Chapter 8

Greening Municipality Through Carbon Footprint for Selective Municipality

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Additional information is available at the end of the chapter

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Abstract

Evaluation of the organizational greenhouse gas (GHG) emissions from operational activities of selective municipality was investigated in this study. The selected municipality is located in Songkhla Province, the southern part of Thailand, and is divided into seven functional units. The total GHG emissions were estimated at 16,920.29 ton CO_2 eq. in the fiscal year 2016. The carbon footprints under direct, indirect, and optional indirect emissions (scopes 1, 2, and 3, respectively) were found to be 1129.92, 255.24, and 15,535.13 ton CO_2 eq./year, respectively. The highest carbon footprint was from methane emissions related to solid waste decomposition in sanitary landfills (15,524 ton CO_2 eq./year). Therefore, the main GHG mitigation strategy proposed was the installation of waste to energy recovery in order to reduce waste throughput to the landfill. For specific municipal operations, diesel combustion in municipality-owned vehicles had the highest carbon emission followed by fugitive emissions from refrigerants and electricity consumption (746.92, 289.60, and 255.24 ton CO_2 eq./year, respectively). The important constraints in reducing GHG emissions from upstream and downstream of the organizational activities were identified in terms of time, cost, and data accessibility. Further, convergent cooperation and public participation are also significant for effective implementation of global warming mitigation strategies.

Keywords: carbon footprint for organization, GHGs emission, global warming, waste to energy

1. Introduction

1.1. Significance of carbon footprint for organization evaluation

Global warming and climate change have become a serious problem the world is faced with today. Global warming results from the emission of greenhouse gases (GHGs) as a result of anthropogenic activities related to agriculture, transportation, energy production, and use. The production and combustion of carbon-rich fossil fuels, especially coal, oil, natural gas, as well as agricultural activities including deforestation are undoubtedly the chief generators of GHGs. Global warming and climate change are adversely impacting on human and animal life.

The Kyoto Protocol identified the main GHGs accelerating climate change. The Intergovernmental Panel on Climate Change (IPCC) reports has shown that there is a strong correlation between the increasing CO_2 emissions and climate change. Consequently, increasing awareness of the impact of this crisis as well as GHG mitigation is indeed an important achievement, globally. As a result, many countries are making tremendous effort in preparing, coordinating, protecting, and developing strategies aimed at carbon mitigation and effecting changes at both local and national levels.

Carbon footprint (CF) is defined as the measurement of GHG emissions from an individual, product, or organization. According to Wiedmann et al. [1], CF is the measure of CO_2 emissions related either directly or indirectly to an activity during the complete life cycle of a product or a service. However, CF is not only concerned about CO_2 but other GHGs as well. Therefore, in order to simplify CF assessments, GHGs are all expressed in terms of carbon dioxide equivalent (CO_2 eq). This means that an activity is described for a given mixture and quantity of GHGs, in terms of the CO_2 that would have the same global warming potential (GWP), when measured over a specified time scale (normally, 100 years) [2].

Carbon Footprint for Organization (CFO) refers to an approach where the GHGs associated with an organization's activities are evaluated and calculated in terms of CO_2 eq. This is important in order to formulate mitigation strategies for activities where outstanding gains in CO_2 reduction can be achieved. This enables the development of a set of guidelines for the effective reduction of GHG emissions from urban, transportation, industrial, and service sections at both local and national levels. For this reason, CFO evaluations have been conducted worldwide for various organizations including nongovernmental organizations (NGOs), business enterprises, public authorities, and educational institutions at different scales (personal, institutional, city level, regional, national, and international) [3].

However, in Thailand, the evaluation of CFO has progressed at a very slow pace. Only a few large organizations have started to cooperate with the Thailand Greenhouse Gas Management Organization (TGO) in evaluating and verifying GHGs emissions. Most organizations still lack the knowledge, technical expertise, and skills for carbon foot printing. Due to the urgency of this issue, the focus of research in Thailand in relation to climate change is shifting, and already, carbon footprint analysis for local authorities has begun. "Promoting the Carbon Footprint of Local Government Organizations and Reporting Greenhouse Gas Emissions" project was established in order to activate the development of low carbon cities by supporting the implementation and budget of the TGO to report on GHG emissions from various activities and corporate service within the local municipalities. Several municipalities were selected to be part of this project. A GHGs reduction guideline is also in place to support the organization's carbon footprint assessment for Thailand. In order to achieve sustainable low carbon cities, improving the capacity of Thai local government organizations is imperative.

1.2. Carbon footprint for organizations for sustainable municipality

Local governments have a crucial role to play in the management of natural resources and the environment. However, rapid urbanization leading to an increase in both the number and size of cities directly works against their efforts. Consequently, urban areas have the highest GHG emissions due to the high-energy consumption, waste generation, and reduced forest cover. The latter also means reduced natural carbon sinks as forests are able to absorb most of the CO_2 naturally. Local governments should therefore play an instrumental role in global warming mitigation through the effective management of GHGs from their internal activities. Through CFO, they can account for all the GHGs emitted in terms of CO_2 eq, thereby enabling the formulation of management guidelines aimed at reducing GHG emissions.

A number of local authorities also calculated their carbon footprint to achieve various objectives, for example, to integrate sustainability into work performance, to perform a sustainability assessment of their operations, for use as a management tool with staff and customers, as well as for use in policy development. CF analysis can be a strategy through which a municipality can reduce their GHG emissions, promote sustainability, and raise public awareness for the organization as a low carbon city. The current project emphasizes CF performance calculation and mitigation of GHG emission for selected municipalities. Based on the results of the assessment, scenarios for sustainable environmental management were suggested. Mitigation approaches were discussed with operational teams and proposed to the municipality management committee.

In light of this, the Kho-hong Municipality, Hat Yai District, Songkhla Province, Thailand, joined the local GHG emission and reduction program in order to become a carbon neutral city and support the voluntary carbon market in Thailand with TGO. For the purpose of the project, data were collected from municipal activities in one fiscal year. The benefits for municipalities from participating in this program could be divided in terms of output, outcome, and impact. The GHG emission inventory showing the activities of the municipality together with the respective quantities of GHG emissions represents the "Output." In the scope of municipal responsibility and cooperation, there are several strategies for reducing GHG emissions from various activities and operations. Further, the municipal staff and administrators receive knowledge and gain valuable skills and experience in carbon evaluation and mitigation. Previously, lack of these skills and experience hindered efforts to conduct proper carbon foot printing for the municipality. "Outcome" represents the result of the implementation of the GHG emission reduction program in the organization. Consequently, budgetary management for personnel and organizations with improved consciousness of the need to conserve natural resources and the environment is made easier. The "impact" would be the realization of sustainable municipalities. Further, this can be developed as part of the Thailand Voluntary Emission Reduction Program (T-VER) in which case the carbon credits in the voluntary carbon market of Thailand can generate additional revenue for the municipalities [4].

2. Literature review

2.1. Sources of GHG and UNITS OF measurement

2.1.1. GHGs types

The seven GHGs identified in the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) on Climate Change 2014 [5] are considered in the carbon footprint calculation. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

2.1.2. Equivalency factors of global warming potential

The global warming potential (GWP) was established for the comparison of environmental impacts of different gases. Generally, the period set for GWPs is 100 years. GHG evaluation is determined in terms of carbon dioxide equivalents (CO_2 eq) in which case the other GHGs are converted to the universal unit based on their respective equivalency factors for GWP over the 100-year period in line with the latest version of the IPCC report. For example, the GWP of CH_4 as compared to CO_2 is 25. This means that 1 kg of CH_4 has an impact on global warming equivalent to 25 kg of CO_2 for 100 years. In other words, the emission of 1 kg CH_4 is 25 kg CO_2 equivalent. **Table 1** shows the GWPs of the various GHGs in terms of IPCC's Fifth Assessment Report (AR5) [6].

2.1.3. Sources of GHG emissions

These following sources of GHG emissions are taken into account for carbon footprint:

- raw material acquisition
- electricity production and consumption
- combustion processes
- chemical reactions in industry
- processing, manufacturing and operations
- transportation of entire process
- leakage of refrigerants and other fugitive gases
- livestock, agricultural production and waste generation
- waste and waste management
- fossil fuel are included in carbon footprint calculation but CO_2 emissions from biogenic sources are excluded.

2.1.4. Unit of analysis

Unit for GWPs calculation could be obtained from the common unit of measurement which provides a simple guide enabling the policymakers to compare GHGs emission and effectiveness of mitigation measures for various sectors and gases. The unit of analysis can therefore be set as per unit of product such as per kg, per liter, per piece, and so on.

Common Name	Formula	(AR5)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbon	HFCs	124-14,800
Perfluorocarbon	PFCs	7,390 – 12,200
Nitrogen trifluoride	NF_3	17,200
Sulfur hexafluoride	SF_6	22,800

Table 1. GHG and the global warming potential (GWP) [6].

2.2. GHGs protocol emission scopes

Figure 1, adapted from the World Resources Institute (WRI) GHG Protocol, illustrated the three different groups, or "scopes," including direct, indirect, and optional sources of GHG emissions under the GHG Protocol. As the rule of thumb, data for direct emissions, including wastewater treatment, direct energy generation, travel in the company-owned vehicles, landfill gas, and fugitive GHG emissions, should be reported. Further, indirect emissions from subscribed electricity and steam, for example, must be included. Most of the programs do not report GHG emissions from optional source, such as from vehicles that are not owned by the company, outsourced activities, waste disposal, purchased materials, and product use [7].

2.2.1. Principle of GHG protocol

The five principles of the GHG protocol are relevance, completeness, consistency, transparency, and accuracy (**Figure 2**) [8].

2.2.1.1. Relevance

The GHG sources to be selected, the GHG sinks, reservoirs, data, and methodologies for assessment must be appropriate to the specific needs of the intended user.

2.2.1.2. Completeness

It includes all relevant GHG emissions and removals.

All the relevant GHG emissions and removals must be included.

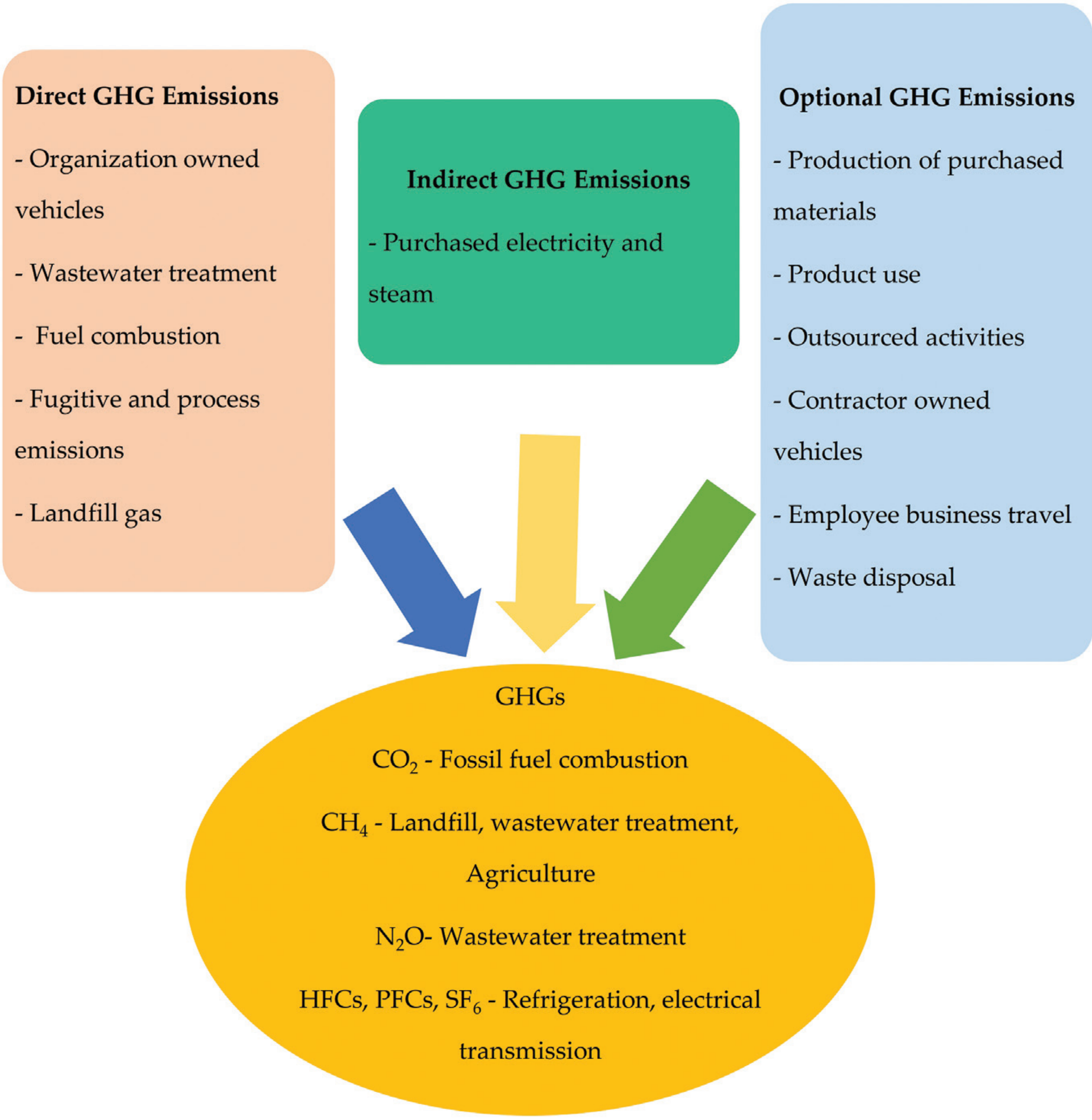

Figure 1. GHGs protocol emissions scopes.

2.2.1.3. Consistency

It enables meaningful comparisons in GHG-related information.

2.2.1.4. Accuracy

It reduces bias and uncertainties as far as is practical.

Bias and uncertainties must be reduced as far as is practical.

2.2.1.5. Transparency

It discloses sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence.

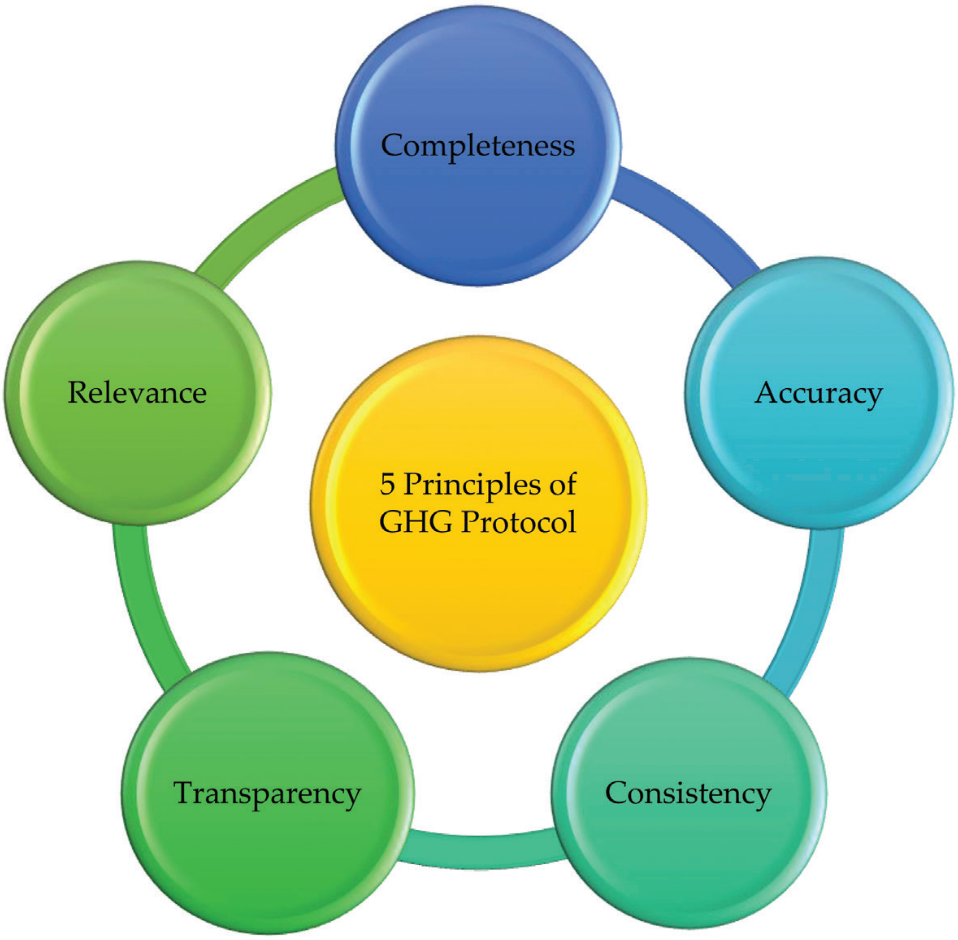

Figure 2. Principles of GHG protocol.

The first principle of relevance is important for providing available information to stakeholders both internal and external to the company. The completeness of the GHG report is measured in terms of how comprehensive and meaningful the compiled information is. Consistency in the organization's reporting of GHG emissions will allow them to track emissions over time to identify trends. Transparency within the GHG report allows for a clear audit trail of the information presented. Accuracy, along with the four other accounting and reporting principles, will ensure that the organization produces a true and fair representation of their GHG emissions [9].

2.3. Scope of the GHG emission source

The GHG emission sources were categorized into three different "scopes." Scope 1 accounts for direct emissions from sources that are controlled or owned by the organization; scope 2 refers to indirect emissions that occur from the generation of subscribed electricity, steam, or heat used by the organization; and scope 3 accounts for all other indirect emissions resulting from the company activities, but emitted from sources not controlled or owned by the company as presented in **Figure 3** [8].

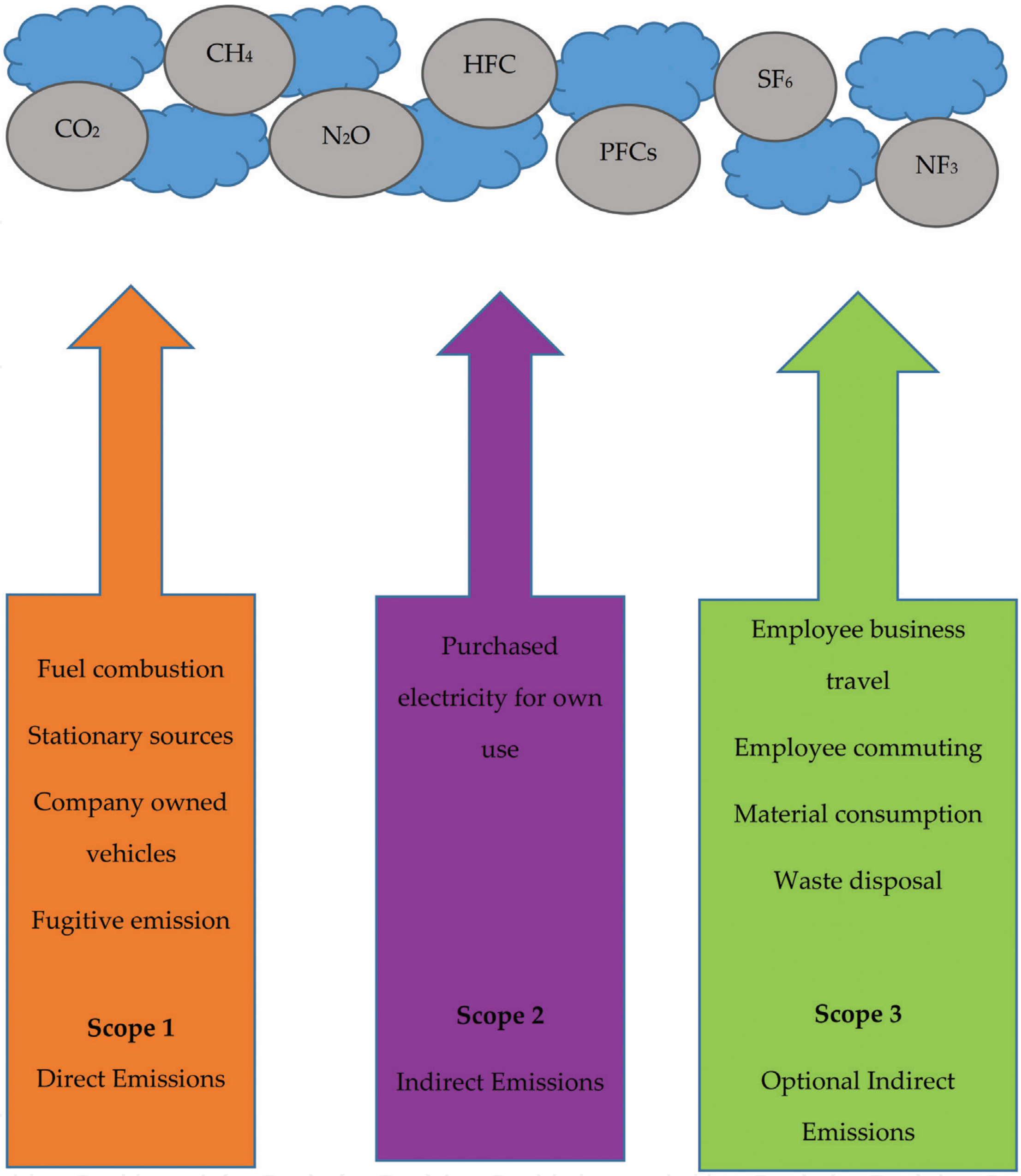

Figure 3. The carbon emission sources in three scopes.

GHG inventories reporting now include all direct and indirect emissions for all activities in the upstream supply chain as well as those emissions resulting from the consumption and disposal of an entity's products. This broadened view highlights the necessity for a consumption-based approach [10]. Consequently, the quantification of scope 3 emissions is a demanding task since a number of sectors have to be analyzed in order to capture changes in the consumption patterns. Downstream purchasing entities often lack access to the detailed information pertaining to the manufacturing of each product they purchase. Further, they lack the resources, and in some cases, the technical capacity to investigate the supply chain for each product. Consequently, the estimation of scope 3 emissions makes use of streamlined methods [11].

The GHG emissions emitted from direct and indirect sources by an entity can be categorized into different scopes:

Scope 1 accounts for direct emissions of GHG emitted from sources, such as fossil fuels burned on site, emissions from entity-leased or entity-owned vehicles, and other direct sources, which are controlled or owned by the entity.

Scope 2 accounts for indirect emissions of GHG emitted from source, such as the electricity generation, the transmission and distribution (T&D) losses associated with some purchased utilities (e.g., chilled water, steam, and high temperature hot water), and heating and cooling, or steam, which are generated off site but purchased by the entity.

Scope 3 accounts for emissions of GHG emitted indirectly from sources, such as T&D losses associated with purchased electricity, employee travel and commuting, contracted solid waste disposal, and contracted wastewater treatment, which are not controlled or

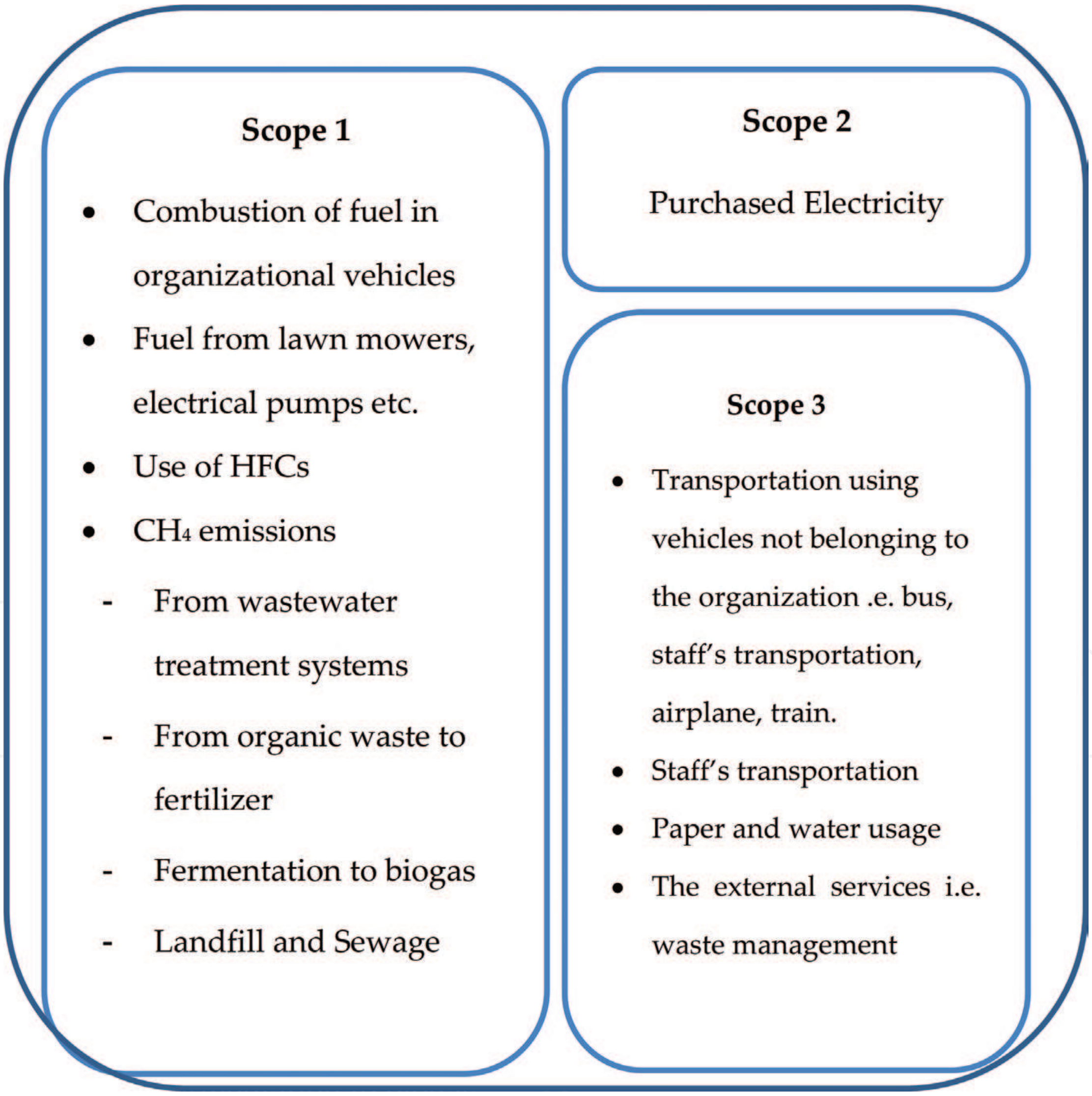

Figure 4. The scope of carbon emission sources in local organization [12].

owned by the entity but associated to the entity's activities. Those GHG emission sources are currently required for federal GHG reporting. Additional sources, such as GHG emissions from leased space, outsourced activities, vendor supply chains, and site remediation activities, are presently optional under federal reporting requirements, but they are substantial.

TGO defined the framework for carbon footprint for organizations in terms of three scopes as illustrated in **Figure 4** [12].

2.4. Step for GHG accounting and reporting

In order to measure the GHG emission and mitigation, the procedure for GHG calculation and reporting is illustrated in **Figure 5** [13].

2.5. Background of Kho-hong municipality

In general, Kho-hong municipality is located on the east of Hatyai municipality as illustrated in **Figure 6**. It is 2.5 km away from Hatyai district office and 30 km away from Songkhla province. The distance from Bangkok is about 1125 km.

The information of Kho-hong municipality could be described as follows:

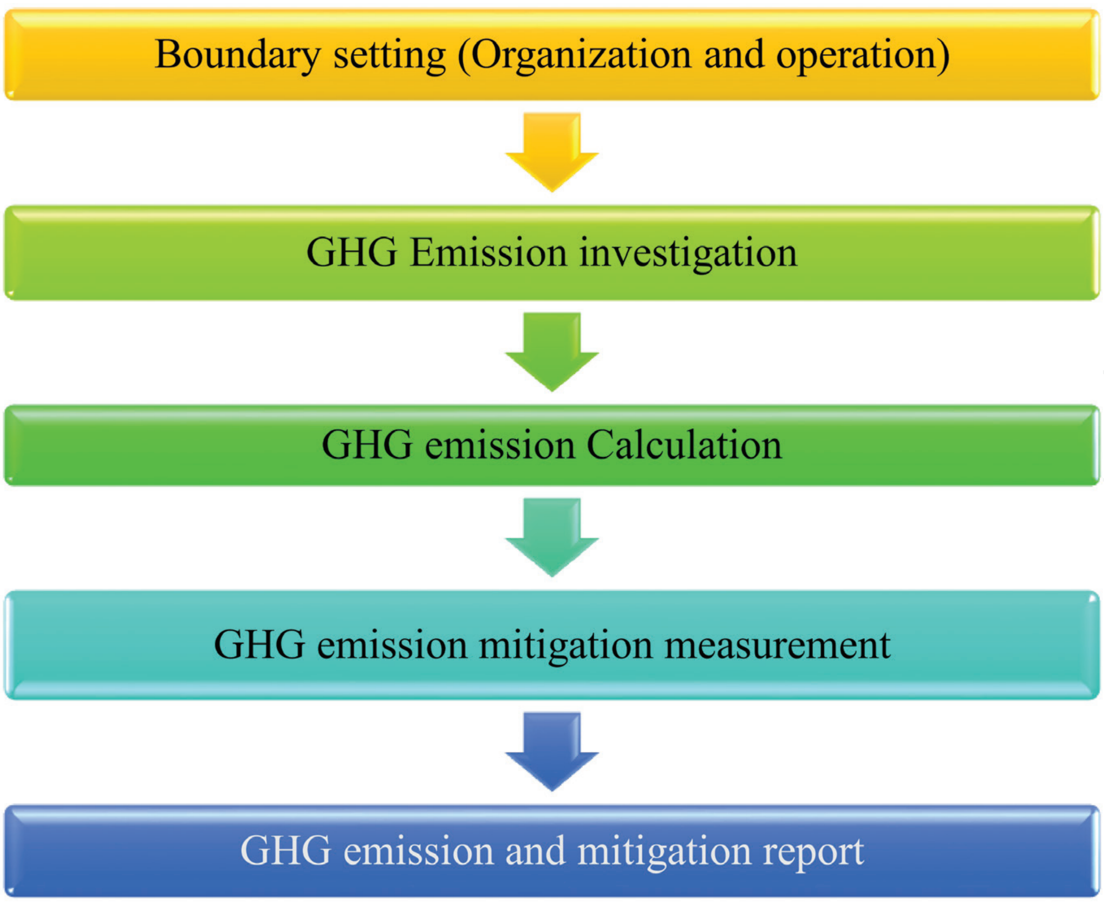

Figure 5. Steps for GHG accounting and reporting (modified from [13]).

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2.5.1. Boundary

Kho-hong municipality territorial areas are as follows:

- In the north, the municipality borders with the Klong-hae municipality and Nam-noi sub-district.
- In the south, it borders with the Ban-pru municipality and Ban-rai sub-district.
- In the east, it borders with the Sub-district Administration Organization (hereafter SAO) of Thung-yai and Na mom and.
- On the western side, the municipality borders with Hat-yai and Kuan-lung municipalities.

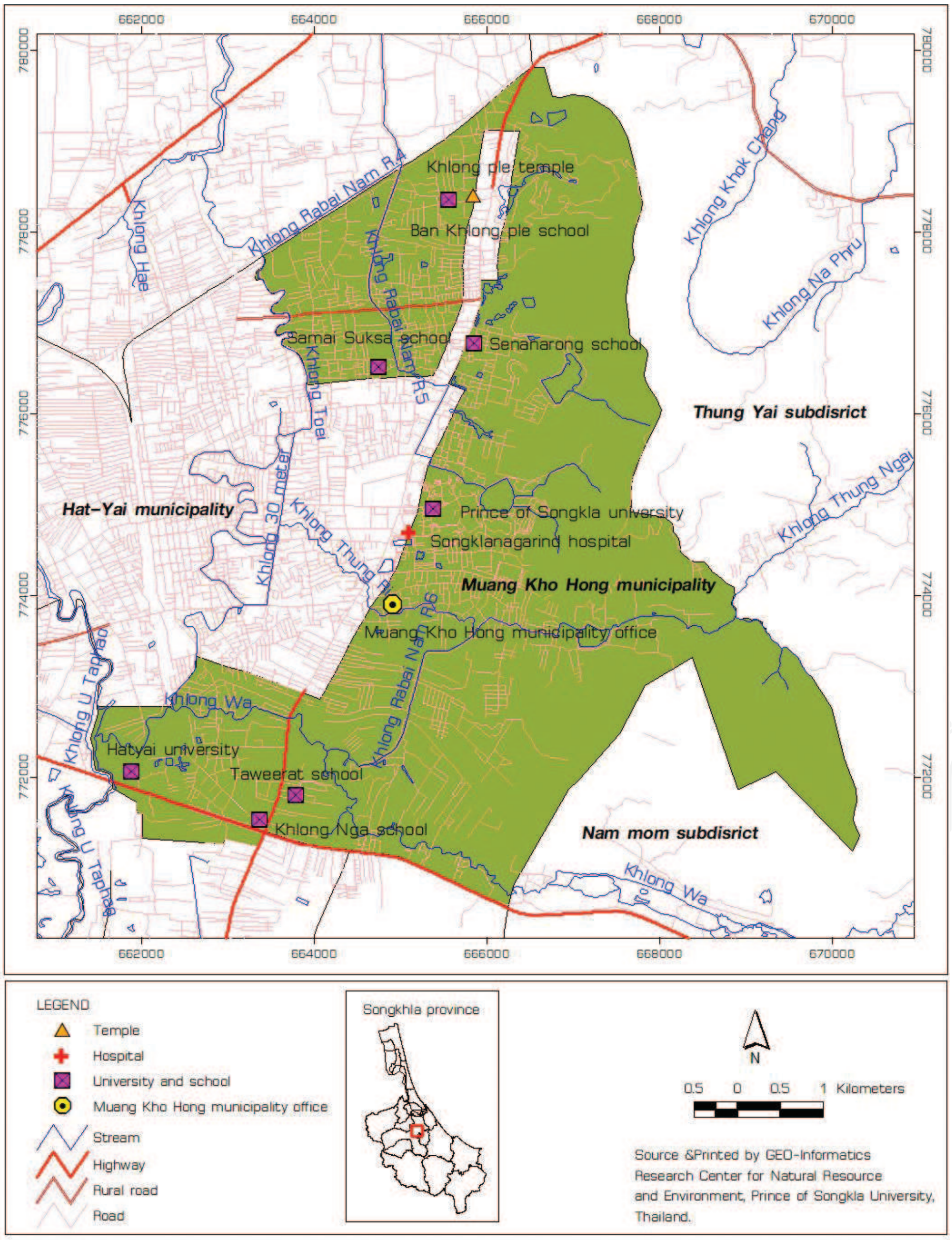

Figure 6. Map of Kho-hong municipality [4].

2.5.2. Population

The current population of Kho-hong municipality is about 45,939 persons which are 22,283 males and 23,656 females (February 2018) [14]. The total household in the municipality is 27,739 households, divided into 30 groups [4].

2.5.3. Geography

The area of Kho-hong municipality is approximately 34.57 km^2 or 8,542.43 acres (**Figure 6**). The area is generally a flat area near Kho-hong hill slope down to the Au-tapao Canal which is the border line of the Kuan-lang and Kho-hong districts. The predominant soil texture is sandy soil and sandy loam, with isolated portions of clay soil [4].

2.5.4. Community settlements

The municipality is located in the area between the floodplain and highland areas in the eastern part of the district. According to data gathered from the Prince of Songkla University (PSU) also located in Kho-hong municipality, the community was not established many years ago, when compared to other municipalities in the Southern provinces of Thailand. The community type is also educational and residential zone. A much older community is located in the northern end of Kho-hong municipality. This area supported the expansion of the city's residential area. However, frequent floods affected the progression of settlements in the municipality.

2.5.5. Climate data

Kho-hong municipality is located in the tropical monsoon zone: the southwest and the northeast monsoon. The northeast monsoon blows from October to mid-January and the southwest

Figure 7. Kho-hong municipality office.

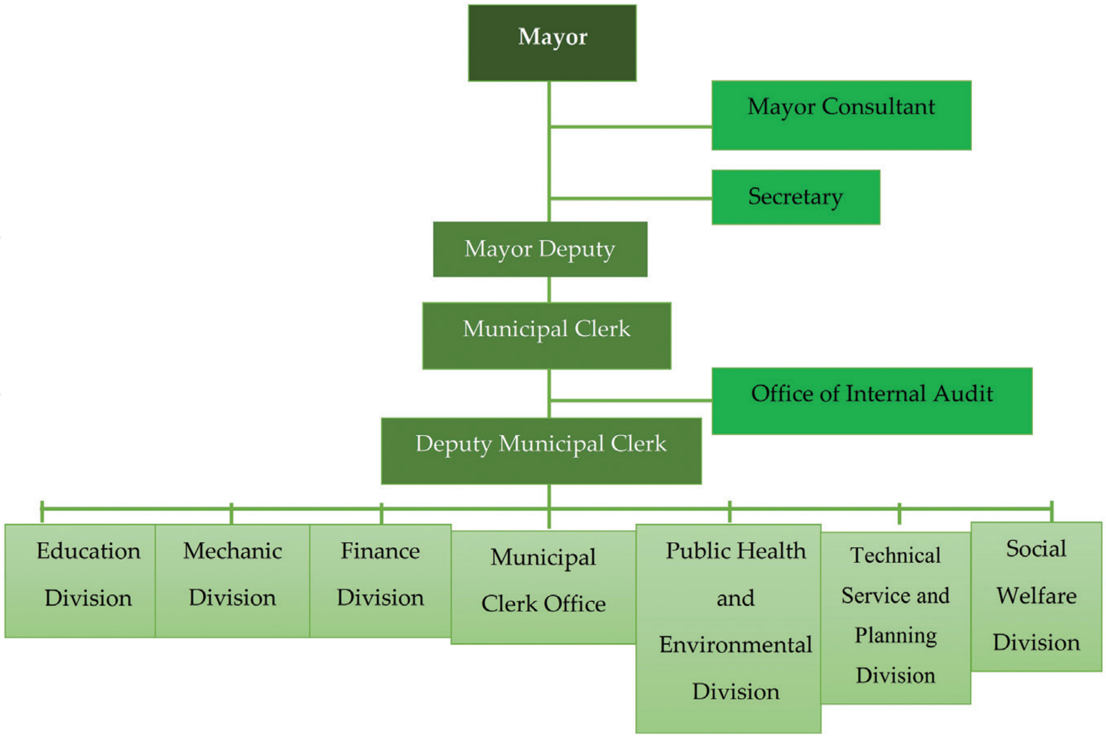

Figure 8. Organization chart for Kho-hong municipality **[5].**

monsoon blows from mid-May to mid-October. Due to the monsoon influence, there are only two seasons: summer which spans from February to July and the rainy season which spans from August to January. The annual rainfall is approximately 1995 mm. The average temperature is 28.1°C. In summer and rainy seasons, the average temperature is about 27.7–29.1°C and the average temperature reduces to 26.7°C in December [15]. The lowest temperature on record was measured at 13.7 on February 4, 2014, at Kho-hong air quality monitoring center. The average minimum and maximum temperatures are 24.8 and 40.3°C, respectively. The relative humidity is 77% [16].

2.5.6. Organization information

Kho-hong municipality office (**Figure 7**) comprises seven divisions based on its function including education service, mechanic, finance, municipal clerk office, public health and environment, technical service and planning, and social welfare. Each division is responsible for municipal council management. According to this classification, **Figure 8** illustrates the organization profiles of Kho-hong municipality which has a service schedule from 8.30 am to 4.30 pm in a full operation mode on weekdays (Monday to Friday). The office closes during weekends and public holidays. The full working time is therefore 8 h a day excluding lunch time break.

3. Materials and methodology

To evaluate CFO, Kho-hong municipality has a committee in order to collect and provide data and relevant information in February 2017. The first step to run the project began with in-house training for staff by consultant from the Faculty of Environmental Management, Prince of Songkla University, Hatyai, Songkhla, Thailand.

3.1. Scope and boundary

Scope and boundary of collecting data were clarified in terms of the following:

3.1.1. Organization boundary

Control approach in terms of operational control which account for the activities owned and run by municipality.

3.1.2. Base year

Single base year approach in fiscal year 2016 started from October 2015 to September 2016.

3.1.3. Geographical operations: Activities

Prior to set the operational boundary, the organization context was defined in terms of

1. layout
2. organization structure
3. the area and amount of staff
4. organization type: management function of Kho-hong municipality.

3.1.4. Operational boundary

In order to obtain an effective data collection, a clear determination of emission sources was necessary. Based on TGO greenhouse gas reporting and literature review, the operational boundary can be classified into three scopes as follows:

Scope 1: All direct GHG emissions, with the exception of direct CO_2 emissions from biogenic sources.

1. GHG emissions from stationary combustion units
    - **1.1.** Electricity production for organization use
    - **1.2.** Fossil fuel combustion from stationary machines which are controlled or owned by organization
2. GHG emissions from mobile combustion
3. Fugitive GHG emissions.

Scope 2: Indirect GHG emissions associated with the consumption of purchased or acquired electricity, heating, cooling, or steam.

Scope 3: All other indirect emissions which are not covered in scope 2 including upstream and downstream emissions, emissions resulting from the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting organization, use of sold products and services, outsourced activities, recycling or used products, waste disposal, and so on [9].

3.1.5. GHG from operational activities

The research is carried out to measure GHG emission from the operation control of Kho-hong municipality for the purposes of consolidating and reporting GHG emissions.

In this study, seven GHGs, which are the target for the first commitment period of the Kyoto Protocol, are included namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFCS), perfluorocarbon (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) were investigated.

With the TGO's guidelines, all of human activities are taken into account to GHG emission. So the assumption and estimation of the GHG were analyzed baseline annual calculation on Kho-hong municipality in fiscal year 2016.

3.1.6. Facilities for consideration in GHG emissions calculation

- The facilities include seven divisions of municipality function namely education service, mechanic, finance, municipal clerk office, public health and environment, technical service and planning, and social welfare.
- Excluded facilities:

  1) The outsource performance related to municipality operation and staff own vehicle.

  2) Dry chemical in extinguisher according to its application was not regarded as an impact on GHG emission.

The activity data and source of GHG emission were provided for evaluating carbon performance as presented in **Table 2**.

3.2. Data collection

In order to achieve data evaluation, data collection and report are requisite to confirm that the process is following principle guidelines of the GHG protocol by TGO, which provided a guideline GHG protocol corporate concept and the GHG emissions report. Data flow (**Figure 9**) was analyzed and evaluation criteria were established before primary data were collected by means of measurement, evaluation, and interview. Secondary data could be reached from calculation, statistical data, exploration, literature review, and so on.

3.3. Data calculation

To achieve the first objective, "Identify and quantify carbon mitigation possibility," all data collected from scopes 1–3 were calculated by Eq. (1). An example of these data and the subsequent carbon footprint calculations has been provided in Appendix A

Scope	Activity
Scope 1	1.1 Stationary combustion
	1.1.1 Gasoline combustion from stationary machine i.e. mower
	1.1.2 Diesel combustion from foggy machine and power supply
	1.2 Mobile combustion
	1.2.1 Gasoline combustion from organization's vehicles
	1.2.2 Diesel combustion from organization's vehicles
	1.3 Septic tank
	1.4 Wastewater
	1.5 Waste recovery - Compost
Scope 2	Electricity consumption
Scope 3	3.1 Paper consumption (A4 and A3)
	3.2 Water consumption
	3.3 Solid waste management

Table 2. Activities data.

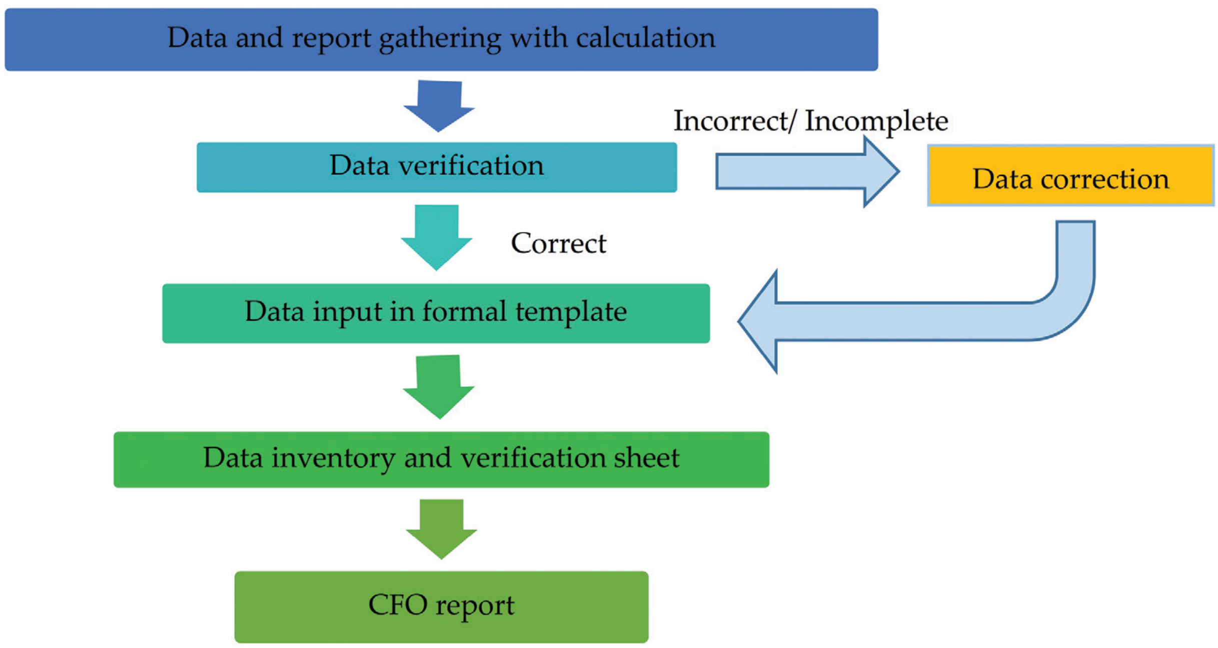

Figure 9. Data flow for carbon footprint evaluation.

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$$CO_2\ Emission = Activity\ Data\ x\ Emission\ Factor \quad (1)$$

3.3.1. Activities data

Activity data and source of GHG emissions were gathered from each division and summarized following the scope as summarized in **Table 3**.

Resource	GHG	Pollution Source	Emission Factor (kg GHG/unit)	Emission Factor Source
Scope 1				
Stationary combustion	CO_2	Gasoline Combustion	2.1816	IPCC Vol. 2 table 2.2 DEDE
	CH_4		0.0001	
	N_2O		0.0000	
Mobile combustion	CO_2	Gasoline Combustion	2.1816	IPCC Vol.2 table 3.2.1, 3.2.2, DEDE
	CH_4		0.0010	
	N_2O		0.0001	
	CO_2	Diesel Combustion	2.6987	IPCC Vol.2 table 3.2.1, 3.2.2, DEDE
	CH_4		0.0001	
	N_2O		0.0001	
Septic tank	CH_4	Wastewater from septic tank	25.00	IPCC 4th Assessment Report, Climate Change 2007
Wastewater w/o treatment	CH_4	Domestic wastewater	25.00	IPCC 4th Assessment Report, Climate Change 2007
Compost	CH_4	Compost waste	25.00	IPCC 4th Assessment Report, Climate Change 2007
R-22 refrigerant	CO_2	Fugitive emission from refrigerant R-22	1,810	R-22 (HCFC-22), World Meteorological Org, 2006, Carbon Footprint for Organization (TGO, 2017)
Scope 2				
Electricity	GHG	Electricity appliances	0.5821	Thailand Grid Mix Electricity LCI Database 2014, Carbon Footprint for Organization (TGO, 2017)
Scope 3				
Paper consumption	GHG	Working documents, meeting documents	2.0859	Thai National LCI Database/MTEC, Carbon Footprint for Product (TGO, 2016)
Water consumption	GHG	Faucets, sanitary wares	0.7043	Thai National LCI Database/MTEC, Carbon Footprint for Product (TGO, 2016)
Sanitary landfill	CH_4	Anaerobic Digestion from Sanitary Landfill	25.00	IPCC 4th Assessment Report, Climate Change 2007

Table 3. Emission source and emission factor.

Figure 10. Verification process in Kho-hong municipality office.

3.3.2. Emission factors

The emission factors were chosen from reliable data sources, that is, IPCC, Thai LCI Database, DEDE, and TGO as presented in **Table 3**.

3.4. Data verification

After the inventory data were compiled by municipality, the verification process began. The collected and analyzed data were verified by a consultancy team from Thaksin University in terms of collection method, data acquisition and accessibility, data correctness, including emission factors and calculations. The meeting was hosted by Kho-hong municipality (**Figure 10**).

4. Results and discussion

The GHG emission sources were summarized by scope. The primary data of each emission source were obtained for calculation in different conversion units. The GHG emission sources were presented for each division document and evidence as presented in **Table 4**. GHG emissions were calculated in terms of ton CO_2 eq. Total direct GHG emissions from stationary and mobile combustion including fugitive emissions were calculated to be 1129.92 ton CO_2 eq. The diesel combustion from mobile source occupies the biggest portion of scope 1 emissions of about 746.92 ton CO_2 eq/year. Meanwhile, CH_4 emissions generated from waste in sanitary landfill was the major source of alternative indirect emission for scope 3 equal to 15,524 ton CO_2 eq./year or 91.75% of total emissions with regard to municipality responsible for Kho-hong waste management. The least proportion emission was from consumed electricity for the municipality (255.24 ton CO_2 eq./year). Therefore,

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Emission Source	Division	Data Source	Unit	Amount
Scope 1				
Gasoline combustion	Mechanic	Petroleum receipt	L	15,672.63
	Finance			18.00
	Public Health and Environment			6,914.56
Diesel Combustion	Mechanic	Petroleum receipt	L	150,186.67
	Finance			1,090.00
	Technical Service and Planning			2,371.00
	Social Welfare			1,730.00
	Education			1,480.00
	Clerk office			20,275.36
	Public Health and Environment			95,007.62
CH_4 from septic tank		C	kg CH_4	1,324.22
CH_4 from wastewater without treatment		C	kg CH_4	18.13
CH_4 from waste compost		R	kg CH_4	49,309.50
Fugitive refrigerant R-22		R	Kg CO_2	160.00
Scope 2				
Electricity consumption	Technical Service and Planning	Electricity bill from Provincial Electricity Authority of Thailand	kWh	121.00
	Social Welfare			15,459.00
	Education			51,696.38
	Clerk office			348,744.04
	Public Health and Environment			18,202.00
	Mechanic			4,262.00
Scope 3				
Paper use		Annual record	kg	2,227.86
Water consumption	Social Welfare	Water payment bill	m^3	1,653.00
	Education			3,137.00
	Clerk office			3,671.00
	Mechanic			752.00
CH_4 from sanitary landfill		C	kg CH_4	620,960

Remark: C = Calculation, R = Record

Table 4. Summary of carbon emissions for Kho-hong municipality under three scopes.

total emissions from Kho-hong municipality operations were evaluated to be 16,920.29 ton CO_2 eq. The carbon footprints under scopes 1, 2, and 3 are 6.67, 1.51, and 91.81% of the total emission, respectively, as presented in **Table 5**. In comparison, scope 3 revealed the highest carbon footprint in this study. Correspondingly, it was found that 75% of an industry sector's carbon footprint is attributed to scope 3 emissions [17]. The emissions for scope 3 increased due to the increasing population and complex nature of activities performed by different kinds of organizations and the varying scales in which they function [18]. Although scope 3 emissions represent the largest proportion of the organizational carbon footprint, they represent the priority in carbon balance strategies [19].

In order to reduce GHGs emission, several strategies were proposed. 3Rs (Reduce, Reuse, and Recycle) are approaches which would effectively reduce waste at source and transfer stations. Waste to energy is another alternative to waste recovery prior to disposal in landfill. However, the cooperation and participation of municipal staff impacts negatively on GHG mitigation efforts through electricity consumption reduction including energy savings through responsible

Description	Unit	Amount	Emission Factor (kg GHG/unit)	CO_2 Emission (ton CO_2 eq.)	%
Scope 1					
- Gasoline (Stationary)	L	1,666.20	2.1896	3.65	0.02
- Gasoline (Mobile)	L	20,938.99	2.2376	46.85	0.28
- Diesel (Mobile)	L	272,140.65	2.7446	746.92	4.41
- CH_4 from septic tank	kg CH_4	1,324.22	25	33.11	0.20
- Wastewater w/o Treat	kg CH_4	18.13	25	0.45	0.00
- Compost	kg CH_4	49,309.50	25	9.34	0.05
- R-22 refrigerant*	kg CO_2	160	1,810	289.60	1.71
Total				**1,129.92**	**6.67**
Scope 2					
- Electricity	kWh	438,484.92	0.5821	255.24	1.51
Scope 3					
- Paper	kg	2,227.86	2.0859	4.64	0.03
- Water consumption	m^3	9,213.00	0.7043	6.49	0.04
- Sanitary landfill	kg CH_4	620,960.00	25.00	15,524.00	91.75
Total				**15,535.13**	**91.81**
Total				**16,920.29**	**100**

Remark: w/o = Without, IPCC, DEDE – Department of Alternative Energy Development and Efficiency, Ministry of Energy, Thailand, R-22 refrigerant is not included in Kyoto Protocol

Table 5. Carbon footprint evaluation from Kho-hong municipality in 2016.

vehicle usage. Incentives for GHG emission mitigation would be optional for increasing motivation for carbon footprint balance [20]. The three most influential constraints to collect data and GHG emissions reduction from upstream and downstream of the organizational activities would be identified in terms of time, cost, and data accessibility. Many organizations have a poor understanding of GHG emissions directly and indirectly associated with their activities. Consequently, this limited reduction for GHGs mitigation in the local municipality is a subject requiring further exploration. The carbon footprint should also be continually evaluated to monitor the GHG reduction and energy conservation measures [21]. The convergent approaches are practically involved in global warming mitigation thoroughly as well.

5. Conclusion

A general methodology, which provides a practical, reliable, and transparent inventory for practitioners in assessing the carbon footprint for local organizations, was followed. The total carbon footprint for Kho-hong municipality is 16,920.29 ton CO_2eq/year. Carbon footprints under scopes 1, 2, and 3 are 1129.92, 255.24, and 15,535.13 ton CO_2eq/year, respectively. The highest carbon footprint was represented by waste to sanitary landfill (15,524 ton CO_2eq/year) while the highest emission from activities in municipality was due to diesel combustion from municipality-owned vehicles (746.92 ton CO_2eq/year) followed by fugitive emissions from refrigerant (289.60 ton CO_2eq/year), and third emissions were electricity consumption (255.24 ton CO_2 eq/year). The lowest emissions were due to emissions from wastewater without treatment (0.45 ton CO_2 eq/year). Though indirect emissions (scope 3) represent the largest proportion of the organization's carbon footprint, these are seldom the priority in carbon management policies in municipalities. In order to reduce GHGs emission, several strategies were proposed. 3Rs (Reduce, Reuse, and Recycle) are adaptive approaches which would effectively reduce waste at source and transfer stations. Waste to energy is another alternative to waste recovery prior to disposal in landfill. However, the cooperation and participation of municipal staff impacts negatively on GHG mitigation efforts through electricity consumption reduction including energy savings through responsible vehicle usage. Incentives for GHG emission mitigation would be optional for increasing motivation for carbon footprint balance. The carbon mitigation with cost reduction should not only be one's task responsibility but public participation is also required to provide sustainable workplace [22]. Convergent approaches would be a good alternative for GHGs mitigation for local organizations. However, limitations in time, cost, and human behavior (negatively impacting on public cooperation) were some of the most important barriers identified.

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Appendix.A. Example of scope 2 carbon emission from electricity consumption

Division	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	**Total (kWh)**
TSP	0.00	0.00	12.00	13.00	11.00	12.00	12.00	12.00	3.00	13.00	20.00	13.00	121.00
SW	1,969.00	2,052.00	2,334.00	2,483.00	2,118.00	2,581.00	1,308.00	240.00	17.00	28.00	47.00	282.00	15,459.00
Education	2,490.70	4,442.80	4,591.80	4,780.20	4,103.90	5,347.80	2,731.00	4,393.90	2,653.80	4,910.60	5,499.70	5,750.18	51,696.38
Clerk Office	26,049.68	27,119.08	26,904.08	25,900.84	24,281.32	31,626.36	28,570.84	29,183.52	30,021.04	29,485.32	36,292.24	33,309.72	348,744.04
PHE	1,191.00	1,494.00	1,516.00	1,459.00	1,271.00	1,424.00	1,452.00	1,720.00	1,554.00	1,685.00	1,729.00	1,707.00	18,202.00
Mechanic	40.00	55.00	261.00	299.00	319.00	459.00	266.00	845.00	337.00	460.00	921.00	0.00	4,262.00
Total	**31,740.38**	**35,162.88**	**35,618.88**	**34,935.04**	**32,104.22**	**41,450.16**	**34,339.84**	**36,394.42**	**34,585.84**	**36,581.92**	**44,508.94**	**41,061.90**	**438,484.42**

Remark: TSP = Technical Service and Planning Division, PHE = Public Health and Environment Division

Calculation steps

$$GHG\ emissions\ electricity(kg\ CO\ 2\ eq.yr\ -1)\ =\ E\ x\ EF\ e \tag{A1}$$

where E = Electricity consumption (kWh/year).

EFe = CO_2 emission factor for electricity consumption which, is 0.5821 kg CO_2/kWh (Thailand Grid Mix Electricity LCI Database 2014_Update 1 Jan 2017, **Table 3**).

From the data above, the total electricity consumption = 438,484.42 kWh

$GHG\ emissions_{electricity}$ = 438,484.42 × 0.582

= 255,241.78 kg CO_2 eq/year

= 255.24 ton CO_2 eq/year

Table A1. Electricity consumption of Kho-hong municipality in 2016 [4].

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