 0 |

Note: The emissions due to public rail transport (RER, metro, tramway) are negligible.
For the displacement by car, displacement between home and school is 460 km and emissions from travel between home and schools represent 37 kg C equ. (Relatively low emissions)

Displacement outside Paris by train (59,800 km), this mode of transportation is used by students and teachers at different class trips (field trips as an example).Emissions generated by travel by train are 138 kg C equ. They are negligible despite the large number of miles traveled. Indeed the energy used in France by the rail industry is mainly hydro power, a low carbon source.Displacement to the pool by bus, Students move by bus to go swimming (408 km).Emissions generated by travel to the pool account 52 kg C equ. This emission is relatively low. Displacement of the suppliers, only the suppliers of the canteen and the LAS are taken into account. The suppliers don't only move for the school but undertake a tour. It is therefore very difficult to know the mileage generated for an order. The route supplier to school accounted as the return is taken as the finish of one trip. The emissions accounted for the displacement of the suppliers is 1,908 kg C equ /year. These emissions are thus relatively important.

Transport summary:

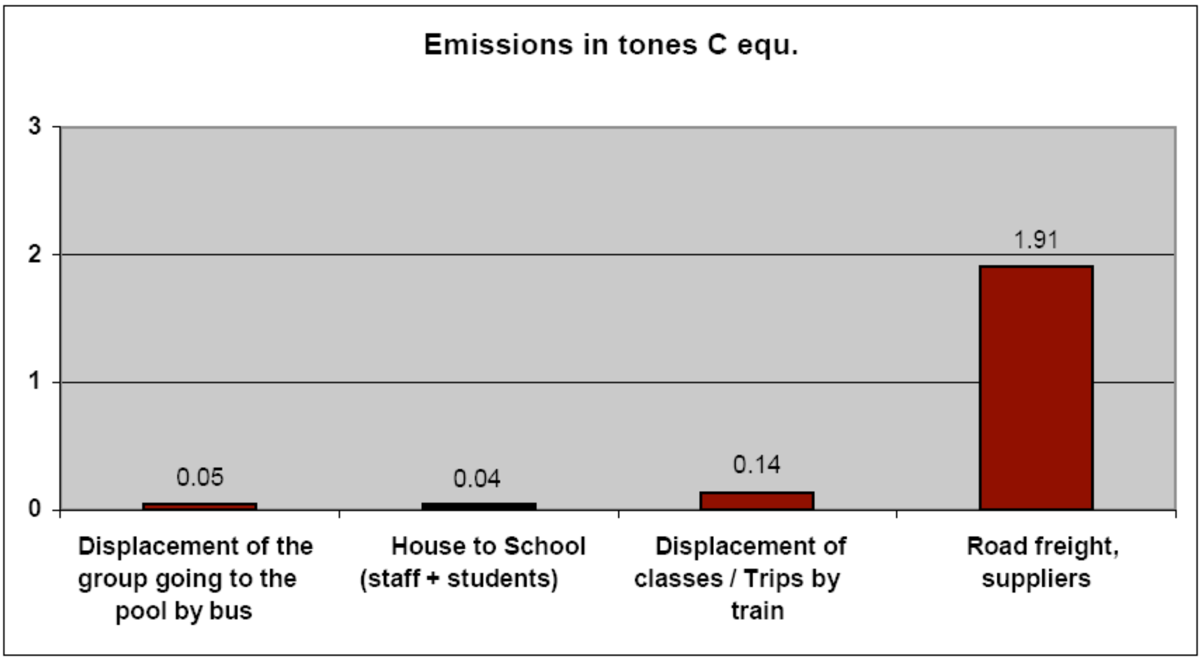


Figure 2.3: Emissions of transports (Source: ADEME, 2005)

The emissions accounted for the transport are 2,135 kg C equ / year. For transport, the main sector is the freight of the providers. Students make several numbers of trips but by metro, as a part its emission is considered negligible due to the type of transport.

III. *Incoming materials*

Consumable manufacturing such as toner, paper for the usage in school premises, etc.
Paper consumption (excluding notebooks) is 2 tons per year which generates emissions of 1.1 tons C equ.

IV. *Canteen*

They accounted here the emissions from animal breeding and the cultivation of various vegetables consumed by the canteen. $N_2O$ emissions associated with the use of nitrogen fertilizers, direct use of fuels in farm vehicles, energy expenditure associated with the manufacture and maintenance of agricultural machines, manufacture of pesticides and fertilizers, etc.

Table 2.8: Emissions of the food consumed at the canteen (Source: ADEME, 2005)

| | Tonnes used | kg C equ. per tonne | kg equ. carbon |
|---|---|---|---|
| Wheat, dry matter | 1 | 82 | **82** |
| Flour | 0 | 105 | **5** |
| Corn | 0 | 100 | **3** |
| Beef | 1 | 3900 | **4 680** |
| Veal | 2 | 10740 | **16 110** |
| Lamb | 1 | 2310 | **1 155** |
| Fish (average) | 2 | 500 | **1 000** |
| Tuna, shrimps | 0 | 1000 | **30** |
| Milk from cow | 0 | 290 | **58** |
| Butter | 0 | 2700 | **540** |
| Raw cheese paste | 1 | 1500 | **1 500** |
| Baked cheese paste | 1 | 3270 | **3 270** |
| Yogurts | 1 | 500 | **500** |
| Farm chicken | 4 | 600 | **2 400** |
| Farm turkey | 2 | 702 | **1 404** |
| Eggs | 1 | 250 | **125** |
| **Total agricultural incoming materials** | | | 32 862 |

We realize here that the emissions generated by the production of food are very important. They represent 32.9 tons C equ. for a total of 82000 meals about and 409 food intakes. Reduced to a meal, these emissions correspond to a ratio of 0.42 kg C equ / meal.

V. *Direct waste and wastewater*

This item covers the treatment of end-of-waste" contained in the dustbin of the school". It arises essentially from paper trash. They assumed that all paper purchased by the school ends up in the school dustbin in the long run and 4.8 tons of food ends up in the garbage.

Table 2.9: Direct waste (Source: ADEME, 2005)

| wastes | Weight (tones) | Emission factor | Emissions kg C equ. |
|---|---|---|---|
| Paper | 2 | 112 | 224 |
| Food waste | 4.8 | 173 | 830 |

The emissions accounted for waste treatment are 1 054 kg C equ. Water consumption is about 3000 m3, we will assume that the volume of water discharged is same as that consumed. This accounts for an emission of 250 kg C equ, which is negligible.

VI. *Property*

Manufacturing vehicles or constructing buildings account for greenhouse gas emissions, that are conventionally distributed throughout the discharge period accounted for the assets. An asset that has been accounted for discharge on the chart is taken as zero for the emissions.

VII. Summary

The total emission is 55 tons C equ.and the detail of emission are shown below

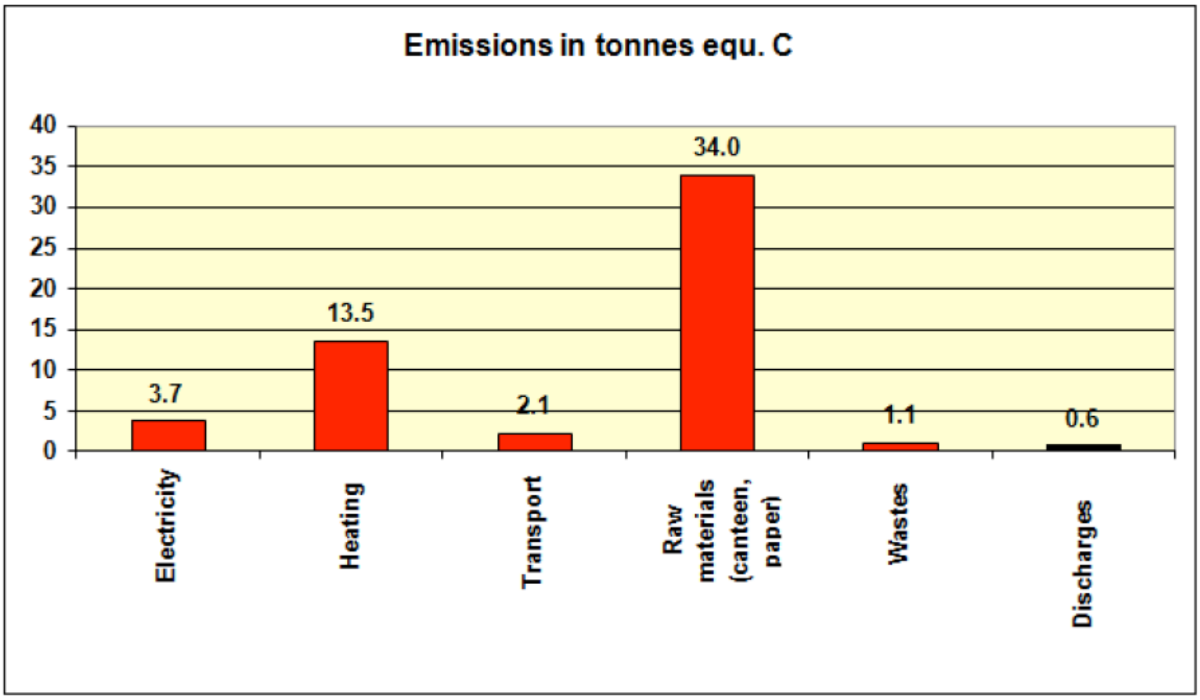


Figure 2.4: the total emission of school (Source: ADEME, 2005)

The summary in figure 2.4 shows that the emissions from raw material is the largest amount of total emission from this territory, heating and electricity is the second and third respectively. So that, to mitigate the GHGs emissions which are released from this territory the first three largest amounts of GHGs emission activities must be a number one considered issues to think about to find options to reduce the emission from these activities.

### 2.4. Emission factors

The greenhouse gas emission factors presented on this page should be used for preparing emission inventories and calculating emission reductions**.** (EIA, 2011)
As explanation above, 2.2.4, to estimate the emission by using equation 2.1 which emission factor value are needed. Table 2.10 shows the some value of emission factors which may use in this study.

Table 2.10: Value of emission factors may use in this study

| No. | Item | Emission factor | Unit for emission factor | Source |
|---|---|---|---|---|
| Energy | | | | |
| 1 | LNG | 0.4862 | kg $CO_2$ eq. per kg | TGO, 2010 |

| | | | | |
|---|---|---|---|---|
| 2 | LPG | 0.498 | kg CO2 eq. per kg | TGO, 2010 |
| 3 | Naphtha | 0.3451 | kg CO2 eq. per kg | IPCC, 2010 |
| 4 | Gasoline | 2.1896 | kg CO2 eq. per litre | TGO, 2010 |
| 5 | Diesel | 2.708 | kg CO2 eq. per litre | TGO, 2010 |
| 6 | Coking coal | 2.6268 | kg CO2 eq. per kg | IPCC, 2010 |
| 7 | Kerosene | 0.3119 | kg CO2 eq. per kg | IPCC, 2010 |

| No. | Item | Emission factor | Unit for emission factor | Source |
|---|---|---|---|---|
| 8 | Fuel oil | 0.3041 | kg CO2 eq. per kg | IPCC, 2010 |
| 9 | Electricity | 0.561 | kg CO2 eq. per kWh | IPCC, 2010 |
| 10 | Natural gas | 0.0099 | kg CO2 eq. per MJ | IPCC, 2010 |
| Materials | | | | |
| 1 | Glass | 1.187 | kg CO2 eq. per kg | TGO, 2010 |
| 2 | Wood | 0.0615 | kg CO2 eq. per kg | TGO, 2010 |
| 3 | Wood chip | 0.0735 | kg CO2 eq. per kg | TGO, 2010 |
| 4 | Paper | 1.4755 | kg CO2 eq. per kg | TGO, 2010 |
| 5 | Cardboard | 0.7243 | kg CO2 eq. per kg | TGO, 2010 |
| 6 | Pulp | 1.0768 | kg CO2 eq. per kg | TGO, 2010 |
| 7 | Kraft paper | 1.1614 | kg CO2 eq. per kg | TGO, 2010 |
| 8 | Natural rubber | 0.4419 | kg CO2 eq. per kg | TGO, 2010 |
| 9 | Synthetic rubber | 2.17 | kg CO2 eq. per kg | TGO, 2010 |
| 10 | Reclaim rubber | 0.7197 | kg CO2 eq. per kg | TGO, 2010 |
| 11 | Rubber | 2.63 | kg CO2 eq. per kg | TGO, 2010 |
| 12 | Steel | 1.76 | kg CO2 eq. per kg | TGO, 2010 |
| 13 | Sinter iron | 0.348 | kg CO2 eq. per kg | TGO, 2010 |
| 14 | Cast iron | 1.47 | kg CO2 eq. per kg | TGO, 2010 |
| 15 | Bronze | 3.47 | kg CO2 eq. per kg | TGO, 2010 |
| 11 | Braze | 2.55 | kg CO2 eq. per kg | TGO, 2010 |
| 12 | Aluminum | 5.91 | kg CO2 eq. per kg | TGO, 2010 |
| 13 | Stainless | 3.65 | kg CO2 eq. per kg | TGO, 2010 |
| Plastic | | | | |
| 1 | PP | 1.97 | kg CO2 eq. per kg | TGO, 2010 |
| 2 | HDPE | 2.14 | kg CO2 eq. per kg | TGO, 2010 |
| 3 | ABS | 3.87 | kg CO2 eq. per kg | TGO, 2010 |
| 4 | PVC | 4.58 | kg CO2 eq. per kg | TGO, 2010 |
| 5 | PU Form | 4.31 | kg CO2 eq. per kg | IPCC, 2010 |
| 6 | PE Form | 2.1 | kg CO2 eq. per kg | IPCC, 2010 |
| 7 | Nylon | 1.91 | kg CO2 eq. per kg | TGO, 2010 |
| 8 | PP Bag | 1.52 | kg CO2 eq. per kg | IPCC, 2010 |
| 9 | PE Bag | 2.636 | kg CO2 eq. per kg | IPCC, 2010 |

| No. | Item | Emission factor | Unit for emission factor | Source |
|---|---|---|---|---|
| Waste | | | | |
| 1 | Paper | 2.93 | kg CO2 eq. per kg | TGO, 2010 |
| 2 | Textile | 2 | kg CO2 eq. per kg | TGO, 2010 |
| 3 | Food / Sludge | 2.53 | kg CO2 eq. per kg | TGO, 2010 |
| 4 | Wood | 3.33 | kg CO2 eq. per kg | TGO, 2010 |
| 5 | Garden & Park | 3.27 | kg CO2 eq. per kg | TGO, 2010 |
| 6 | nappies | 4 | kg CO2 eq. per kg | TGO, 2010 |
| 7 | Rubber & Leather | 3.13 | kg CO2 eq. per kg | TGO, 2010 |

**2.5. Conclusion**

This chapter reviewed the literatures and the other sources which relevant to the study.The Bilan Carbon instrument is seemed  better than the other instrument for estimation of GHGs emission. Especially,in part of emission factor Bilan Carbon has section for adjustment the value of emission factor to be suitable for each situation or location i.e. country. Thus, Bilan Carbon can be used for GHGs emission estimation in every place with accuracy and reliability.

## Chapter 3

## Methodology

The main objectives of this study are evaluate the GHG emissions for municipalities in Thailand using data collected at the municipalities, using the Bilan Carbone tool and analyze the results, compare to each other municipalities and identifying the different activities which lead to GHGs emission.
To fulfill the objectives of the study, the methodology of the study is as listed below.

**Step 1: Studying the Bilan Carbone tool**
Reviewing of literatures which are related and studying the Bilan Carbone tool to understand the various activities emitting GHGs, the various activities to be selected as per different scopes in GHG emission evaluation in Bilan Carbone tool, comparison of Bilan Carbone with other GHG assessment tools.

**Step 2:Definition of the scope of the study**
To discuss and define the scope of the study about which activities need to be considered and which data or information is needed.

**Step 3: Data collection**
Collect the raw data related to the various activities in the scope considered and to be used as input in the Bilan Carbone tool at the selected municipalities.Activities considered for GHG emission inventory are shown as figure 3.1

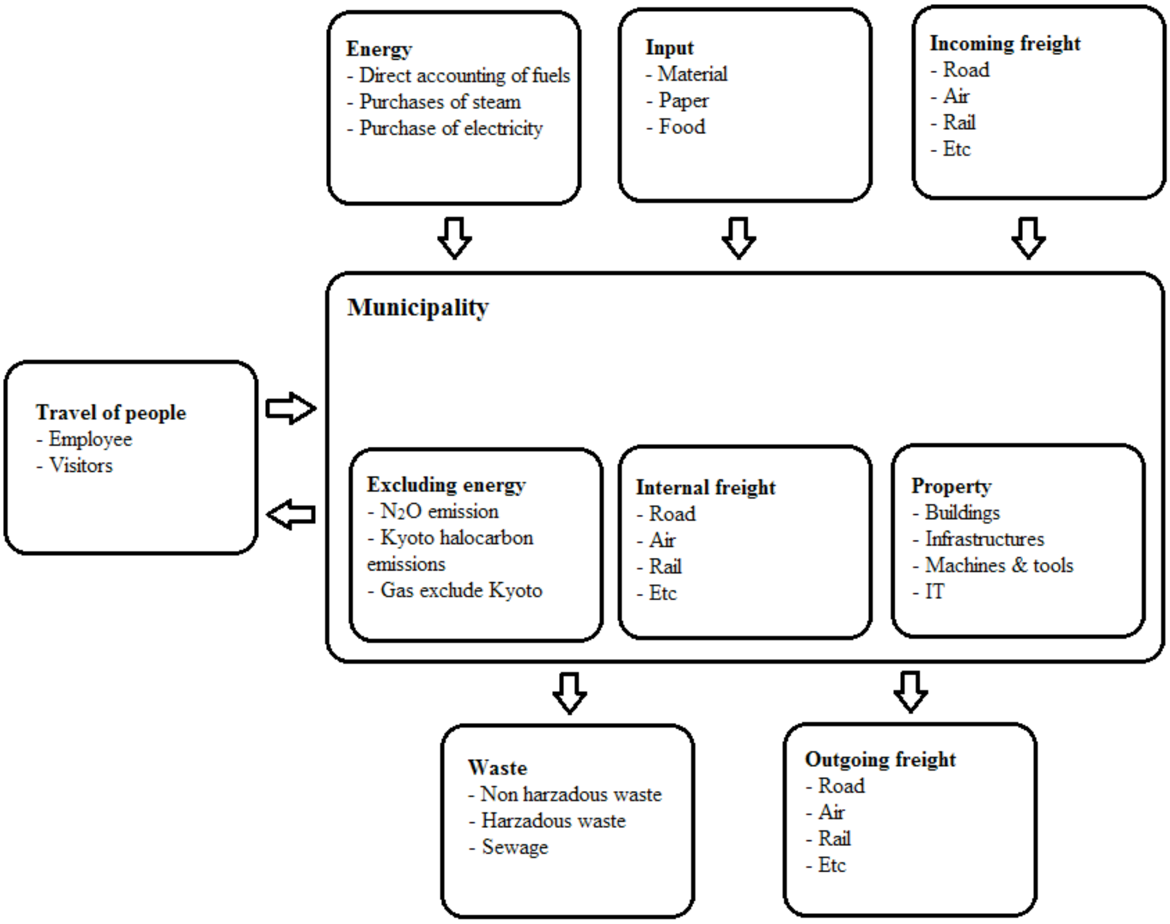


Figure 3.1: Activities considered for GHG emission inventory

*Date required:*

Energy use

Direct use of fuels, of fossil or organic origin (bio-fuels) for heating, industrial processes or the production of electricity or vapour for the entity's own use.

Table 3.1: The data required to estimate GHGs emission for energy use part.

| Type of energy | Data required | Where to find it |
|---|---|---|
| Natural gas | kWh,toe | Bills, meter |
| Coal | Tonnes,toe | Bills |
| Petroleum products | Tonnes, litres, toe, kWh | Bills, meter |
| Organic based fuels | Tonnes, litres, toe, kWh | Bills, meter |
| Electricity purchased | kWh, CO2/kWh | Bills, meter, publication under European detective on emission permits. |
| Water vapour purchased | kWh, CO2/kWh, tonnes, toe | Bills, meter, publication under European detective on emission permits. |
| Electricity producted on site by co-generation | Data related to the fuels used | Bills, meter |
| Water vapour producted on site by co-generation | Data related to the fuels used | Bills, meter |

(Source: ADEME, 2009)

Excluding energy use

Excluding energy use is chemical reactions other than combustion for energy purpose, for example: decarbonation by cement manufactures, flaring gases by refiners, N2O emission by nitrogenous fertilizers used etc.

Table 3.2: The data required to estimate GHGs emission for excluding energy use part.

| Type of gas concerned | Type of process concerned | What necessary information do you have on your premises? (examples) | What information may you need to look for outside? (examples) | Where to find it (examples) |
|---|---|---|---|---|
| $CO_2$ | Construction material production (carbon removal) | Production carried out | Nature and volume of the greenhouse gas produced per unit of production | Internal measurements ; Research centres; Professional bodies |
| | Petrochemicals (flare pits, etc.) | Volume of gas burnt (flare pit counter) | Carbon content of the gas burnt | Internal measurements ; Research centres; Professional bodies |
| | Sanitation (decomposition) | Volume or tonnage of waste processed | Carbon gas emissions per unit of weight or volume | Internal measurements ; Research centres; Professional bodies |
| Methane | Farming: digestion by ruminants | Herd composition. Possibly food supply mass. | Emissions according to the type of food. Emissions according to the reject processing system. | INRA, GIEC, professional technical centres, universities, etc. |
| | Waste processing | Tonnage of waste processed | Emissions according to the type of processing and the type of waste | Internal measurements ; Research centres; Professional bodies |
| | Gas operations | Leaks: differences in counters | Equivalent of the gas which leaks | ADEME, MIES, GIEC |
| $N_2O$ | Industrial sources | Volumes purchased or produced | Nature and volume of the greenhouse gas produced per unit of production | Union des Industries Chimiques; Internal measurements ; Research centres, etc. |
| | Use of fertiliser | Tonnage spread – surfaces fertilised | Emissions factor according to the type of crop and the nature of the soil | INRA, GIEC, professional technical centres, universities, etc. |
| HFC, PFC | Cold chain | Cooling fluid recharge bills | Carbon equivalent of the gas which leaks | ADEME, GIEC, professional refrigeration union, etc. |
| | Alumina electrolysis emissions | Production figures | Emissions per unit of weight according to the nature of the process used | Internal measurements; Research centres, Professional aluminium smelter union |
| | Semi-conductor industry | Chemical compound purchase bills | Carbon equivalent of the gases emitted | ADEME, GIEC, professional union, etc. |
| $SF_6$ | Double glazing, manufacture of electrical equipment | $SF_6$ purchase bill | Leak rate during industrial processes; leak rate at the end of life of the sold products | Internal measurements; Research centres |

(Source: ADEME, 2009) Incoming materials and tertiary services

This item covers everything that physically enters the municipality, except for durable goods (machines-tools, buildings). Materials used for own consumption, such as chemical or reactive products, paper or toner cartridges, food products used by the municipality restaurant etc.

Bilan Carbon categorize them into the item which is easier to understand i.e. metals, plastic materials, glass, paper and cardboard, construction materials, and chemical industry.

Freight

- Incoming freight: road, air, rail, etc.
- Outgoing freight: road, air, rail, etc.
- Internal freight: road, air, rail, etc.

Data can be collected in various units such as amount of fuel use, km of vehicle, km of person, number of passenger and etc.

Passenger travel

- Employee daily commute (home – work): car, bus, coach, train, plane, boat, etc.
- Employee business travel: car, bus, coach, train, plane, boat, etc.
- Visitor travel to municipality: car, bus, coach, train, plane, boat, etc.

Data can be collected in various units such as fuel supplied, km of vehicle, km of person, number of passenger, number of vehicle and etc.

Wastes generated

Data from the Scrap yard as per the type of waste (hazardous or non-hazardous), the state of the waste (solid or liquid), the weights (tons or liters) of the waste generated.

Data collection of waste generated can be collect in form of tones per year and percentage of recycle material.

Property

- Computers, office equipment like printers, photocopiers and fax machines: Data for the quantities of this type of equipment used in the factory (amort period, money spend, amount of purchase).
- Buildings, roadways, car parks: Data for area of buildings by type, roadways and car parks, the type of construction material used (amort period, surface area, tones used of material, and etc.).
- Machines and vehicles: Data for weights of the machines from the nameplates or manuals and for the vehicles from the company records and vehicle type (among period, tones of material, length and width).

**Step 4: Input the data collected and the specific emission factors for the data to evaluate GHG emissions for the municipality using the Bilan Carbone tool.**

**Step 5: Analyze and compare the result with other municipalities to identify the different activities which lead to GHGs emission.**

**Step 6: Suggest alternative options to mitigate GHGs emissions in the municipality (propose)**

# Chapter 4

## Estimation of activity data and results of Chiang Mai Municipality

### 4.1. Introduction

Chiang Mai is located in the northern Thailand. The Chiang Mai Municipality is regarded as a form of local government in Thailand. It is a key agent in Chiang Mai's development for sustained livable city.

**Area:** 40.216 square kilometers
**Population:** 146,800
**Households:** 71,514

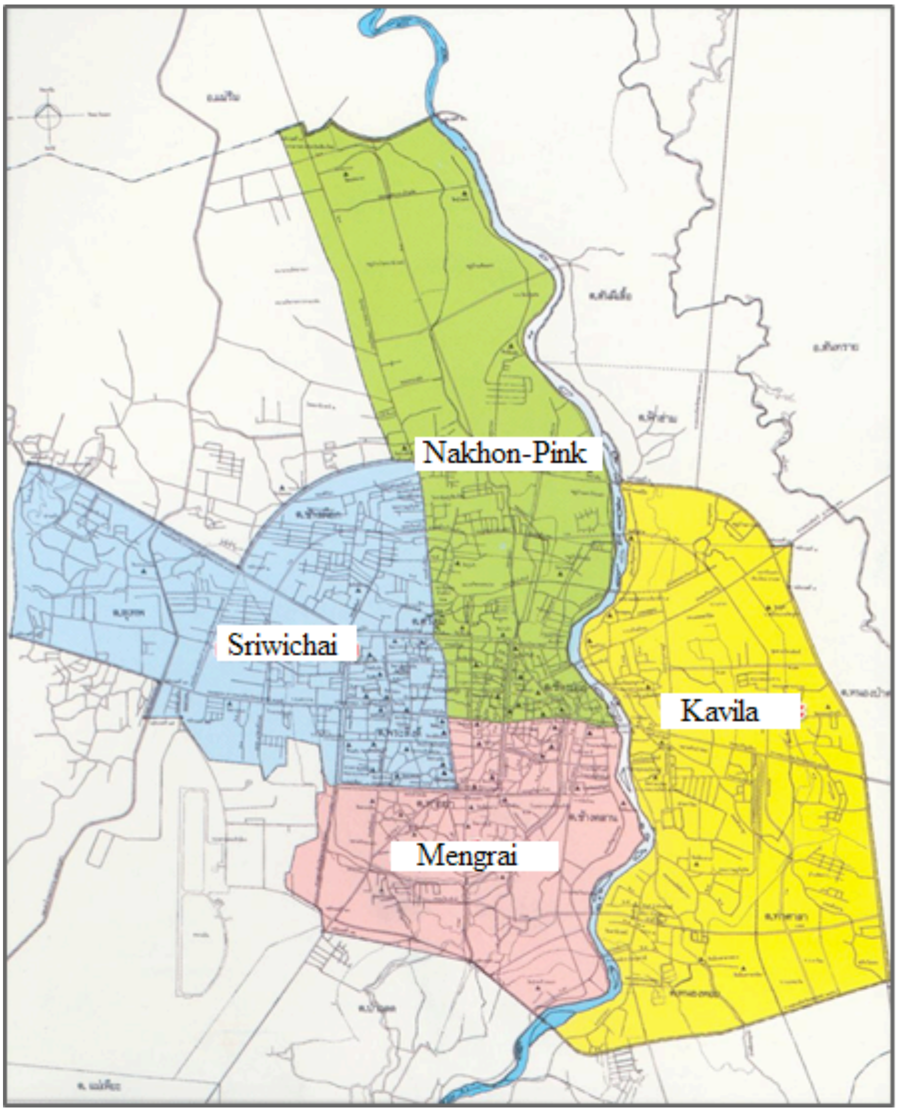


Figure 5.1: Area under control of Chiang Mai municipality

### 4.2. Activities considered for GHG emission inventory

The various activities taken into consideration for evaluating GHG emissions for Nonthaburi municipality are shown below. The activities have been categorized by selecting the Bilan Carbone tool as a reference.

The various activities or processes considered as sources of GHG emissions are:

| Item | Details |
|---|---|
| Energy use | Direct use of fuels, of fossil or organic origin (bio-fuels) for heating, industrial processes or the production of electricity or vapour for the entity's own use. |
| Refrigerant leaks and fertilizer use | Excluding energy use is chemical reactions other than combustion for energy purpose, for example: decarbonation by cement manufactures, flaring gases by refiners, N2O emission by nitrogenous fertilizers used etc. |
| Input materials | This item covers everything that physically enters the municipality, except for durable goods (machines-tools, buildings). Materials used for own consumption, such as chemical or reactive products, paper or toner cartridges, food products used by the municipality restaurant etc. |
| Freight | This item covers the activities in context of work by the municipality. Internal freight, incoming freight, and outgoing freight are considered. |
| Travel of people | This item covers the activities travel by employee and visitor. |
| Waste generated | Data from the Scrap yard as per the type of waste (hazardous or non-hazardous), the state of the waste (solid or liquid), the weights (tons or liters) of the waste generated. |
| Property | This item covers all of the assets of the municipality, including buildings, roads, vehicles and IT. |

### 4.3. Activities data of Chiang Mai municipality

The estimation of GHG emission would be done for the whole year. The data collection is done on a sample basis for the different activities considered for estimation of GHG emission. Hence, it is necessary that the various activity data be extrapolated for the year on the basis on the data collected for varying time periods.

#### 4.3.1. Energy use

The energy use in the municipality is in terms of electricity consumption for running activities in the municipality. The Table 5.1 gives the total electricity consumption for the year 2010, within the boundary selected. The electricity consumption is obtained from the Bureau of Technical at the municipality. Total electricity consumption for the year 2010 was 966,182 kWh.

Table 51:Energy consumption for the year2010

| Type of energy | Amount | Unit |
|---|---|---|
| LPG | 37.58 | Tons |
| Diesel | 38,460 | Liters |
| Petrol | 25,750 | Liters |
| Electricity | 351,840 | kWh |

#### 4.3.2. Refrigerant leaks and fertilizer use

The capacity of air conditioning system is used for estimating the leakages of refrigerant. The capacity of air conditioning system used and the fertilizer use are shown in the Table 5.2 and Table 5.3, respectively. The capacities of the refrigeration system and the fertilizer use were obtained by Bureau of Environment and Health and Bureau of Technical at the municipality, respectively.

Table 5.2.Capacity of air conditioning system

| Type of air conditioning system | Refrigerant used | Refrigeration capacity (kW) |
|---|---|---|
| Split type | R-22 | 3,270 |

Table 5.3.Fertilizer use

| **Use of Fertilizer** | |
|---|---|
| **Fertilizer** | **Kilograms** |
| (N-P-K 15-15-15) | 1,970 |

### 4.3.3. Input materials

The most of incoming materials for the municipality consist of the material for office work, maintenance building and road in the municipality, and services. The incoming materials are measured in terms of budget in baht as show in table 5.4.

Table 5.4:The budget for materials use, obtained from the Bureau of Finance of the municipality.

| Item | Budget (Baht) | Budget in K Euro |
|---|---|---|
| Service Employment Contract | 377,702,200 | 9,443 |
| Materials | 79,646,300 | 1,991 |

### 4.3.4. Freight

The freight refers to the transport of goods. The freight is sub-divided into internal freight within the premises of the municipality, the incoming freight from suppliers and the outgoing freight carrying the waste. Table 5.5 shows the annual diesel and petrol consumption in the municipality for freight movement. The data for diesel and petrol consumption is obtained from the Bureau of Finance at the municipality.

Table 5.5: Fuel consumption for internal freight

| Year 2010 | Diesel (Liter) | Petrol (Liter) |
|---|---|---|
| **Amount of use** | **1,516,113** | **34,320** |

### 4.3.5. Passenger travel

The travel of passengers is sub divided as daily commute of employees to their work place; travels of people come to use services at municipality and travel of visitors to the municipality.

The data regarding daily commute of the employees to the municipality is obtained using a survey, answered by 325 employees out of the 1,951 employees at the municipality. The Table 5.6 gives the annual distance covered by employees for commuting using various modes of transport. Travel of visitor data is shown in table 5.7.

Table 5.6: Daily commute of employees to their work place

| **Employees: home to work transport** | | | |
|---|---|---|---|
| **Vehicle Type** | **Amount of vehicle** | **Fuel use** | **Liters** |
| Motorcycles < 125 cc | 11 | Gasoline | 22,943 |
| Motorcycles = 125 cc | 14 | Gasoline | 63,200 |
| Summary | | | 86,143 |
| **Employees: home to work transport** | | | |

| Vehicle Type | Amount of vehicle | Fuel use | Kilometers |
|---|---|---|---|
| Car 1500 cc | 221 | Gasoline | 2,583,840 |
| Pick up average size | 190 | Diesel | 1,485,792 |
| Van | 2 | Diesel | 19,200 |
| Car NGV | 5 | Natural Gas | 39,360 |
| Car LPG | 25 | LPG | 178,560 |
| Motorcycles | 319 | Gasoline | 1,700,880 |
| Summary | | | 6,007,632 |

Table 5.7: Travels of people come to use services at municipality and travel of visitors to the municipality.

| Business travel by air | |
|---|---|
| **Type** | **Passenger.km** |
| Domestic travel | 141,642 |

**Domestic travel = distance < 3,600 km.

**4.3.6. Wastes generated**

The wastes generated by the municipality are non-hazardous. The data for waste generated is obtained from the records of Bureau of Environment and Health at the municipality. Table 5.8, 5.9, and 5.10 give the annual weight of non-hazardous waste (mixed house hold waste) generated, Materials incinerated, and BOD, respectively. Total waste generated by the municipality is 384.38 tons per year.

Table 5.8: Waste generated by the municipality

| | Amount (Tons) |
|---|---|
| Waste for TPS | 391.25 |
| Hazardous waste | 50 |
| Infectious waste | 6 |

**4.3.7. Property**

The property is classified into four titles; building, road, vehicle and machine, and IT. The data for building, road, and weight of vehicle and machine are obtained from Bureau of Technical at the municipality. The data for IT in form of budget is obtained by Bureau of Finance at the municipality. Table 5.9 and 5.10 show the area data road and number of IT device. The total weight of vehicle owned by the municipality is 489 tons.

Table 5.9: Area of roads in the municipality

| | Concrete (square meter) | Asphalt (square meter) |
|---|---|---|
| Road (TC4) | 1,542,696 | 485,624 |

Table 5.10: Amount of devices owned by municipality

| | Photocopier | PC |
|---|---|---|
| Amount of devices | 65 | 264 |

### 4.4. Estimation of emission

### 4.4.1. Energy use

The total GHG emission from the energy use is estimated for electricity consumption in Chiang Mai municipality and the other units under the municipality. Electricity is consumed in various sections of the municipality like office or administrative buildings, school, pawn shop and the health clinics. Figure 5.4 below shows the emissions in tons of CO2 eq. resulting from energy use. Total annual GHG emission from energy use is about 533 tons of CO2 eq.

The emission factors for Thailand from TGO are used in freight category:

| | | | |
|---|---|---|---|
| Diesel | = | 0.3215 | kg equ.$CO_2$ per liter. (TGO, 2011) |
| Petrol | = | 2.1896 | kg equ.$CO_2$ per liter. (TGO, 2011) |
| Electricity | = | 0.5610 | kg equ.$CO_2$ per kWh. (TGO, 2011) |

Figure 5.4: Annual GHG emissions due to energy use in the municipality

### 4.4.2. Refrigerant leakages and fertilizer use

All of the air conditioners in the municipality is split type air conditioners. The leakage of the refrigerant used in air conditioning equipment also leads to GHG emissions. The CFC R-22 is used as the refrigerant for the air conditioning devices in the municipality. The annual emissions from refrigerant leaks amount to 223tonnes of CO2 eq., corresponding to a refrigeration capacity of 3,790 kW.

Chiang Mai municipality used fertilizer about 1,970 kg of N-P-K fertilizer which has 16 percent of nitrogen. The annual emissions of this category are shown in figure 5.5. The emission factors of nitrous oxide and R-22 refrigerant are 2.05 and 1810 kg equ.$CO_2$ per kg respectively. (TGO, 2011)

Figure 5.5: Annual GHG emissions due to Refrigerant leakages and fertilizer use in the municipality

### 4.4.3. Incoming materials

The most of incoming materials for the municipality consist of the material for office work, maintenance building and road in the municipality, and services. The incoming materials are measured in terms of budget in baht. The GHG emissions from the incoming materials are shown in figure 5.6.Use of monetary ratios, category 1 is for the service employment contract and category 2 is for the materials use in the municipality in amount of 9,443,000 and 1,991,000 Euro, respectively.The emission factors of services with low level of equipment and IT & consumable for Thailand are not available. Thus, the emission factors for France in the program are used and the values are 36.6667 and 916.6667 kg equ.$CO_2$ per K euro respectively. Total emission from this category is 2,180 kg equ.$CO_2$ per kg.

Figure 5.6: Annual GHG emissions due to incoming materials in the municipality

### 4.4.4. Freight

The freight or transport of goods consists of three components, which is incoming freight from suppliers, outgoing freight to transport waste and the internal freight to collect waste, water the garden, and etc. inside the municipality. The internal freight contributes total GHG emissions due to freight movement. Total emission from this category is 4,558kg equ.$CO_2$ per kg.

The emission factors for Thailand from TGO are used in freight category:

| | | | |
|---|---|---|---|
| Diesel | = | 0.3215 | kg equ.$CO_2$ per liter. (TGO, 2011) |
| Petrol | = | 2.1896 | kg equ.$CO_2$ per liter. (TGO, 2011) |
| Garbage truck 16 tons | = | 0.0632 | kg equ.$CO_2$ per ton-km. (TGO, 2011) |

#### 4.4.5. Travel of employee and visitors

The passenger travel, which leads to GHG emission, include home to work of employees and travel of visitors are taking into an account. The annual emission of this category is 1,865kg equ.$CO_2$ per kg as shows in figure 5.7.The employees commute to work using their personal vehicles or by public vehicles in a few cases. For GHG emissions due to commuting, the major contributor is car, the reason being 61% of the employees using car daily. Employees commuting by Motorcycles account for 39% of the GHG emissions for daily commute, as seen in the Figure 5.8.The emission factors from Bilan Carbone which are used in travel category:

| | | | |
|---|---|---|---|
| Rural periphery | = | 0.1540 | kg equ.$CO_2$ per vehicle.km. |
| Urban bus | = | 0.0843 | kg equ.$CO_2$ per passenger.km. |
| Mini bus | = | 0.0990 | kg equ.$CO_2$ per passenger.km. |
| Motorcycle < 125 cm3 | = | 0.1063 | kg equ.$CO_2$ per vehicle.km. |
| Mix travel | = | 0.1870 | kg equ.$CO_2$ per vehicle.km. |
| Short-haul in class not known | = | 0.1247 | kg equ.$CO_2$ per passenger.km. |

Figure 5.7: Annual GHG emissions due to Travel of employee and visitors of the municipality

Figure 5.8: Share of GHG emissions due to home-work of employees

#### 4.4.6. Waste generated

The wastes generated of activities in the municipality lead to GHG emissions. The total yearly emissions resulting from waste generated are 435 tons of $CO_2$ eq. as shown in table 4.12 A majority of the GHG emission for waste are accounted for by non-hazardous for TPS (88%), followed by the various non-hazardous wastes for incineration (1%), hazardous waste (1%), and sewage (10%) as shown in the Figure 5.9. The emission factors from Bilan Carbon which are used in waste category:

| | | | |
|---|---|---|---|
| Average household waste from TPS utilization | = | 154 | kg equ.$CO_2$ per ton. |
| Average household waste for incinerated | = | 304 | kg equ.$CO_2$ per ton. |
| Sewage (BOD = 20 kg per $m^3$) | = | 124.67 | kg equ.$CO_2$ per $m^3$. |

Figure 5.9: Annual GHG emissions due to waste generate of the municipality

Figure 5.12: Share of GHG emissions due to wastes generated

### 4.4.7. Assets

The assets of the municipality, consisting of infrastructure like office buildings, education buildings, parking space, roads, machinery and vehicles, and lastly IT and office equipment also contribute to GHG emissions. This is due to the embedded energy in the constituent materials and the processing energy expended for the various assets owned by the municipality. The total GHG emission due to assets is 18,970 tons of $CO_2$ eq. as shown in figure 5.13. The emission factors which are used in assets category:

| | | | |
|---|---|---|---|
| Road (TC4, concrete) | = | 366.6667 | kg equ.$CO_2$ per $m^2$. |
| Road (TC4, bitumen) | = | 102.6667 | kg equ.$CO_2$ per $m^2$. |
| Vehicle weight | = | 5500 | kg equ.$CO_2$ per ton. |
| Amount of purchases IT | = | 916.6667 | kg equ.$CO_2$ per K euro. |

Figure 5.13: Annual GHG emissions due to assets of the municipality

# Chapter 5

# Conclusion

## 5.1. Conclusion

GHG emission estimation for municipality is becoming an important activity, not only for Thailand but for over the world, as organizations focus on reducing their impact on the environment. GHG emission inventory is the first step to be conducted in order to assess the baseline emissions and then take relevant mitigating actions.

The emission sources of Chiang Mai municipality is energy use, refrigeration leakage, material input, freight transport, travel of people, asset. The corresponding amounts of Chiang Mai municipality is 530 ton $CO_2$ eq., 311 ton $CO_2$ eq., and 2,181 ton $CO_2$ eq., 4,558 ton $CO_2$ eq., 1,865 ton $CO_2$ eq., 435 ton $CO_2$ eq., and 11,695 ton $CO_2$ eq., respectively. The major sources of emission are asset, freight, material input, and transportation of people. The total emissions of Chiang Mai municipality is 21,540 tons of $CO_2$equivalents per year.

Chiang Mai municipality generated 0.27 ton $CO_2$ eq. per employee from energy sector, 0.174 and 0.114 ton $CO_2$ eq. per employee from refrigeration leakage and fertilizer use, 1.325 and 1.080 ton $CO_2$ eq. per employee from material input, 133.60 and 113.40 ton $CO_2$ eq. per square kilometre from freight sector, 1.07 and 0.96 ton $CO_2$ eq. per employee from travel sector, 0.24 and 0.22 ton $CO_2$ eq. per employee from waste generated.

For appropriate estimation of GHG emission, emission factors used should be specific to the case of the country and the activity. This study estimated the GHG emission for the municipality using emission factors relevant to the country and the activity. For some cases, where emission factors are observed to not vary much between locations, emission factors available in the Bilan Carbone tool were used.

### 5.2. Recommendation for further study

1. The carbon footprint should be estimated for industry manufacturing different type of products. The observed share of the overall GHG emission for the various sources might be totally different as compared to the engine, which being an automotive component uses significant fossil fuels in its lifetime.

2. The emission factors for the case of India should be used for estimating the carbon footprint. The India specific emission factors should be reviewed for the case of sources of emission like amortization of different vehicles, upstream processes for fuel, assets like office equipment and vehicles, industrial metal buildings and parking spaces, wastes generated.

3. Global average values or regional values of emission factor have been used for incoming material like aluminium, copper, rubber and LDPE bags used for packaging. The emission factor for these materials specific to the case of India should be used.

# Chapter 7
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