CARBON FOOTPRINT OF MAHIDOL WITTAYANUSORN SCHOOL PUBLIC ORGANIZATION NAKORN PATHOM PROVINCE

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ABSTRACT

This study aimed to evaluate the emissions of greenhouse gases (GHGs), in terms of carbon dioxide equivalent (CO_2e), from the use of resources and the production of waste at Mahidol Wittayanusorn School Public Organization, Nakorn Pathom Province. The selected school is a medium-sized boarding school with 715 students and 168 school staff. The primary and secondary data were collected in 2011 in accordance with the guidelines on carbon footprint assessment issued by the Organization of Thailand Greenhouse Gas Management Organization Public Organization.

The results show that GHG emissions of the school were totally equal to 1,277.59 tonCO_2e and the average GHG emission per person was equal to 1.44 tonCO_2e/person/year. The GHG source that emitted most GHGs was electricity consumption which accounted for 81.63 percent of the total emission, followed by the GHG emissions of solid waste from the school which accounted for 16.39 percent. The activity emitting least GHGs was tap water use, with the proportion at 0.16 percent.

From statistical analysis, as the significance level was set at 0.05, it was found that both the season and the time of study were NOT significant factors that affected the volume of GHG emissions from activities of fuel consumption, tap water use, paper use and quantity and quality of wastewater at the school in 2011.

The findings of the study of GHG emissions can be used for proposing energy saving measures to reduce GHG emissions. Additionally, it can be used for setting up a plan of improving data collection and storage system of GHG emissions for the evaluation in the following years.

KEY WORDS: CARBON FOOTPRINT / ORGANIZATION CARBON FOOTPRINT / SCHOOL CARBON FOOTPRINT

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คาร์บอนฟุตพริ้นท์ของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน จังหวัดนครปฐม
CARBON FOOTPRINT OF MAHIDOL WITTAYANUSORN SCHOOL PUBLIC ORGANIZATION NAKORN PATHOM PROVINCE

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บทคัดย่อ

การศึกษาครั้งนี้เป็นการศึกษาปริมาณการปลดปล่อยก๊าซเรือนกระจกที่เกิดขึ้นจากการใช้ทรัพยากรและของเสียที่เกิดขึ้นของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน จังหวัดนครปฐม ซึ่งเป็นโรงเรียนประจำขนาดกลาง และเป็นโรงเรียนวิทยาศาสตร์ต้นแบบของประเทศ มีจำนวนนักเรียน715 คน และบุคลากร 168คน ทำการเก็บรวบรวมข้อมูลปฐมภูมิและทุติยภูมิปี พศ. 2554 ตามแนวทางการประเมินคาร์บอนฟุตพริ้นท์องค์กรขององค์การบริหารจัดการก๊าซเรือนกระจก ประเทศไทย

จากการศึกษาพบว่าโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชนมีการปล่อยก๊าซเรือนกระจกเท่ากับ 1,277.59 tonCO_2e เฉลี่ยการปล่อยก๊าซเรือนกระจกต่อคนเท่ากับ 1.44 tonCO_2e/คน/ปี โดยที่การใช้ไฟฟ้าเป็นกิจกรรมที่ก่อให้เกิดก๊าซเรือนกระจกสูงสุดหรือคิดเป็นร้อยละ 81.63 รองลงมาคือปริมาณการปล่อยก๊าซเรือนกระจกที่เกิดขึ้นจากปริมาณขยะของโรงเรียน คิดเป็นร้อยละ 16.39 ส่วนกิจกรรมที่ปล่อยก๊าซเรือนกระจากน้อยที่สุดคือการใช้น้ำประปา หรือคิดเป็นร้อยละ0.16

ผลการศึกษาทางสถิติพบว่า ทั้งฤดูกาลและช่วงเวลาเรียน ไม่ได้เป็นปัจจัยส่งผลแตกต่างอย่างมีนัยสำคัญทางสถิติที่ระดับ0.05 ต่อปริมาณการปลดปล่อยก๊าซเรือนกระจกทั้งจากกิจกรรมการใช้เชื้อเพลิง การใช้ไฟฟ้า การใช้น้ำประปา การใช้กระดาษ และจากปริมาณและคุณภาพน้ำเสียที่เกิดขึ้นของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ. 2554

จากผลการประเมินปริมาณการปลดปล่อยก๊าซเรือนกระจกที่ได้สามารถนำมาใช้ในการเสนอแนะมาตรการประหยัดพลังงานเพื่อลดการปล่อยก๊าซเรือนกระจก และนำไปสู่การวางแผนปรับปรุงการจัดเก็บข้อมูลปริมาณการปล่อยก๊าซเรือนกระจกสำหรับการประเมินในปีต่อไป

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CHAPTER I
INTRODUCTION

1.1 Introduction

The present increase of population has led to increasing demand for products and services. Therefore, manufacturers and service providers have boosted their products and services to meet the demand, as well as fundamental needs and convenience of people. As of industrial sector, there is high competition in production, marketing and service. New technologies have been introduced to enhance their production and reduce costs, time and expenses that they would have to spend. As of agricultural sector, new technologies have been developed, such as agricultural machinery and innovation techniques for increasing agricultural products. Consequently, many processes and activities related to the above progression have emitted tremendous amount of Carbon Dioxide and other greenhouse gases (GHGs) which are the causes of Global Warming.

Other than the industrial sector and agricultural sector which are the major sources of GHGs, the people sector, which are the largest global consumers of products and services, is the most GHG emitting sector and causes most Global Warming, though individually the GHG emission per person is much less comparing to the emission rate of industrial sector. Nowadays, the Global Warming problem is one of the most interested issue for government, private and people sectors to be addressed. There are campaigns and activities for educating people and organizations about Global Warming mitigation. Moreover, some rules and regulations were set up for making people be responsible for their actions that emit GHGs to the environment.

Carbon Footprint is a tool for quantitative method of measuring the impact of products and services created by human on the environment. Global Warming Potential (GWP) is also used as an indicator. Additionally, Carbon Footprint is considered as a corporate social responsibility (CSR) performance of the business sectors. For these reasons, this study was commenced to research on Carbon Footprint by measuring amounts of greenhouse gases emitted in a specific area. Mahidol Wittayanusorn School Public Organization was selected as a location for this research. The Organization Carbon Footprint was also studied as it is one of several programs initiated for GHG emission reduction, leading to achieving Global Warming mitigation goal. It is expected that the findings of this research would encourage the students, the teachers, and other personnel of the school to realize their roles of mitigating the environmental impacts, especially in reducing greenhouse gas emission which would escalate climate change problem. Moreover, they would know the amounts of Carbon Dioxide released from school's activities, as well as from each person, so that they could improve the activities for lesser emission or offsetting the carbon emission.

Mahidol Wittayanusorn School Public Organization was a medium-sized secondary and boarding school with 715 students and 168 school staff (all of the students lived in school campus and most of the school staff also lived in residential buildings of the school). Therefore, the GHG emission from activities of the school could represent the GHG emission from people living in the school. This study aimed to evaluate the emissions of GHGs from the use of resources and the producing of waste at the school. The data of vehicle fuel consumption, electricity consumption, tap water used, paper used, cooking gas consumption, solid waste generated and wastewater generated were collected from all activities and services of the school, and used for calculating the Organization Carbon Footprint.

1.2 Objective

1.2.1 To measure the amount of greenhouse gases generation from the action of Mahidol Wittayanusorn school Public Organization, Nakorn Pathom Province.

1.2.2 To compare the amount of greenhouse gases generation from the school between different season and school sessions of the Mahidol Wittayanusorn school Public Organization, Nakorn Pathom Province.

1.2.3 To study greenhouse gas generation reduction by using resource consumption reduction measure of the Mahidol Wittayanusorn school Public Organization, Nakorn Pathom Province.

1.3 Scope of the study

1.3.1 Scope of area

This study is a survey research at Mahidol Wittayanusorn School Public Organization in Nakhon Pathom Province.

1.3.2 Scope of data

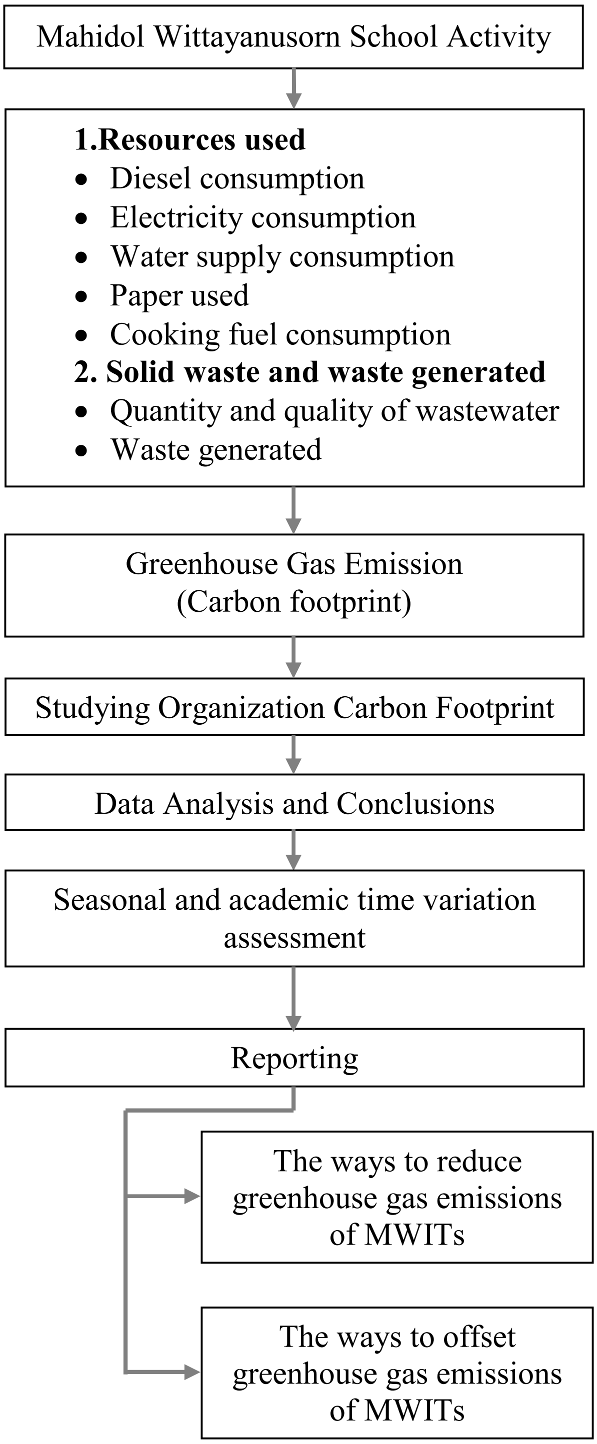
In the study, data from both direct and indirect emission sources of greenhouse gases were collected, as the following list:

1) Diesel fuel consumption
2) Electricity consumption
3) Water supply consumption
4) Paper used
5) Cooking fuel consumption
6) Quantity and quality of wastewater
7) Waste generated

1.3.3 Scope of time

The primary data and the secondary data of Diesel fuel consumption, Electricity consumption, water supply consumption, paper used, cooking fuel consumption, quantity and quality of wastewater and waste generated from January to December year 2011

1.4 Conceptual framework



1.5 Expected Benefits

1.4.1 The amount of carbon emissions from the activities of the Mahidol Wittayanusorn School Public Organization, Nakhon Pathom Province, would be obtained.

1.4.2 Significant level of Carbon Dioxide emitted from the Mahidol Wittayanusorn School Public Organization, Nakhon Pathom Province, could be estimated.

1.4.3 Some appropriate ways to reduce and offset carbon emissions from the activities of the Mahidol Wittayanusorn School Public Organization, Nakhon Pathom Province, would be suggested. Information from this study would be useful for determining the carbon footprint and doing research on related subjects.

1.6 Definition of terms

1.6.1 Carbon Footprint: Amount of greenhouse gas emissions of the product or service

1.6.2 Organization Carbon Footprint: The assessment of greenhouse gas emissions from all activities of the organization.

1.6.3 Carbon Dioxide Equivalent (CO2e): Show the ability of a mixture of greenhouse gas, equal to the ability of an amount of Carbon Dioxide, to cause global warming, which is calculated by multiplying the mass of the greenhouse gas by the global warming potential of the gas.

1.6.4 Greenhouse Gas (GHG): Gas components in the atmosphere created by both natural and anthropogenic activities. They can absorb and emit radiation at wavelengths in the frequency range of infrared radiation being emitted from the Earth's surface, clouds and the atmosphere.

1.6.5 Global Warming : is the rise in the average temperature of Earth's atmosphere and oceans.

1.6.6 Global Warming Potential (GWP): Greenhouse gas emissions or global warming potential, assessed by measuring or calculating the actual potential of each greenhouse gas and converting into a form of Carbon Dioxide equivalents, using the IPCC's values of global warming potential over the past 100 years (GWP100).

CHAPTER II
LITERATURE REVIEW

In this study, the concepts, theories and documents related to determination of carbon footprint of the Mahidol Wittayanusorn School Public Organization were studied in order to provide fundamental information and guidelines for other similar research. The information and database were categorized into the following issues:

2.1 Carbon Footprint
2.2 Greenhouse Gases and Climate change
2.3 Climate Change
2.4 United Nations Framework Convention on Climate Change: UNFCCC
2.5 Standard for calculating Greenhouse Gas emissions (ISO 14064)
2.6 Related Research

2.1 Carbon Footprint

2.1.1 Definition of Carbon Footprint

Carbon footprint means the amount of greenhouse gases (GHGs) emitted by organizations, products or services.

Carbon footprint for organization means the estimated GHGs emitted from all activities of an organization.

The carbon footprint is a measure of the exclusive total amount of carbon dioxide and other GHGs emitted by human activity or accumulated over the full life cycle of a product or service (Wiedmann and Minx, 2007).

A carbon footprint is a measurement of the impact human activities have on the environment in terms of GHG emissions generated by the activities, by measuring emitted carbon dioxide. The carbon footprint is for estimating that how much impact on global warming a country, a person or an organization may cause. The estimation depend mainly on an assessment of a quantity of carbon released into the environment, and how much an organization promote renewable energy and clean energy, like wind power or solar energy, and reforestation. The carbon footprint is a subset of the ecological footprint, which includes all human demands on the biosphere (Wiedmann and Minx, 2007).

Carbon footprint for organization is the amount of GHGs emitted from each activity of the organization, such as fuel combustion, electricity consumption, waste treatment, transportation, etc., measured in terms of tons of carbon dioxide equivalent (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

Calculation of Carbon Footprint for Organization (CFO), or Corporate Carbon Footprint (CCF), is a means of identifying the amount of GHGs emitted from all activities of an organization. The data can be used for setting up an effective GHG mitigation plan at company or industry level and national level (Thailand Greenhouse Gas Management Organization Public Organization, 2011).

2.1.2 Measuring Carbon Footprint

Carbon Footprint, or measurement of the total amount of carbon dioxide (CO_2) and other GHGs emitted from a process, can be categorized into 2 types: measurement of direct emissions and of indirect emissions.

1) Measurement of direct emissions; for instances, emissions from fuel combustion, transportation, or electricity consumption in an organization or a household, etc.

2) Measurement of indirect emissions; for instance, emissions from products or services, such as using plastic bags or non-biodegradable food packages, etc.

Carbon footprint is a Global Warming Potential (GWP) indicator, quantitatively representing the impact of products or services from human activities on the environment (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

2.1.3 Calculating Carbon Footprint for Organization

There are several ways of calculating the emissions and removals of GHGs, such as creating a model, using mass balance equation, using correlation analysis of facility-specific data, multiplying collected activity data of an organization by emissions or removals factors and convert the results into units of tons or kilograms of carbon dioxide equivalent (CO_2e) in equation as follows:

$$\text{GHG Emissions} = \text{Activity Data} \times \text{Emissions Factor}$$

Equation 2-1 greenhouse gas emission calculate equation

If the primary data of GHG emission factors cannot be collected, it is acceptable to use the secondary data suitable with the activities or sub-processes that are not directly under the control of the organization, or to use the factors that have been presented by reliable sources. However, the latter alternatives would give less accurate result than the former one (Thailand Greenhouse Gas Management Organization Public Organization, 2011).

2.1.4 Level of preparation of the carbon footprint

2.1.4.1. Carbon Footprint of Product. The carbon footprint of product is the amount of GHGs emitted by a single unit of the product throughout its life cycle. The GHG emissions during the acquisition of raw materials, transportation, assembly, deployment and waste treatment are accumulated and calculated in units of carbon dioxide equivalent (CO_2e).

Carbon footprint labeling is a way for manufacturers to express their Corporate Social Responsibility (CSR). They show how much CO_2 their products release, which doesn't mean that those products are environmentally friendly.

2.1.4.2. Carbon Footprint for Organization: Organization Carbon footprint is the amount of GHGs emitted from each activity of the organization, such as fuel combustion, electricity consumption, waste treatment, transportation, etc., measured in terms of tons of carbon dioxide equivalent. It can be broken down into 3 scopes as follows:

Scope I: The calculation of direct emissions carbon footprint from sources that are owned or controlled by the reporting company, such as combustion of engine, use of company owned vehicle, use of chemical for water treatment, leak or spill of substance from a process, etc.

Scope II: The calculation of energy indirect emissions carbon footprint that are a consequence of the operations of the reporting company, such as the purchase of electricity, heat, steam, etc.

Scope III: The calculation of other indirect emission carbon footprint, such as business travel of employee by non-company owned vehicle, a trip to a seminar, use of tools and instruments, etc.

The amount of GHG emissions from activities of an organization, both directly and indirectly, such as fuel combustion, electricity consumption, waste treatment, transportation, etc., is shown in units of carbon dioxide equivalent (CO_2e). The related references are as follows:

- ISO 14064-1: 2006, Greenhouse Gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

- ISO/PDTR 14069: 2011, Greenhouse Gases - Quantification and reporting for GHG emissions for organizations - Guidance for the application of ISO 14064-1 GHG Protocol Corporate Accounting and Reporting Standard (The GHG Protocol), published in 2001, revised in 2004) (Thailand Greenhouse Gas Management Organization Public Organization, 2011).

2.1.5 Benefits of Carbon Footprint Optimization

2.1.5.1. Benefits to the manufacturer

- It is a way of tracking down carbon footprint of the product in each stage, which could help setting up strategies for reducing GHG emissions from the production cycle.

- Reducing GHG emissions could result in a reduction of production costs.

- It brings good image of social responsibility to manufacturers.

- It is a preparation of manufacturers for future requirement of some countries for carbon footprint labels on importing goods.

- It can be used for estimating how much carbon offsetting of products or services is required in order to balance the carbon cycle.

- It can be used for calculating the amount of carbon credits that could be earned if certain actions on the products are taken.

2.1.5.2. Benefit to the consumer

- Consumers can decide to buy products which are environmentally friendly.

- Consumers can directly help reducing global warming and GHGs.

2.1.5.3. Benefit to the society

- A green supply chain mechanism is established.

- There is more competition to improve the products among the manufacturers of the same product type, to release less GHGs (Athiwath Jirajariyawate, 2010).

2.2 Greenhouse Gases and Climate Change

"Greenhouse Gases" in the atmosphere are the barriers which block radiation within the thermal infrared range reflected from the Earth's surface. Therefore, the energy from the Earth's surface could penetrate the dense GHGs layer only by the wind current and cloud moving in the layer. The phenomenon of retaining heat in the atmosphere is called "Greenhouse Effect" as it is similar to the effect of solar radiation passing through glass and warming a greenhouse for growing plants in cold countries; however, the glass can reflect the radiation inside the greenhouse to keep the temperature inside higher than its surroundings (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

Climate Change can be defined as a change of climate system as a result of human activities, which directly and indirectly change the components of the Earth's atmosphere, in addition to the natural fluctuations of climate observed during the same period. The factors fluctuating include temperature, humidity, precipitation and season, which are important factors to the living of all lives that have to adapt to the changed climate (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

2.2.1 The impact of greenhouse gases and climate change

More than 60 percent of greenhouse gases caused by human activities are the increased carbon dioxide. In 1991, there was totally 26.4 million tons of carbon dioxide released. The change happened so rapidly. Scientists estimated that, 10,000 years before the industrial revolution begun, there was less than 10 percent change of the amount of carbon dioxide. The balance could be maintained by nature. However, during the last 200 years, the amount of carbon dioxide has changed by 30 percent higher. Although there is absorption of carbon dioxide by oceans and plants, the amount of carbon dioxide is still rising by at least 10 percent in every 20 years (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

From a study of Intergovernmental Panel Climate Change (IPCC), the amount of major greenhouse gases in the atmosphere, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) has rapidly increased during the last 200 years, since the industrial revolution in Europe. The amount of CO_2 has increased from 280 ppm in year 1800 to 360 ppm in year 2000. The amount of methane has also increased more than double since year 1800, from 750 ppb to 1,750 ppb in year 2000, while the N_2O concentration was tending to increase when there was the agricultural revolution; however, the increase rate of N_2O then was so low comparing to after the industrial revolution. The N_2O concentration has increased from 270 ppm around year 1800 to 310 ppm in year 2000 (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

Human activities have caused concentration of GHGs in the atmosphere to continually increase. It is anticipated that GHGs concentration will still continue to increase. For instance, CO_2 concentration was estimated to increase from current 300 ppm to 600 ppm, or as high as 900 ppm, within 100 years. As for methane, the concentration may increase from 1,750 ppb today to 3,500 ppb within year 2100 as shown in Figure 2-1

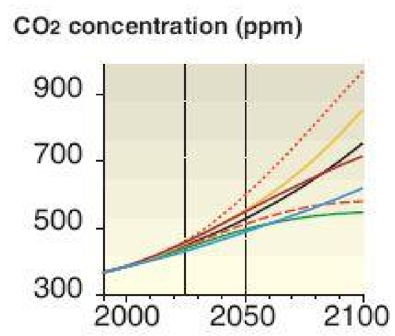


Figure 2-1 The graph shows the forecast of Climate Change.
Source : UNEP, Vital Climate Change Graphics, 2005 (referred by Thailand Greenhouse Gas Management Organization Public Organization, 2012)

Climate Change has become a topic to talk about more often today due to the abrupt change of weather condition recently. The scientists believe that the combustion of fossil fuel, a major source of energy for the industrial development during these last 200 years, is the main cause of rising concentration of greenhouse gases in the atmosphere, leading to greenhouse effect or global warming.

Global warming has great effect on how living creatures survive as rising in average temperature leads to fluctuation of seasons. As a result, the creatures which are not able to adapt to changing environment are going to die gradually and will be wiped out eventually. As to the impacts on human, the rising temperature may cause some regions to become desert. People would face shortage of food and potable water. In some areas, more possibility of heavy rainfall may cause inundation of flood water. The melting of icebergs at the poles and of snow at mountain summits would raise sea level. Coastal areas would be directly affected by global warming, causing some low areas to submerge forever (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

The increasing amount of GHGs will result in rebalancing of the Earth's climate system to maintain the long-term balance of Earth's energy budget; therefore, the Earth has to enhance the average albedo. As denser GHGs in Earth's atmosphere reduce the average albedo of the Earth, the climate system of the Earth has to adapt itself to the new circumstance in order to keep the balance between the incoming and outgoing energy of the Earth. This adaptation includes adaptation to global warming of Earth's surface and biosphere. Adding more heat is the easiest solution for the climate system to release the excess energy. However, very little temperature increase could even bring about consequent climatic changes, such as covering of clouds, direction of wind, etc. Some of these consequences could activate continuous effects and cause more temperature rise, while some of them could lower the temperature rise.

2.2.2 The environmental impact of greenhouse gases

For most scientists, the issues of Climate Change are not about whether it is an important problem, but are about how it is occurring, what are the impacts and what are the best ways to keep track of such impacts. Computer simulation models which can simulate the complexity of Earth's climate system still cannot give us clear answers to those questions. Although there are no certain answers to the when-where-how questions, the results obtained from all climate models show the matters to which human must pay great attention, such as the following:

- The rain condition in each region is predicted to change. The hydrologic cycle will be shorter, resulting in more frequent of rainfall. However, evaporation rate will be higher, which mean more arid land during harvest season. More new arid or dryer region, especially in poor countries, could lead to less amount of clean water for consumption which badly affects population health. Due to high uncertainty level of the regional model, the scientists still cannot assess the risk of water fluctuation at regional level. As for the global level, however, the population growth and the expansion of socio-economic activities have affected the quantity of clean water, certainly escalating the water resource crisis.
- Climate condition and agricultural areas may shift away from equator toward the poles if the temperature rises by 1-3 degrees (Celsius). More arid climate during dry season would reduce the production per area of crops in warm climate regions. Some agricultural areas, plains area in America for instance, would be more likely to be affected by arid climate. The warm agricultural zones would be shifted toward the poles by 150 – 550 km. The agricultural areas located between warm and cold latitude, in the North of Canada, Scandinavia, Russia and Japan, and in the South of Chile and Argentina may benefit from Climate Change.

- The melting of icebergs and the expansion of seawater may cause sea level rise which would threaten the coastal area. Within year 2100, higher global temperature may raise seawater level by 15-95 cm, or 50 cm for the best approximation. The highest risk areas are the unprotected areas and coastal areas of poor countries with dense population. For example, Bangladesh which has flood-prone coastal areas is likely to be affected. Small island nations, for instance, Maldives, are at high risk of the impact (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

2.2.3 The global impact of climate change

There is a little amount of Carbon dioxide and other gases, such as methane (CH_4) and nitrous oxide (N_2O), in the Earth's atmosphere. For their ability to absorb thermal energy, they are called greenhouse gases. When the amount of these gases is increasing, the Earth's atmosphere can absorb more thermal energy instead of radiating the energy back to the outer space. As a result, the Earth's energy balance changes, global atmospheric temperature rises and many consequences occurs, for example, seasons and precipitation changes, seawater level rises due to the melting of icebergs, seawater expands due to rising of temperature, higher frequency and severity of storms and disasters occurs, etc. as shown in Table 2-1

Table 2-1 Impacts predicted to occur due to global climate change

Projected Changes during the 21st century	Examples of projected impacts
• More hot days • More severe heat waves	• Increased incidence of serious illness • Increased heat stress in wildlife and livestock • Crops damage
• More intense weather events	• Flood and landslide • Soil erosion • Crops damage

Table 2-1 Impacts predicted to occur due to global climate change (cont.)

Projected Changes during the 21st century	**Examples of projected impacts**
• Increase in tropical cyclone intensities	• Increased risks to human life • Increased risk of infectious disease epidemics • Crops damage
• Intensified drought and flood	• Decreased agricultural productivity • Decreased hydro-power potential
• Increased Asian summer monsoon precipitation variability	• Increased flood and drought magnitude in temperate and tropical Asia

Source : IPCC, 2001, referred by Thailand Greenhouse Gas Management Organization Public Organization, 2012

These changes have effects on reproductions of living beings in the ecosystem, food production for human, public health, and economic and social development. Severity of the impacts of climate change in each country is different, depending on the geography and other enabling factors. Because climate condition could cause the changing of seasons and suitable environmental condition is a fundamental basis for preservation of the natural resources, Climate Change could extensively affect natural resources, bioresources and human ways of living (Organization of Thailand Greenhouse Gas Management Organization Public Organization, 2012).

2.2.4 The impact of Climate Change in Thailand

Thailand signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC) as a Non-Annex I country, which do not have legally binding emission reduction target for contributing to only 0.6 percent of global greenhouse gas emissions, relatively low compared to other countries. Additionally, the per capita emission of greenhouse gases of Thailand is lower than the global average. It is nice to have low emission rate; however, the impacts Thailand is facing are not as low as the emission rate since Climate Change has global impacts. The severity of the impacts in Thailand is determined by the environment and geography of the region. Events occurred in Thailand as a result of Climate Change are as follows:

• **Major Floods:** The exposure to major floods has increased by many folds, from once in 100 years to 3-6 times in 100 years. Southeast Asia region has a tendency to have more melting of icebergs in the poles, leading to rising of water level in rivers and of the sea level.

During the last 30 years, Thailand has got flood problems so often, mostly in the towns located in flood-prone areas, especially in eastern coastal areas and southern of Thailand which connect to an ocean. There are also flood problems in big cities like Bangkok, Hat Yai and Chiang Mai, especially during rainy seasons, as the amount of rainfall is higher than the retention capacity and the drainage systems are inefficient. Flooding has brought huge damages to lives and property. The flood streams destroyed crops and infrastructures like roads and buildings, washed away fertile topsoil, caused contamination in water resources, and take away many lives. Moreover, stagnant water in some areas led to spread of diseases in humans, plants and animals. There was also growing number of pests in agricultural areas. Some lost their lands and had to migrate in order to survive. In consequence, local and national production declined, people's emotional stresses increased and criminal rate escalated.

• **Sea Level Rise:** Climate Change caused rising of seawater level by 0.09 – 0.88 m, influencing ocean waves and coastal erosion, threatening the coastal ecosystem which is an important source of bio-natural resources and a workplace for coastal communities. Additionally, tourism which is crucial for the locals and economy of the country was also affected. The current rising sea level caused shorelines and mangrove forests to be flooded. Although, these shorelines can shift into inland sites if they are flooded, manmade structures have blocked this natural mechanism. As a result, the shorelines keep being flooded and eroded until the ecosystem there is ruined. The areas that need attention and protection include the mangrove forests in Samut Songkhram, Petchaburi, Surat Thani, Nakhon Si Thammarat, Ranong, Phang Nga, Phuket, Chanthaburi and Trat. Sea level rising can result in intrusion of seawater into land, causing problem of salty underground water to the communities that depend on it like some in Bangkok and Samut Prakan. Furthermore, pumping up underground water in Bangkok has led to relative sea level rise, of which the rate is increasing each year.

• **Temperature Rise:** Climate Change caused rising of average and maximum temperature in each area. As a result, there are more hot days, more extreme heat waves, and more natural disasters, such as storm and heavy flood, having an effect on human health. Moreover, climate change is a reinforcing factor causing severe urban heat island in the areas with conditions suitable for trapping of heat. The urban heat island is a phenomenon of urban environment having higher temperature than the outside environment, for all seasons and period of time; it can happen in both big and small cities. This phenomenon has been known for more than a century. It is estimated that the number of affected population of the phenomenon would reach as many as half of the number of total population on Earth within the late of this century. Rise of temperature caused higher demand for energy and electricity in cooling system, leading to increasing of electricity generation and water shortage for generating the electricity during dry season.

• **Drought Event:** As Thailand is an agricultural country, water resource is one of the most crucial factors for country development. The top problems related to water resources in Thailand are water shortage and drought, which happen mostly in summer and dry season due to lack of rainfall for long period of time, leading to drying up of natural water storage and running out of water supply for consumption. Lack of rainfall also results from the consequences of global warming.

The total amount of fresh water on Earth was decreasing at an average rate of 21-31 percent each year. It was the consequence of higher concentration of GHGs in the atmosphere which caused more solar radiation to be trapped on Earth, increasing the average temperature. The warmer weather on Earth resulted in change of hydrologic cycle including precipitation and evaporation. The amount of water in streams and underground has decreased owing to increasing of heat on Earth. As a result, less frequency of precipitation occurred, leading to drought event.

Drought condition has great effects on Thailand agriculture. Commercial crops were affected. For example, areas for corn fields were limited and production per area was relatively low due to more inconsistent of rainfall, which also threaten sugar cane production.

• **Biodiversity:** There is a high possibility that the population of many species of animals and plants would decline and some might become extinct because of the Climate Change and dispersion of their habitats. As most plant and animal species require signals from the climate in order to complete their life cycles so that they can survive, change of temperature and precipitation makes all living things in ecosystem need to adapt themselves to the new condition. However, there was extinction of some species at a few mountain summits because they were not able to migrate to higher areas or adapt to the warmer climate. Consequently, some valuable natural resources of the country were lost forever.

Climate Change affecting the water level has caused less diversion of biodiversity. In the area with decreased water level, there were great impacts of this change along the shorelines of lakes or reservoirs; the number of plants in the areas declined, migration of aquatic animals was affected, some species were lost and the amount of underground water flowing through rivers also decrease.

• **Health:** As Climate Change cause higher temperature in each area, it also results in more hot days, more extreme heat waves and more disasters like heavy storm and flood, all of which affect human health. In Thailand, health problem will be among the top problems of Climate Change, especially when there is also pollution problem, which cause more spread of infectious diseases. As a result, a lot of people might have health problem due to Climate Change. Temperature rise would also cause more heat waves. Furthermore, rapid change of temperature correlates with the rate of illness and death in the elderly and babies, as well as the patients who have a problem of respiratory system or coronary artery.

(Organization of Thailand Greenhouse Gas Management Organization Public Organization, 2012)

2.3 Global Warming

Global warming is the rise in the average temperature of the earth which causes climate change. Global warming may lead to the change in rainfall and sea level and vast impact to plants, animals, and human (Thailand Greenhouse Gas Management Organization Public Organization, 2010).

2.3.1 Causes of Global Warming

Global warming or climate change is the rise in the average temperature of the earth from the Greenhouse Effect. The major cause of global warming is the additional of carbon dioxide (to the atmosphere?) from human activities including fuel combustion, transportation, and industrial production as well as the additional of nitrous oxide and chlorofluorocarbons. The deforestation, to build human facilities, is also the cause of the global warming, given that plants are able to remove carbon dioxide from the atmosphere. Thus what we have been doing to the earth, they have been returning to us in a form of global warming (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

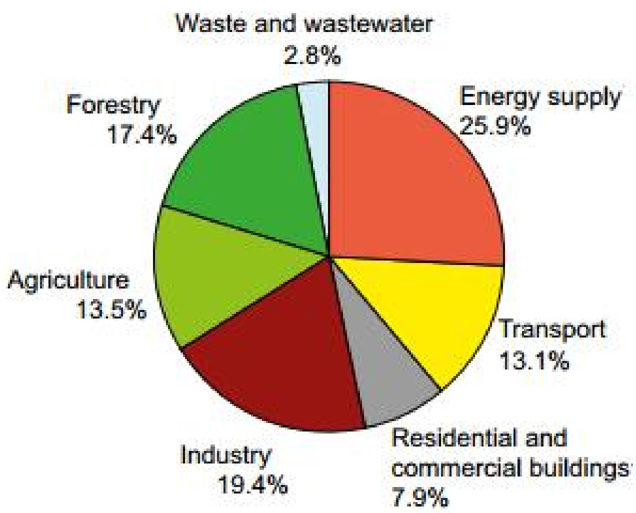


Figure 2–2 GHG emissions from various sectors.

Source: IPCC Fourth Assessment Report: Climate Change 2007, Working Group III: Mitigation of Climate Change, Chapter 1. This is a snapshot of emissions in 2004 as cited in Union of Concerned Scientists, 2013

2.3.2 Global Warming Factors

Major cause of global warming is air pollution in the form of gases released from industrial sectors. These gases allow sunlight pass through the layer of atmosphere to the earth's surface which is well known as the Greenhouse Effect. Greenhouse Effect is the effect that the earth's atmospheric layers act like glass which allow the short wavelength rays pass through them whereas the long wavelength rays which are reflected from the earth's surface are absorbed. The energy is released from the absorption process and stay in the earth's surface and atmospheric layers. It is therefore similar to the glass that covers the earth's surface and maintains balance of temperature for living creatures on the earth. However, there are some types of gases, which are able to absorb the long wavelength infrared rays and release heat causing the rise in global temperature, accumulated in atmospheric layers exceed the balance level. These affect the global climate and living creatures on earth.

"Greenhouse gases (GHG)" in the atmosphere are obstacles to infrared reflecting from the earth's surface to the atmosphere which are similar to light reflection. The energy released from earth's atmosphere is therefore exporting by wind and cloud in the atmospheric layers accumulated with dense GHG. The effect is called "Greenhouse Effect", given that it is similar to the effect of the plantation greenhouse in the cold climate countries that allows sunlight to pass through the glass to let the heat accumulate in the greenhouse to maintain warm condition in the greenhouse despite the cold weather outside (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

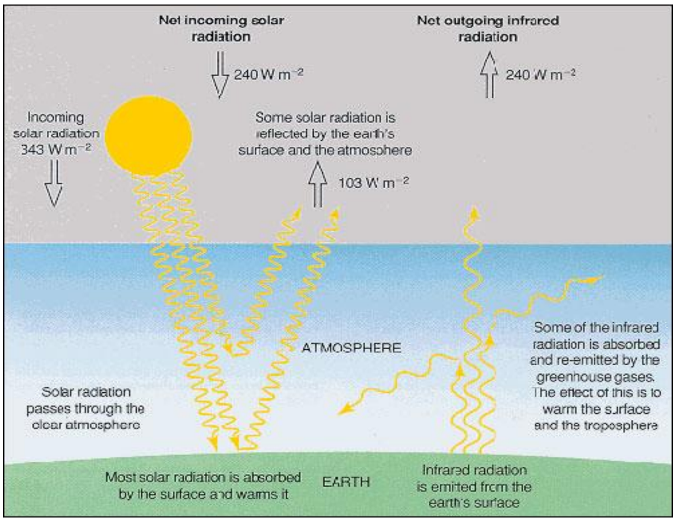


Figure 2-3 The radiation absorption and emission of the earth's surface and atmosphere.

Source: "Radiative Forcing of Climate Change" The 1994 Report of the Scientific Assessment Working Group of IPCC as cited in Thai Meteorological Department, 2012

2.3.3 Greenhouse Gases (GHG)

Greenhouse gases are gases that posses the ability of absorption and emission radiation within the thermal infrared range. These gases are necessary in maintaining the earth atmospheric temperature. If there were no GHG as other planets in solar system, the earth's temperature during the day would be very hot and during the night would be very cold. Given that these gases absorb heat radiation in the day time and gradually release them in the night time, the earth atmospheric temperature is thus maintained stable (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

There are 6 types of gases and chemicals that affecting global warming.

1) Water vapor (H2O) is major type of GHG found on earth at the presence of 0 - 4% in the air depending on the geographic, climate, and temperature. Water vapor is mostly found in the tropical zone near by the equator and coastal zone but rarely found in the cold climate polar zone and low temperature area. Water vapor is essential to the living creatures and is part of natural water cycle. Water can occur in 3 states and are therefore heat conductors and scatters for the atmosphere and surface.

Anthropogenic sources of water vapor are fuel and natural gas combustion and respiration of plants and animals from the agriculture.

2) Carbon dioxide (CO_2): In the early stage of the earth and solar system, there was 98% of carbon dioxide due to the smaller sun with lesser sunlight. Carbon dioxide provides the earth with warmth that is suitable for living creatures. As time went by, the sun was getting larger and rain washed atmospheric carbon dioxide to the earth's surface. Some type of planktons and plants converted atmospheric carbon dioxide into their food by photosynthesis process causing the decrease of the greenhouse effect. Carbon dioxide occurs naturally from melting of calcium carbonate which is released from volcanoes and respiration of living creatures (Thailand Greenhouse Gas Management Organization (Public Organization), 2010).

The increment of carbon dioxide was due to various types of combustion such as fuel combustion, factory combustion, and deforestation by burning the forest for making habitat and agriculture. The deforestation by burning the forest was the fastest way to release carbon dioxide into the atmosphere, given that plants and trees are able to capture carbon dioxide before accumulating in the atmosphere. When forest area is less, carbon dioxide is able to accumulate more in the atmosphere causing the heat to accumulate at the earth's surface and atmosphere of the higher rate of approximately 1.56 Watt/m2 (excluding indirect effect).

3) Methane (CH_4): Sources of methane are both natural and anthropogenic including rice fields, decomposition of living creature, rice plantation, livestock farming, fossil fuel, oil, and natural gas combustion, especially combustion that occur naturally and other fuel combustion which are able to increase methane level in the atmosphere of approximately 20% of the total atmospheric methane. There were also IPCC's report showing that the rice fields in Asian and Australia released a large number of methane into the atmosphere with the different in quantity depending on the type and quality of soils. Even though methane emission to the atmosphere is only 1.7 ppm, methane contains higher GHG characteristics than carbon dioxide, say, methane absorbs infrared ray better than carbon dioxide at the same volume. The methane average accumulation time is approximately 11 years which is considered less than carbon dioxide. The direct impact from greenhouse effect from methane is less than the impact of greenhouse effect from carbon dioxide. However, it is

considered to be the second most impact gas next to the carbon dioxide with the average energy of the direct impact of methane of 0.47 Watt/m2.

4) Nitrous oxide (N_2O) occurs naturally from the decomposition of living creatures by bacteria. The increment of nitrous oxide, at present, are from the industrial sectors that using nitric acid in the production process, such as nylon industry, chemical industry, or some type of plastic industry. Even though nitrous oxide occurs naturally in the large quantity, the incremental rate is still considered in a balance. The increasing nitrous oxide resulted in the heat accumulated in the earth's surface of approximately 0.14 Watt/m2. When nitrous oxide is released into the stratosphere, it will react with ozone causing the reduction in the shield to Ultra Violet (UV) to the earth.

5) Chlorofluorocarbons (CFCs)

Gases consisting of CFCs also known as Freon does not occur naturally but it is the human innovation. CFCs occur from factories and everyday use equipment and devices such as refrigerators, air conditioners, and spray bottles.

CFCs consisting of chlorine, fluoride, and bromine are able to destroy ozone. CFCs in the earth's surface typically react with other chemicals but when CFCs absorb UV in the stratosphere the molecule is breaking in to chlorine atom and will react with ozone to form Chlorine mono oxide (ClO) and oxygen. If an atom of chlorine destroys a molecule of ozone at a time, this will not be a problem. However, an atom of chlorine is able to destroy a molecule of ozone at a thousand times. This is because of the chain reaction when the ClO reacts with single oxygen molecule producing a single chlorine molecule

This type of gases has decreased 40% when comparing to the past 10 year because of the Montreal Protocol. However, the CFCs that are accumulated in the atmosphere caused by human activities are still the cause of the accumulation of energy on the earth's surface of approximately 0.28 Watt/m2. Moreover, the indirect effect of the gas is dangerous to the atmosphere and living creatures. Given that the gas is able to react with ozone, the atmospheric ozone is therefore reduced or the ozone hole can occur. This causes the short wavelength rays that are dangerous to the living creatures on earth pass through to the earth more and exceed the balance level.

6) Ozone (O_3)

O_3 consists of 3 oxygen molecule. Its presence in the atmosphere is only 0.0008%. Ozone is an unstable gas. It lasts in the air for 20 – 30 weeks and then decomposes. Ozone is formed by UV absorption by oxygen (O_2) which then produces single oxygen atom (O). The single oxygen atom reacts with oxygen and other molecule (M) as binding agent producing ozone. Ozone performs 2 roles as a good gas and a bad gas at the same time depending on where it is.

- Stratospheric Ozone.

Stratospheric ozone or good ozone acts as a shield protecting living creatures on earth from Ultra Violet (UV), a harmful radiation. Ozone is naturally present on the surface at 10%. Most of stratospheric ozone forms thin layer at a height of 20 – 30 kilometer filtering 90% UV from sun before it reaches earth's surface. If human exposes to this kind of radiation, there is a risk for skin cancer. As for bacteria, it would be killed.

- Tropospheric Ozone.

Tropospheric Ozone is bad ozone harmful to the living creatures. Tropospheric Ozone has the most characteristics of GHG. When it absorbs infrared ray, the accumulation of heat of approximately 2.85 Watt/m^2 would occur. Tropospheric Ozone is formed by biomass combustion and engine combustion where most of which is formed from the traffic jams, engines, machines, and factories and is mixing with smoke. When it is presenting in the lower atmospheric layer or at the surface, it acts in a more harmful way due to its human toxicity as shown in Table 2-2 (Thailand Greenhouse Gas Management Organization Public Organization, 2010).

Table 2-2 GHG types and sources

GHG	Sources	Rise in global heat (%)
Carbon dioxide (CO_2)	1) Natural: living creatures' respiration. 2) Anthropogenic: fuel combustion from factories, deforestation (CO_2 absorption decreasing)	57

Table 2-2 GHG types and sources (cont.)

GHG	Sources	Rise in global heat (%)
Methane (CH_4)	1) Natural: living creatures' decomposition and natural combustion. 2) Anthropogenic: rice fields, flooded area, fossil fuel, coal, and natural gas combustion.	12
Nitrous oxide (N_2O)	1) Anthropogenic: Industrial sectors using nitric acid in production process, plastic industry, nylon industry, chemical industry, biomass fuel combustion, fertilizers, and forest burning. 2) Natural: in balance condition.	6
Gases consisting of Chlorofluorocarbon (CFCs)	Anthropogenic: Industrial sectors, everyday use equipment and devices such as foam, spray bottle, cooling machine, refrigerators, air conditioners, solvents (these gases are able to react with ozone causing the reduction of atmospheric ozone or holes in ozone layers).	25

Source: Usa, 2007

2.4 United Nations Framework Convention on Climate Change (UNFCCC)

2.4.1. Background and objective of United Nations Framework Convention on Climate Change (UNFCCC)

During a decade of 1980, scientific evidences have convinced that there was a link between GHG emission from human activities and climate change. The finding has leaded to the awareness of the problem and global concerns. The international meetings were held and Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC) was formed in 1990. United Nations Framework Convention on Climate Change (UNFCCC) were then drafted by INC and was accepted at United Nations headquarter on May 9th, 1992. UNFCCC was then opened for signature during the Earth Summit in June 1992 at Rio de Janeiro, Brazil where 154 countries have signed and the convention entered into force on March 21st, 1994 (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

UNFCCC is an international environmental treaty dealing with the climate change which believed to be a result from the greenhouse effect from the accumulation of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and replacement of chlorofluorocarbons (CFCs). It was firmly believed by scientific evidence that the global temperature would rise 0.2 to 0.5 degree Celsius in the near decade and the sea level would rise 20 centimeter by the year 2040 and 65 centimeter in the next century as well as the hurricanes, droughts, wild fire, and floods (Houghton et al., 1990, as cited in King Mongkut's University of Technology Thonburi, 2012). The global community is therefore set to meet continuously to deal with the problem.

The objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system whereas the stabilization needs to be conducted in an appropriate time without interference with the food production and sustainable economic development" (Thailand Greenhouse Gas Management Organization Public Organization, 2012).

2.4.2 Principle of United Nations Framework Convention on Climate Change (UNFCCC)

1. Precautionary principle which emphasizes prevention of possibly dangerous events including uncertainty potential threats to the atmosphere at an early stage. The example of the principle is the reduction of GHG emission to the level of 1990 by the year 2000.

2. Principle of "common but differentiated responsibilities" whereas the parties to the convention, Annex I and Noon-Annex I countries, have commitment about climate change mitigation.

3. Principle of communication which requires parties to the convention to exchange information about climate change with transparency according to the convention's National Communication requirement. The content and timeframe of the country report is different among Annex and Non-Annex countries.

4. Principle of supporting developing countries. Given that developing countries have potential impact to the climate change, developed countries should provide financial and technological support to developing countries to protect the environment.

Global Environmental Fund is a mechanism under the convention to support developing countries in management of climate change. The convention also requires developed countries to provide technological assistance to developing countries.

After the convention is in effect, the Conferences of the Parties (COP) will be held annually. The objective of the COP is to have parties maintain their GHG level at a safety level for the ecosystem self-restoration with an assurance that no harm will be done to the food and sustainable economic development. However, there is no target for GHG emission reduction (Office of the Natural Resources and Environmental Policy and Planning, 1997 as cited in King Mongkut's University of Technology Thonburi, 2012).

2.4.3 Thailand's commitment under UNFCCC.

Thailand has ratified UNFCCC as a Non-Annex I country on December 28th, 1994 which was effective for Thailand on March 28th, 1995. Thailand's commitments under article 4 of UNFCCC are as follow.

- Response to GHG emission reduction by implementation of policy that does not affect the country's economic and society system under concepts of common but differentiated responsibilities, precautionary, and equity. However, there are no target emission reduction requirements.
- Prepare National Communication for the secretariat of the convention to express the country's participation to the parties.
- Attend negotiation meeting and technical development meeting such as Conferences of the Parties (COP) or Intergovernmental Panel on Climate Change (IPCC).
- Conduct academic research and development on climate change (Office of the Natural Resources and Environmental Policy and Planning, 1997, as cited in King Mongkut's University of Technology Thonburi, 2012).

2.5 Standard for Calculating Greenhouse Gases Emission (ISO 14064)

ISO 14064 is a GHG calculation standard used as a manual in preparation of GHG management and development system for both public and private sector. The standard is also used for policy formulation and project development initiation in dealing with challenges from climate change (Jay Wintergreen, 2006).

2.5.1 ISO 14064 consists of 3 parts namely

1. ISO 14064-1:2006 The first part underlines principles for quantification and reporting of GHG emissions and removals at the organization level covering from setting organizational boundary, GHG inventory, calculation, reporting, development of management measures, and verification by internal audit.

2. ISO 14064-2:2006 The second part emphasizes principles of quantitative analysis, monitoring, and reporting of reduction and removal of GHG at the program level which helps reducing GHG emission or increasing the efficiency if

GHG removal from the atmosphere as well as the baseline specification, documentation, and verification.

3. ISO 14064-3:2006 The third part indicates principles of documentation and verification of GHG quantification results including evaluation of assessment procedure and preparation for document evaluation and verification of GHG.

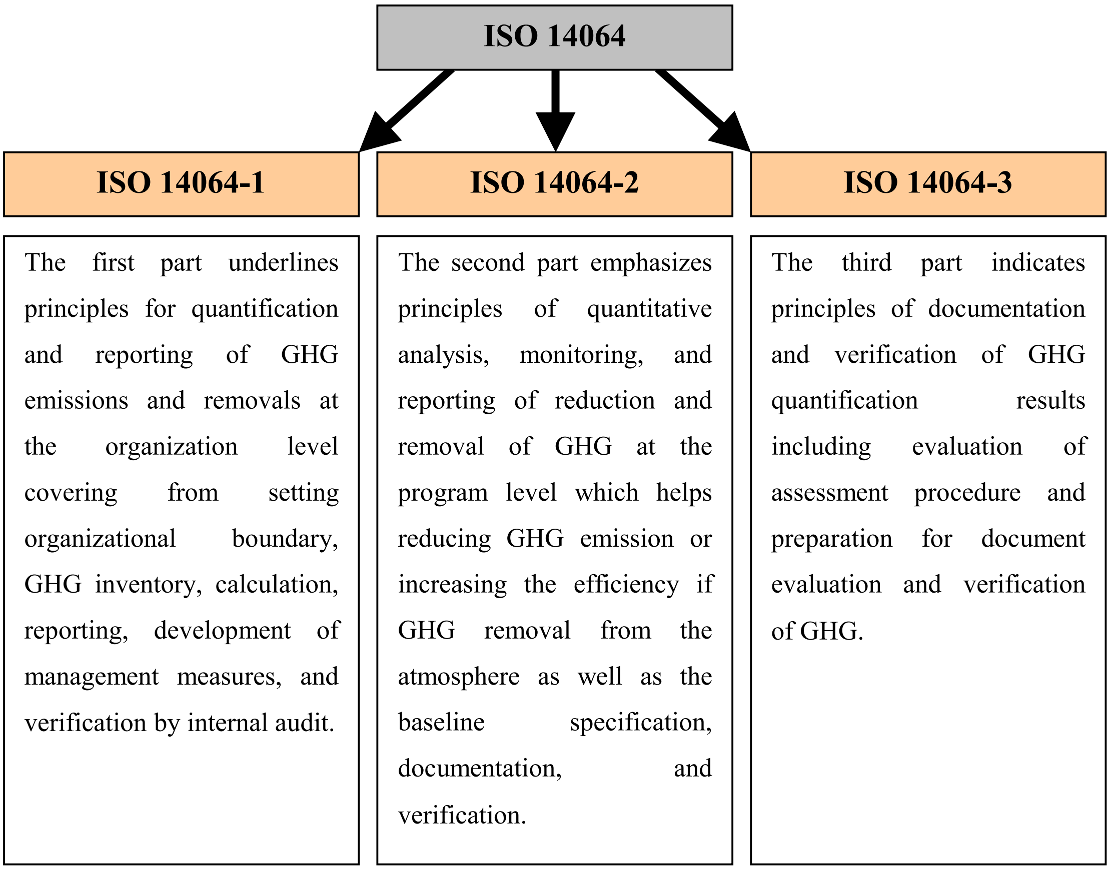


Figure 2-4 Relation of serial sub-standard of ISO 14064.

Source: Kitikorn Jamorndusit, 2011.

2.5.2 Benefits of ISO 14064

ISO 14064 is a guideline for checking or identifying procedures to be applied by organization as well as the way to express organization responsibility to GHG emission reduction programs which would be benefit for society and environment.

1) Environmental aspects are considered in GHG assessment.

2) Providing reliable, consistent, and transparent GHG emissions and removals quantification, monitoring, and reporting procedure.

3) Providing management strategies and organization plan for implementation of GHG related project.

4) Providing progress monitoring for GHG emissions and removals projects.

5) Providing carbon credit trading and certification (Bureau Veritas Certification, 2010).

2.6 Related Research

Thanut Poolpratini and et al. (2010) studied about carbon footprint analysis of the department of chemical engineering, Kasetsart University. Their results showed that the total GHG emission was 1,036.43 ton CO_2e or 2.28 tonCO2e per person per year which can be categorized into 7.84, 548.09, and 480.49 tonCO_2e of Type I, II, and III emission, respectively. The results can be used for a suggestion of GHG emission reduction measures.

Preechaphol Chusri (2010) studied about perception and attitude toward carbon footprint labeled products. His results showed that the sampling group learned about carbon footprint labeling mostly agreed about having carbon footprint labeling. His work also showed that 54.5% of the sampling group considered carbon footprint labeling as an important factor in buying products and the sampling group also considered carbon footprint labeling as an important factor for consumers and exporters. His findings also suggested that the sampling group mostly agreed that the carbon footprint labeling would help mitigating global warming and provide consumers participation.

Rattanawan Mungkung and et al. (2010) studied about carbon footprint analysis and management of rice products in term of carbon footprint labeling to support the low carbon economy for global warming mitigation. Their results showed that 5 kilograms of Jasmine Rice released 48 kgCO_2e of GHG most of which were released during plantation process.

Rattanawan Mungkung and et al. (2011) studied about carbon footprint of rice products by partially analyzing carbon footprint from the initial production process to the export of products according to PAS 2050 standard. They studied 3 rice products namely Jasmine Rice, noodles, and dried noodles. Their findings showed that the major GHG emission were from the production and rice plantation process.

Pimpha Wiriyapattanachai (2010) conducted a study about entrepreneur participation in global warming mitigation by applying carbon footprint management according to Thailand Greenhouse Gas Management Organization (Public Organization) program. Her study showed that entrepreneur participation was able to reduce GHG emission with a little additional cost. For energy saving program, her study also showed the return of investment after a short period of time after the investment of the program. Moreover, the study also pointed out that most of the people do not aware of the carbon footprint. Therefore, the public sector should further support the knowledge of the carbon footprint to create public awareness of the global warming.

Hogne N. Larsen and et al (2011) studied about "Investigating the Carbon Footprint of a University - The case of NTNU" they apply an Environmental Extended Inpute Output (EEIO) model to calculate the Carbon Footprint of the Norwegian University of Technology and Science (NTNU) Results show that the Carbon Footprint of NTNU is an average of 4.6 tonnes per student.

Leticia Ozawa-Meida and et al (2011) studied about "Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study" This paper presents a consumption-based carbon footprint study for a UK university including scope 1, 2 and 3 emissions under the classification of the WRI/WBCSD Greenhouse Gas Protocol Corporate Standard. The scope 3 emissions comprised around 79% of the total university's greenhouse gas emissions.

Thomas Wiedmann and et al (2007) studied about "A Definition of 'Carbon Footprint'" In this report they suggest a definition of the term of carbon footprint and they also suggest that it is important for a 'carbon footprint' to include all direct as well as indirect CO_2 emissions. In addition the method is used to calculate carbon footprint is also important on the practices of carbon trading and carbon offsetting.

P.-A. Jacinthe and et al (2002) studied about "Carbon budget and seasonal carbon dioxide emission from a central Ohio Luvisol as influenced by wheat residue amendment" This paper presents that the intensity of CO_2 emission was higher in the late winter (mean: 2.79 g CO_2-C m−2 per day) and summer seasons (2.45 g CO_2-C m−2 per day) and lowest in the autumn (1.34 g CO_2-C m−2 per day).

CHAPTER III
RESEARCH METHODOLOGY

The research was to obtain the greenhouse gas (GHG) emission from Mahidol Wittayanusorn School Public Organization activities. The survey research was conducted to collect information about school activities. The GHG emission was then calculated by using the carbon footprint assessment guideline of Thailand Greenhouse Gas Management Organization Public Organization. The research procedures can be described as follow.

3.1 Research Boundary

Mahidol Wittayanusorn School Public Organization, a residential high school, located Phutthamonthon, Nakhon Pathom Province, Thailand.

3.2 Research tools and instruments

3.2.1 Resources utilization and waste generation record forms for Mahidol Wittayanusorn School Public Organization.

3.2.2 Thailand Greenhouse Gas Management Organization Public Organization carbon footprint assessment guideline.

3.2.3 The World Business Council for Sustainable Development (WBCSD) GHG emission calculation equations. GHG emission was calculated from the equations using information from school activities and multiplies by emission or absorption factor. The results were converted into the unit of ton (kg) of Carbon Dioxide Equivalent.

3.3 Data collection

Data collection was carried out by the researcher. The data was collected from Finance and Facilities Section, Buildings and Transportation Section, and School Residence Hall Section. The school GHG emission was then calculated based on these data.

3.4 Research Procedures

3.4.1 Assess GHG emission from Mahidol Wittayanusorn School Public Organization activities and services by applied the adapted procedure which was cited in the World Business Council for Sustainable Development (WBCSD) report, "the Greenhouse Gas Protocol: a corporate and reporting standard". The procedure consists of 5 steps as is shown in figure 3-1.

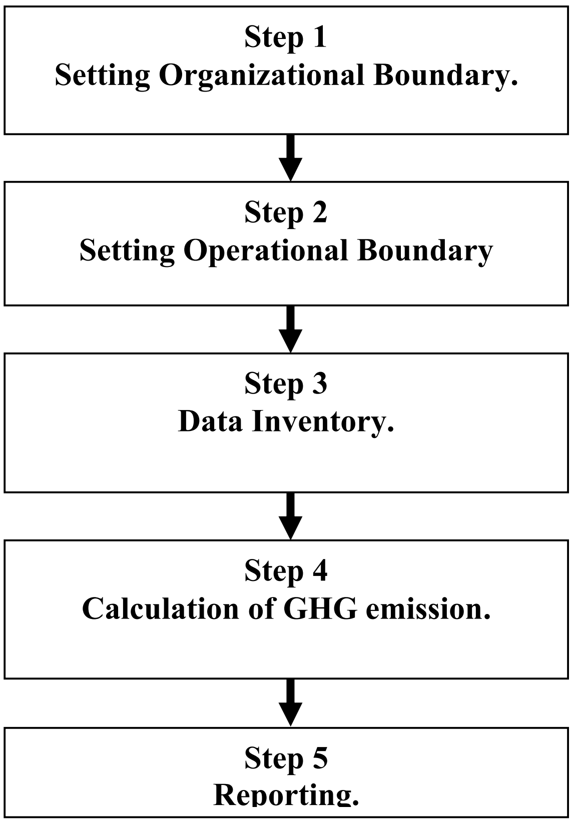


Figure 3-1 GHG emission assessment procedure for the organization.

Step 1: Setting Organizational Boundary.

The research boundary covered Mahidol Wittayanusorn School Public Organization area including :

- Four school buildings namely 1st, 2nd, and 3rd building, and Pra Ubalee Kunupamachan Hall.
- Three residence halls which are 7th, 8th, and 9th residence halls.
- School cafeteria consisting of 13 food stores located on the 1st floor of Pra Ubalee Kunupamachan Hall.
- Reception rooms in 4 buildings which are 10th, 11th, 12th, and 14th building.

Step 2: Setting Operational Boundary.

Conduct a survey of activities and services that release GHG for Mahidol Wittayanusorn School Public Organization by setting operational boundary which then will be assessed according to the examples of activities that release and absorb GHG for academic institutions as are specified by Thailand Greenhouse Gas Management Organization Public Organization guideline. The sources of direct and indirect GHG emission were also determined. According to WBCSD, GHG emission can be categorized into three scopes as follow (examples of setting operational boundary are shown in Annex B)

Scope I: Direct emissions which are emissions from the use of school-owned vehicles and school wastewater treatment process.

Scope II: Energy indirect emission from purchased electricity.

Scope III: Optional emissions which are emissions from the use of water supply, paper, cooking fuel, and the production of waste.

Step 3: Data Inventory.

Data collection in the study was conducted by collecting records from each section responsible for data as is shown in table 3-1.

Table 3-1 Data collection boundary from resource utilization by Mahidol Wittayanusorn School Public Organization activities.

Scope	Activities that release and absorb GHG.	Data sources	Calculation
Scope I	Fuel consumption.	Buildings and Transportation Section.	The multiplication of fuel consumption by fuel emission factor.
	Wastewater generated.	Finance and Facilities Section.	1) Calculation as is cited by UNFCCC (2006). 2) Calculation as is cited by IPCC (2006).
Scope II	Electricity consumption.	Finance and Facilities Section.	The multiplication of electricity consumption by electricity emission factor.
Scope III	Water supply consumption.	Finance and Facilities Section.	The multiplication of water supply consumption by water supply emission factor.
	Quantity of paper used.	Finance and Facilities Section.	The multiplication of quantity of paper used by paper emission factor.
	Waste generated.	Buildings and Transportation Section.	The multiplication of waste generated by emission factor of each waste type.
	Cooking fuel.	Food stores in school cafeteria.	The multiplication of cooking fuel consumption by cooking fuel emission factor.

** **Remark**: wastewater generation rate was assumed at 80% of water supply consumption.

Source: Thailand Greenhouse Gas Management Organization Public Organization, 2011.

Step 4: Calculation of GHG emission.

To obtain accurate results, the calculation that is widely used and accepted internationally was applied in the study. The emission factors were cited from Intergovernmental Panel on Climate Change (IPCC) and international database.

The emission factors applied in the study are shown in table 3-2. The calculation was based on 2001 WBCSD guideline and equations as is shown in equation 3-2 (refer to Thailand Greenhouse Gas Management Organization Public Organization, 2011). in equation 3-1 and Table 3-2

Emission = Activity Data (AD) x Emission Factor (EF)

Equation 3-1 GHG emission calculate equation

Emission	= GHG emission
Activity Data (AD)	= a factor that quantifies an activity used to calculate the emissions generated
Emission factor (EF)	= a factor that allowing GHG emissions to be estimated from a unit of available activity data

Figure 3-2 WBCSD's equation for GHG emission calculation.

Table 3-2 Emission factor

Items	**Units**	**Emission factor** ($kgCO_2$)	**Data sources**
Water supply	m^3	0.0264	Metropolitan Waterworks Authority (Thailand)
Electricity	kWh	0.5610	TC common data
Paper	Kg	0.7350	SiamPro

Table 3-2 Emission factor (cont.)

Items	Units	Emission factor ($kgCO_2$)	Data sources
Waste			
Paper	Kg	1.4755	Converted data from JEMAI Pro using Thai Electricity Grid
Textile	Kg	2.0000	IPCC 2006 Vol.5
Food/sludge	Kg	2.5300	IPCC 2006 Vol.5
Wood chip	Kg	0.0735	Converted data from JEMAI Pro using Thai Electricity Grid
Neppies	Kg	4.0000	IPCC 2006 Vol.5
Garden & Park	Kg	3.2700	IPCC 2006 Vol.5
Rubber and Leather	Kg	3.1300	IPCC 2006 Vol.5
Glass	Kg	1.1870	Converted data from JEMAI Pro using Thai Electricity Grid
Aluminum (can)	Kg	4.4315	Jap supplier, G2G cal. By JEMAI Pro
Foam boxes	Kg	2.2971	Converted data from JEMAI Pro using Thai Electricity Grid
Clear plastic bags (PP)	Kg	2.3990	Ecoinvent 2.0, IPCC 2007 GWP 100a
Plastic bags (PE)	Kg	1.5200	Converted data from JEMAI Pro using Thai Electricity Grid
Clear plastic bottles (PET)	Kg	3.7700	ETH-ESU 96 PET ETH S
Plastic bottles (HDPE)	Kg	1.6170	Converted data from JEMAI Pro using Thai Electricity Grid
Plastic containers (PP)	Kg	1.6862	Converted data from JEMAI Pro using Thai Electricity Grid
Metals	Kg	1.76	Ecoinvent 2.0, IPCC 2007

Table 3-2 Emission factor (cont.)

Items	Units	Emission factor ($kgCO_2$)	Data sources
Energy (stationary combustion)			
Natural gas	MJ	0.0099	Ecoinvent 2.0
Natural gas	Scf	0.0670	IPCC
Cooking gas (LPG)	MJ	0.0612	Frankin US 98
Cooking gas (LPG)	L	1.6812	IPCC
Cooking gas (LPG)	kg	3.1100	IPCC
Coking coal	Kg	2.6268	IPCC
Lignite	Kg	1.0624	IPCC
Bituminous coals	Kg	2.5070	IPCC
Diesel fuel	L	2.7080	IPCC 2007, DEDE
Heavy fuel oil	kg	0.6200	LCA DK
Heavy fuel oil	L	3.0883	IPCC
Kerosene	L	2.4777	IPCC
Biomass	Kg	0.6930	IPCC
Energy (mobile combustion)			
Diesel	L	2.7446	IPCC
Natural gas (CNG)	kg	2.2472	IPCC
Cooking gas (LPG)	L	1.5362	IPCC
Cooking gas (LPG)	kg	2.8400	IPCC
Gasoline	L	2.1896	IPCC
Bio-diesel	L	2.6265	U.S.Energy Information Administration
Chemical			
Sodium Chloride	kg	0.2020	Sodium chloride, powder, at plant/RER S, ECOINVENT 2.0

Table 3-2 Emission factor (cont.)

Items	Units	Emission factor ($kgCO_2$)	Data sources
Acetic Acid	kg	0.9321	Converted data from JEMAI Pro using Thai Electricity Grid
Sodium Hydroxide	kg	1.0377	Ec Converted from JEMAI Pro using Thai Electricity Grid
Sodium sulphate	kg	0.4740	Sodium chloride, powder, production mix, at plant/RER U, ECOINVENT 2.0
Hydrochloric acid	kg	0.8960	ETH-ESU
Sulfuric acid	kg	0.1380	Sulphuric acid, liquid, at plant/RER U, ECOINVENT 2.0
Alcohol	kg	1.2600	Ecoinvent 2.0, IPPC 2007 GWP 100a (Ethanal from ethylene, at plant/RER S)
Ammonium sulphate	kg	2.6600	Ecoinvent 2.0, IPPC 2007
Potassium hydroxide	kg	5.9653	Converted data from JEMAI Pro using Thai Electricity Grid
Citric acid	kg	1.5800	Replacement of Acetic acid, 98% in H_2O, at plant/kg/RER, ECOINVENT 2.0
Nitric acid	kg	0.3230	Converted data from JEMAI Pro using Thai Electricity Grid
Sodium hypochloride	kg	0.3249	Converted data from JEMAI Pro using Thai Electricity Grid
Laboratory equipments			
Heat resistant plastic bag (PP)	kg	2.399	Ecoinvent 2.0

Table 3-2 Emission factor (cont.)

Items	**Units**	**Emission factor** ($kgCO_2$)	**Data sources**
Aluminium Foil	kg	1.238	Environmental Profile Report for the European Aluminium, Industry
Rubber gloves	kg	0.4419	TH-Research

Source: Thailand Greenhouse Gas Management Organization Public Organization, 2011.

To calculate emission in ton of 6 GHGs from the Kyoto Protocol, the unit conversion to ton of Carbon Dioxide Equivalent, by multiply by Global Warming Potential (GWP) from the Intergovernmental Panel on Climate Change (IPCC), is required in Table 3-3

Table 3-3 Global Warming Potential (GWP).

GHG	**Acronym**	**GWP**
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	298
Hydro fluorocarbons	HFCs	124 – 14,800
Perfluoro carbons	PFCs	7,390 – 12,200
Sulphur hexafluoride	SF_6	22,800

Source: IPCC Fourth Assessment Report (2007) as is cited in Thailand Greenhouse Gas Management Organization Public Organization, 2011.

Step 5: Reporting.

The report must consist of :

- General information including name, location, number of person, types of activity that release GHG, carbon footprint assessment and reporting for the organization.
- Detail for the setting of organizational boundary, sources of direct and indirect GHG emission, and time and date of data collection.
- Methodological information and calculation factors which are widely used and accepted internationally. References for those methodological information and calculation factors are also required.
- Total GHG emission and GHG emission by sources in the unit of kilograms Carbon Dioxide Equivalent for Mahidol Wittayanusorn School Public Organization (shown in the form of charts).
- Analysis and discussion of the GHG emission assessment results.

3.4.2 Calculate GHG emission per person for students and staffs.

The GHG emission per person for Mahidol Wittayanusorn School Public Organization was calculated by dividing the total emission by total number of students and staffs in 2011.

3.4.3 Compare GHG emission between season and academic term and vocation for Mahidol Wittayanusorn School Public Organization.

The GHG emissions for Mahidol Wittayanusorn School Public Organization were compared between season and academic term and vocation by computer system. The SPSS/FW program (Statistical Package for Social Sciences / for window) was applied. The F-test was used for analyze the seasonal variation and the t-test was used for analyze the different between academic term and vocation. The statistical significant analysis was analyzed at a level of 0.05

3.4.4 GHG emission reduction activities for Mahidol Wittayanusorn School Public Organization.

The GHG emission assessment for Mahidol Wittayanusorn School Public Organization was analyzed to develop the GHG emission reduction activities. Various activities were considered to find activities that suitable for the school. The study focused on the electricity saving measures for residence halls. Five electricity saving measures were applied to the 7th and 8th girl residence halls starting from December 2012 to January 2013. These measures were :

1) Reduce the usage of air conditioner by rearranging the students who stay at the school during the weekend and holidays in the same air conditioning room (typical residence hall rooms capacity is 6 persons a room). For the rooms with less than 3 students, an alternative of ceiling fan is recommended over the air conditioning.

2) Set the temperature for air conditioner at 25 degree Celsius and the operation time from 8.30pm to 5.00am.

3) Half of the hall way lighting, which are not close to each other, will be turned off after 11.00pm. Half of the restroom lighting, 3 lights, will also be turned off.

4) Turning off the light at midnight and encourage students to go to bed no later than midnight. No electronic devices such as laptops, lamps, and hair dryers, are allowed after midnight, except for the room air conditioners and ceiling fans.

5) Having the school announcement in the morning to have students turn off the light and electronic devices before leaving residence hall to create awareness for students.

To apply electricity saving measures, the head of student and the head of residence hall in each floor were asked to turn off restroom lights, hall way lights, and check the air conditioner temperature. The student committee was asked to announce to students every morning to turn off the light and unnecessary electronic devices and to announce the energy saving tips to help create awareness to students and staffs. Teachers from girl residence halls were also help turning air conditioners on and off and warned students by knocking doors to have them turn their lights and electronic devices off after midnight as well as rearranging students to stay together in scheduled air conditioned residence hall rooms at full capacity (6 persons).

Electricity consumption for 7th and 8th residence halls during December 2012 and January 2013, the time that the electricity saving measures were applied, were compared to electricity consumption at a time before applying electricity saving measures or in November 2012 to figured out whether the electricity saving measures were able to reduce the electricity consumption or not. The different between electricity consumption was then converted into the electricity cost by Provincial Electricity Authority of Thailand rate in 2011.

CHAPTER IV
THE RESULT OF RESEARCH

The study of carbon footprint for Mahidol Wittayanusorn School Public Organization in 2011 was conducted by collecting school activities information and assessing the greenhouse gas (GHG) emission from those activities. The GHG emission reduction measures were studied by analyzing the GHG emission data. The GHG emission reduction activities were then developed to reduce the GHG emission. The GHG emission study for Mahidol Wittayanusorn School Public Organization in 2011 were conducted in 3 components namely are :

- Direct emissions (Scope I): GHG emission from travel by school-owned vehicles and the GHG emission from the school wastewater treatment process.
- Indirect emission (Scope II): GHG emission from purchased electricity.
- Optional emissions (Scope III): GHG emission from water supply consumption, the use of paper, and the production of waste.

4.1 Direct GHG emission from travel by school-owned vehicles and the GHG emission from the school wastewater treatment process (Scope I).

4.1.1 Travel by school-owned vehicles in 2011 consumed the total of 14,816 liters of diesel fuel as is shown in figure 4-1.

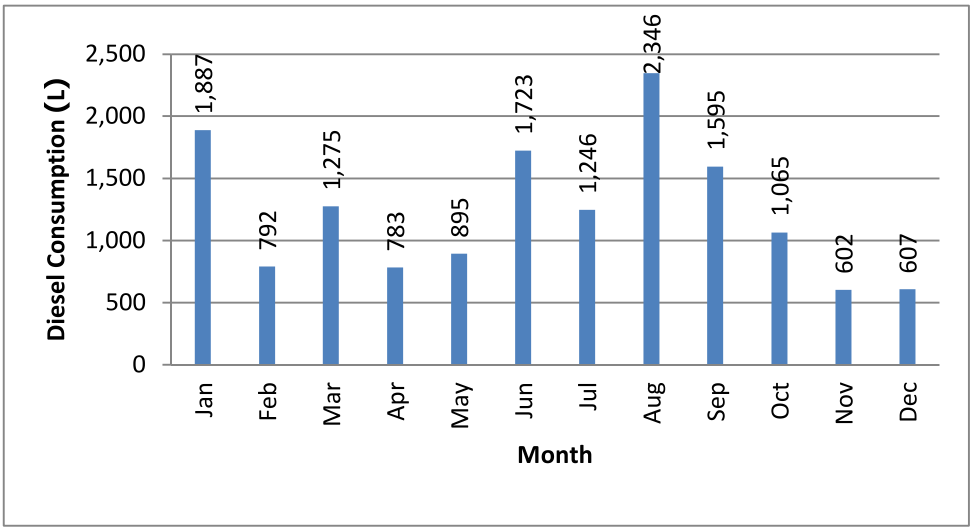


Figure 4-1 diesel fuel consumption in 2011 from travel by school-owned vehicles for Mahidol Wittayanusorn School Public Organization.

4.1.2 GHG emission from travel by school-owned vehicles for Mahidol Wittayanusorn School Public Organization in 2011 was 6,463.92 kgCO_2e which was calculated from the multiplication of quantity of diesel fuel consumed by the diesel fuel emission factor of 0.5200 kg (the diesel fuel density is 0.839 kg/L). GHG emission from travel by school-owned vehicles for Mahidol Wittayanusorn School Public Organization in 2011 is shown in figure 4-2.

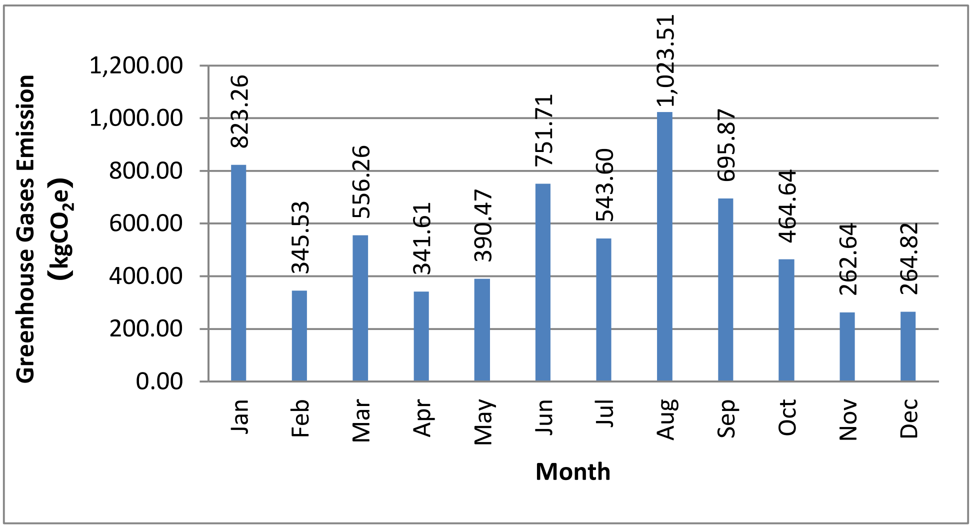


Figure 4-2 GHG emission from travel by school-owned vehicles for Mahidol Wittayanusorn School Public Organization in 2011.

4.1.3 The quantity of wastewater generated in Mahidol Wittayanusorn School Public Organization in 2011 was 6,1380,000 liters which was calculated from 80% of the quantity of water supply consumption as is shown in figure 4-3.

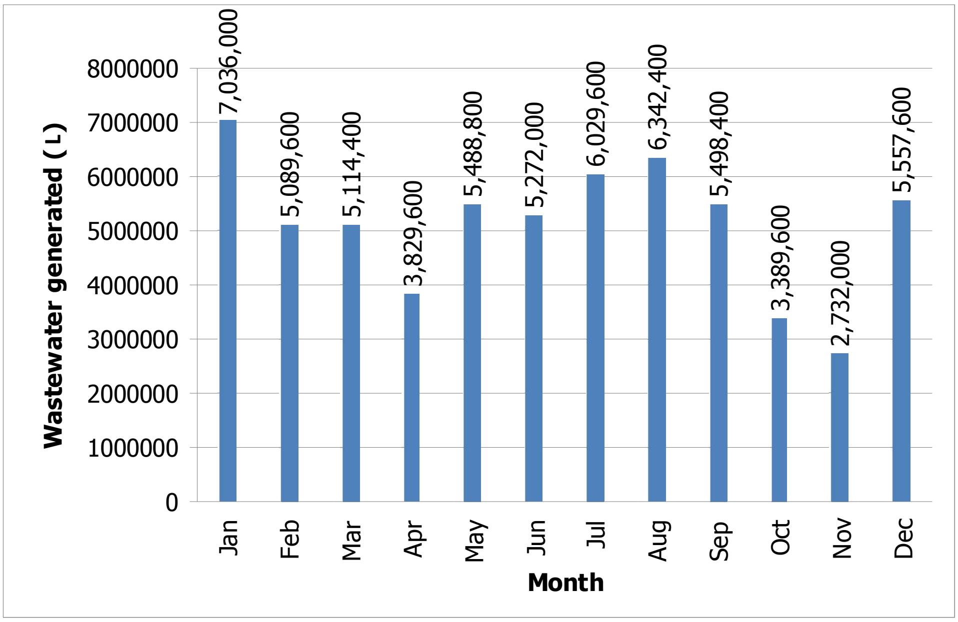


Figure 4-3 The quantity of wastewater generated for Mahidol Wittayanusorn School Public Organization in 2011.

4.1.4 The GHG emission from the school wastewater treatment process for Mahidol Wittayanusorn School Public Organization in 2011 was 9,535.68 kgCO2e which was calculated from the multiplication of quantity of wastewater generated by values of BOD and Nitrogen and the emission factor. The CH_4 and N_2O emission factor for Mahidol Wittayanusorn School Public Organization were 0.18 kgCH_4 and 0.005 kgN_2O-N, respectively. For N_2O emission, the multiplication by 44/28, which is the constant for unit conversion from kg N_2O-N to kg N_2O, is required. The obtained CH_4 emission and N_2O emission were then multiplied by their Global-Warming Potential (GWP) of 25 and 28, respectively.

4.2 Indirect GHG emission from purchased electricity for Mahidol Wittayanusorn School Public Organization in 2011 (Scope II).

4.2.1 Electricity consumption for Mahidol Wittayanusorn School Public Organization in 2011, taken from the electricity consumption of every sector of the school, was 1,858,920 kWh as is shown in figure 4-4.

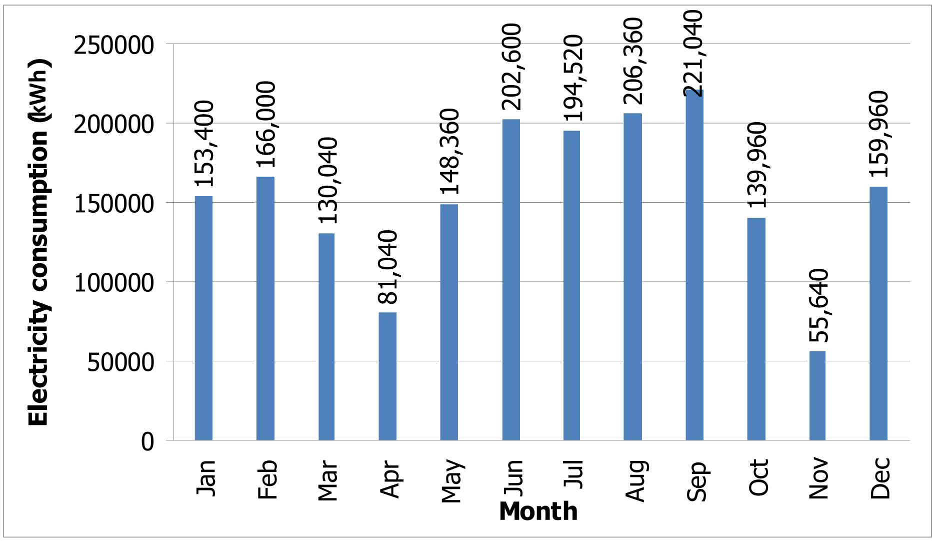


Figure 4-4 electricity consumption for Mahidol Wittayanusorn School Public Organization in 2011.

4.2.2 GHG emission from electricity consumption for Mahidol Wittayanusorn School Public Organization in 2011 was 1,042,854.12 kgCO2e which was calculated from the multiplication of the quantity of electricity consumed by the electricity emission factor of 0.5610 kWh. (Monthly) GHG emission from electricity consumption for Mahidol Wittayanusorn School Public Organization in 2011 is shown in figure 4-5.

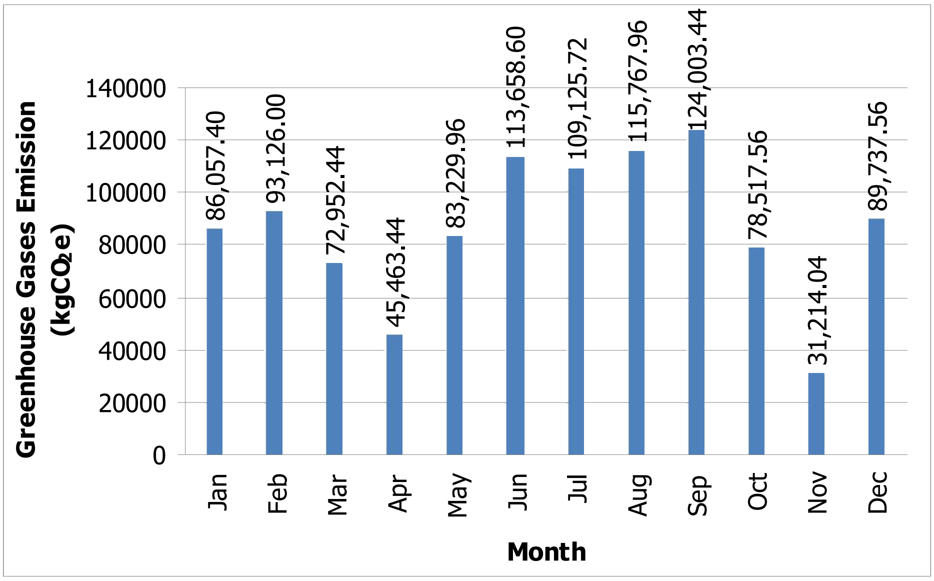


Figure 4-5 GHG emission from electricity consumption for Mahidol Wittayanusorn School Public Organization in 2011.

4.3 Optional emission from the use of water supply and paper and from waste generated in the Mahidol Wittayanusorn School Public Organization in 2011 (Scope III).

4.3.1 Water supply consumption for Mahidol Wittayanusorn School Public Organization in 2011 was 76,725 m^3, mainly used for washing, cleaning, and drinking, as is shown in figure 4-6.

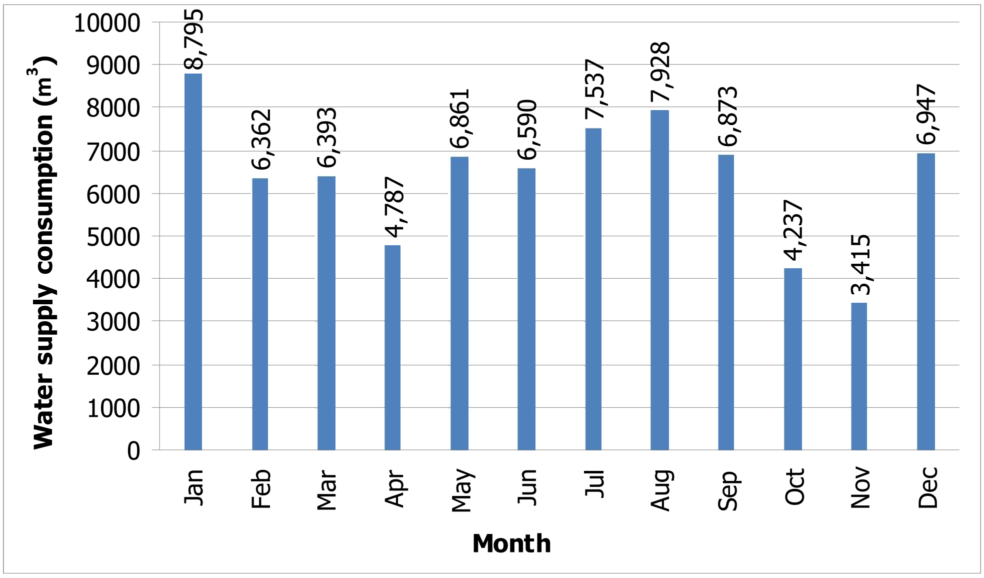


Figure 4-6 water supply consumption for Mahidol Wittayanusorn School Public Organization in 2011.

4.3.2 GHG emission from water supply consumption for Mahidol Wittayanusorn School Public Organization in 2011 was 2,025.54 kgCO_2e as is shown in figure 4-7. The emission was calculated from the multiplication of quantity of water supply used by the emission factor of water supply of 0.0264 m^3

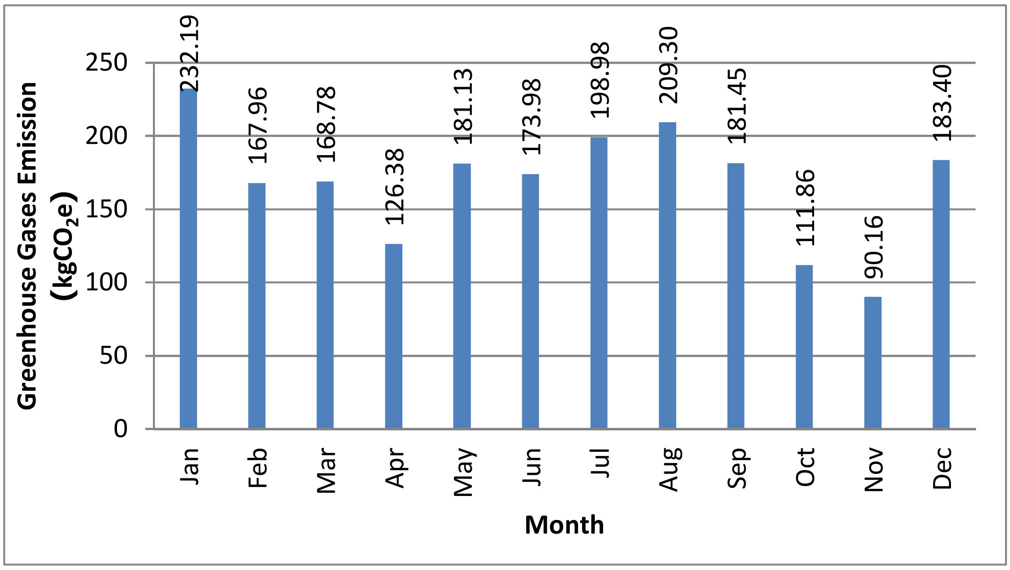


Figure 4-7 GHG emission from water supply consumption for Mahidol Wittayanusorn School Public Organization in 2011.

4.3.3 There were 11 types of paper used in Mahidol Wittayanusorn School Public Organization in 2011 which were 1. Large rolls of soft tissue paper 2. Paper napkins 3. Grey-white paper 4. Poster paper (hard) 5. Poster paper (soft) 6. Drawing paper (100lb) 7. card paper (180 gsm) 8. Cover paper (120 gsm) 9. Color copy paper (80 gsm) 10. Copy paper (80 gsm) and 11. Copy paper (70 gsm). The quantity of paper used for the school in 2011 was 3,289.84 kg as is shown in figure 4-8.

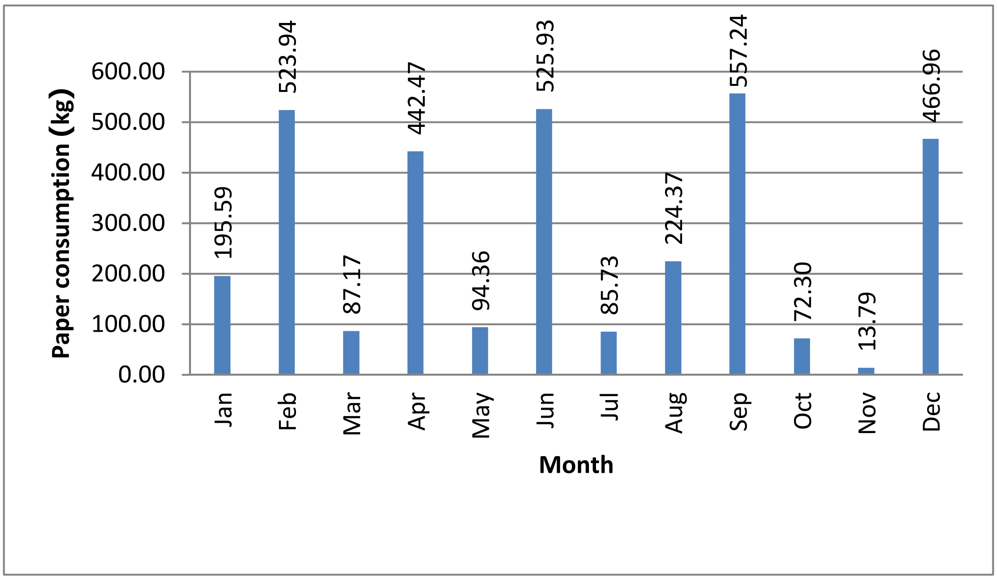


Figure 4-8 The quantity of paper used for Mahidol Wittayanusorn School Public Organization in 2011.

4.3.4 GHG emission from the use of paper for Mahidol Wittayanusorn School Public Organization in 2011 was 2,418.03 kgCO2e as is shown in figure 4-9. The emission was calculated from the multiplication of quantity of paper used by the emission factor for paper of 0.7350 kg.

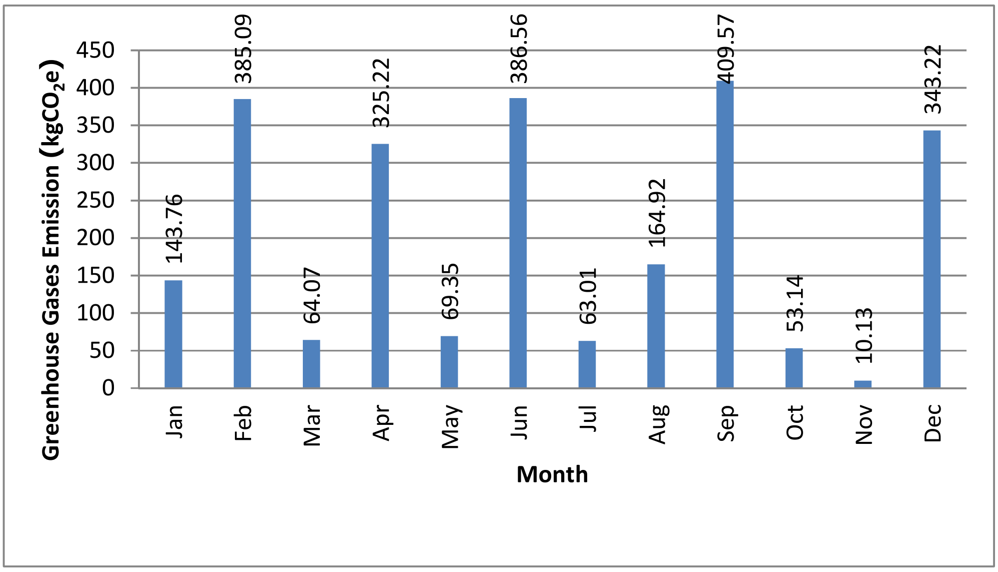


Figure 4-9 GHG emission from the use of paper for Mahidol Wittayanusorn School Public Organization in 2011.

4.3.5 There were 14 types of waste generated in Mahidol Wittayanusorn School Public Organization in 2011 namely 1. Clear plastic water bottles (Polyethylene Terephtalate; PET) 2. Clear plastic bags (Polypropylene; PP) 3. Plastic bags (Polyethylene; PE) 4. Glass 5. Paper 6. Sanitary pads 7. Plastic boxes 8. Aluminum (can) 9. Metals 10. Foam 11. Food scraps 12. Tree leaves/branches 13. Leather/rubber and 14. Fiber and textile. Waste composition was calculated based on the average of three waste composition samplings a week. Waste composition in the school during school days is shown in table 4-1 and during school holidays is shown in table 4-2.

Table 4-1 Waste composition for Mahidol Wittayanusorn School Public Organization during school days in 2011.

Type of waste	Composition (%)
Clear plastic water bottles (Polyethylene Terephtalate; PET)	5.12
Clear plastic bags (Polypropylene; PP)	2.7
Plastic bags (Polyethylene; PE)	3.02

Table 4-1 Waste composition for Mahidol Wittayanusorn School Public Organization during school days in 2011. (cont.)

Type of waste	Composition (%)
Glass	9.73
Paper	15.75
Sanitary pads	9.36
Plastic boxes (Plastic containers)	2.15
Aluminum (can)	4.17
Metal	1.03
Foam	0.5
Food scraps	35.2
Tree leaves/branches	7.5
Leather/rubber	2.44
Fiber and textile	1.33
Total	**100**

Table 4-2 Waste composition for Mahidol Wittayanusorn School Public Organization during school holidays in 2011.

Type of waste	Composition (%)
Clear plastic water bottles (Polyethylene Terephtalate; PET)	6.42
Clear plastic bags (Polypropylene; PP)	2.16
Plastic bags (Polyethylene; PE)	2.8
Glass	7.35
Paper	14.75
Sanitary pads	7.5

Table 4-2 Waste composition for Mahidol Wittayanusorn School Public Organization during school holidays in 2011.(cont.)

Type of waste	Composition (%)
Plastic boxes (Plastic containers)	3.52
Aluminum (can)	4.5
Metal	2.55
Foam	2.8
Food scraps	30.5
Tree leaves/branches	7.65
Leather/rubber	3.7
Fiber and textile	3.8
Total	**100**

4.3.6 GHG emission from waste generated for Mahidol Wittayanusorn School Public Organization in 2011 was 209,425.24 kgCO_2e which consisted of the emission during school days of 164,396 kgCO_2e and the emission during school holidays of 45,029.23kgCO_2e. The emission was calculated from the multiplication of the amount of waste generated by the emission factor for each type of waste. The GHG emission from each type of waste for the school during school days is shown in table 4-3 and during school holidays is shown in table 4-4.

Table 4-3 GHG emission per day from waste generated for Mahidol Wittayanusorn School Public Organization during school days in 2011.

Day	Weight of waste (kg)	GHG Emission (kgCO_2e)
Monday	353	803.32
Tuesday	279	634.92
Wednesday	247	562.10
Thursday	269	612.16
Friday	334	760.08

Table 4-3 GHG emission per day from waste generated for Mahidol Wittayanusorn School Public Organization during school days in 2011.(cont.)

Day	Weight of waste (kg)	GHG Emission ($kgCO_2e$)
Saturday	258	587.13
Sunday	324	737.32
Weekly Total	2064	4697.03
GHG emission from the total of waste generated (35 weeks)		**164,396.00**

Table 4-4 GHG emission per day from waste generated for Mahidol Wittayanusorn School Public Organization during school vocation in 2011.

Day	Weight of waste (kg)	GHG Emission ($kgCO_2e$)
Monday	174	396.43
Tuesday	158	359.98
Wednesday	165	375.93
Thursday	169	385.04
Friday	182	414.66
Saturday	112	255.17
Sunday	138	314.41
Weekly Total	1098	2501.62
GHG emission from the total of waste generated (35 weeks)		**45,029.24**

4.3.7 GHG emission from the use of cooking fuel, Liquefied Petroleum Gas (LPG), for Mahidol Wittayanusorn School Public Organization cafeteria in 2011 was 4,870.44 $kgCO_2e$ which was calculated from the multiplication of the quantity of cooking fuel by the cooking fuel emission factor of 0.498 kg. The GHG emission from the use of cooking fuel for Mahidol Wittayanusorn School Public Organization cafeteria in 2011 by food store is shown in table 4-5.

Table 4-5 GHG emission from the use of cooking fuel for Mahidol Wittayanusorn School Public Organization cafeteria in 2011.

Store number/Type of food store	**Cooking fuel container size (kg)**	**Quantity used a month**		**Total weight (kg)**	
		School days	**School holidays**	**School days**	**School holidays**
1. Beverages	15	1	0.5	15	7.5
2. Fruits	15	1	0.5	15	7.5
3. Dessert	15	2	1	30	15
4. Various cooked food served with steamed rice	15	5	2	75	30
5. Snacks and fried meatballs	15	4	1	60	15
6. Various cooked food served with steamed rice	15	5	2	75	30
7. Noodles	15	10	4	150	60
8. Chicken and rice	15	4	2	60	30
9. Various cooked food served with steamed rice	15	6	3	90	45
10. Various cooked food served with steamed rice	15	8	3	120	45
11. Northeastern Thailand food	15	4	1	60	15
12. Various cooked food served with steamed rice	15	10	4	150	60

Table 4-5 GHG emission from the use of cooking fuel for Mahidol Wittayanusorn School Public Organization cafeteria in 2011.(cont.)

Store number/Type of food store	**Cooking fuel container size (kg)**	**Quantity used a month**		**Total weight (kg)**	
		School days	**School holidays**	**School days**	**School holidays**
13. Noodles	15	8	3	120	45
Total cooking fuel used a month				1,020	405
Cooking fuel emission factor (kg)				0.4980	0.4980
GHG Emission per month (kgCO_2e)				507.96	201.69
School days (8 months during June – September and November – February) School holidays (4 months during March – May and October)				4,063.68	806.76
GHG Emission per year (kgCO_2e)				**4,870.44**	

It can be concluded that in 2011, activities that release most of GHG for Mahidol Wittayanusorn School Public Organization were electricity consumption, the production of waste, and water supply consumption, respectively. GHG emission from each activity of the school is shown in figure 4-10.

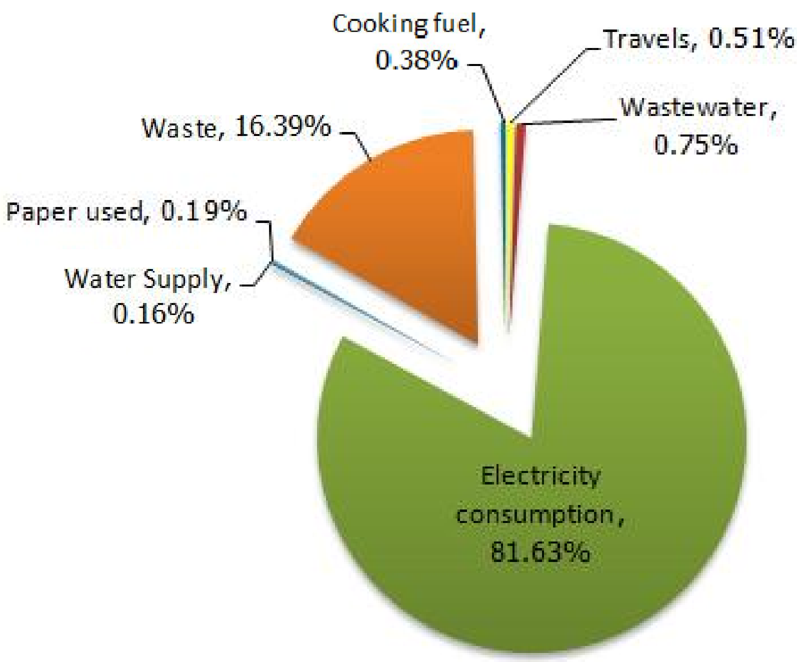


Figure 4-10 GHG emission from each activity of Mahidol Wittayanusorn School Public Organization in 2011.

4.4 Statistical analysis for seasonal variation and school time variation of GHG emission

4.4.1 Diesel fuel consumption and GHG emission.

1) Seasonal variation of diesel fuel consumption and GHG emission (One-Way ANOVA) in Table 4-6

Table 4-6 Seasonal variation of diesel fuel consumption and GHG emission analyzed by F-test.

Comparison		Average	SD	F	sig
Items	Season				
Diesel fuel consumption	summer	984.33	257.87	2.221	0.164
	rainy	1595.00	495.75		
	winter	927.00	616.37		

Table 4-6 Seasonal variation of diesel fuel consumption and GHG emission analyzed by F-test.(cont.)

Comparison		Average	SD	F	sig
Items	**Season**				
GHG emission	summer rainy winter	429.44 694.06 424.06	112.50 217.90 268.91	2.177	0.169

Seasonal variation (summer, rainy, and winter) of the diesel fuel consumption and GHG emission from diesel fuel consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in table 4-6. It was found that there was no statistically significant seasonal variation for the diesel fuel consumption in 2011. There was also no statistically significant seasonal variation for GHG emission from the diesel fuel consumption in 2011.

2) School time variation of diesel fuel consumption and GHG emission (t-test).

Table 4-7 School time variation of diesel fuel consumption and GHG emission analyzed by t-test.

Comparison		Average	SD	t	sig
Items	**School time**				
Diesel fuel consumption	School days School holidays	1004.50 1349.75	214.38 645.12	-1.370	0.203
GHG emission	School days School holidays	438.24 587.74	93.53 281.67	-1.359	0.206

School time variation (Table 4-7) for the diesel fuel consumption and GHG emission from diesel fuel consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by t-test is shown in table 4-7. It was found that there was no statistically significant difference in diesel fuel consumption between school days and school holidays in 2011. There was also no statistically significant difference in GHG emission from diesel fuel consumption between school days and school holidays in 2011.

4.4.2 Electricity consumption and GHG emission.

1) Seasonal variation of electricity consumption and GHG emission (One-Way ANOVA) in Table 4-8

Table 4-8 Seasonal variation of electricity consumption and GHG emission analyzed by F-test.

Comparison		Average	SD	F	sig
Items	**Seasons**				
Electricity consumption	summer	119813.33	34805.66	3.939	0.059
	rainy	192896.00	31114.26		
	winter	133750.00	52326.92		
GHG emission	summer	67215.28	19525.97	1.798	0.220
	rainy	102214.66	30498.14		
	winter	75033.75	29355.40		

Seasonal variation (summer, rainy, and winter) in Table 4-8 for the electricity consumption and GHG emission from electricity consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in table 4-8. It was found that there was no statistically significant seasonal variation for the electricity consumption in 2011. There was also no statistically significant seasonal variation for GHG emission from the electricity consumption in 2011.

2) School time variation of electricity consumption and GHG emission (t-test).

Table 4-9 School time variation of electricity consumption and GHG emission analyzed by t-test

Comparison		Average	SD	t	sig
Items	**School time**				
Electricity consumption	School days School holidays	124850.00 169940.00	30151.19 52183.28	-1.577	0.146
GHG emission	School days School holidays	62540.85 95336.34	18481.80 29274.82	-2.021	0.071

School time variation (summer, rainy, and winter) in Table 4-9 for the electricity consumption and GHG emission from electricity consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in table 4-9. It was found that there was no statistically significant difference in electricity consumption between school days and school holidays in 2011. There was also no statistically significant difference in GHG emission from electricity consumption between school days and school holidays in 2011.

3) Comparison of electricity consumption and GHG emission between 2011 and 2012 (t-test) in Table 4-10

Table 4-10 Comparison of electricity consumption and GHG emission between 2011 and 2012 by t-test.

Comparison		Average	SD	t	sig
Items	**(Year)**				
Electricity consumption	2011 2012	154910.00 200073.33	49736.18 50957.41	-2.197	0.039*
GHG emission	2011 2012	86904.51 112241.14	27902.00 28587.10	-2.197	0.039*

** Remark * Statistically significant difference at 0.05

Result from the comparison of electricity consumption between 2011 and 2012 for Mahidol Wittayanusorn School Public Organization by t-test is shown in table 4-10. It was found that there was a statistically significant difference at 0.05 between electricity consumption in 2011 and 2012. There was also a statistically significant difference at 0.05 between GHG emission from electricity consumption in 2011 and 2012. Hence, the electricity consumption in 2012 was higher than in 2011 and the GHG emission from electricity consumption in 2012 was higher than in 2011.

4.4.3 Water supply consumption and GHG emission.

1) Seasonal variation of water supply consumption and GHG emission (One-Way ANOVA) in Table 4-11

Table 4-11 Seasonal variation of water supply consumption and GHG emission analyzed by F-test.

Comparison		Average	SD	F	sig
Items	Seasons				
Water supply consumption	summer	6013.66	1087.79	0.127	0.883
	rainy	6633.00	1440.00		
	winter	6379.75	2231.98		
GHG emission	summer	158.75	28.72	0.127	0.883
	rainy	175.10	38.01		
	winter	168.42	58.92		

Seasonal variation of water supply consumption and GHG emission from water supply consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in table 4-11. It was found that there was no statistically significant seasonal variation of water supply consumption in 2011. There was also no statistically significant seasonal variation for GHG emission from water supply consumption in 2011.

2) School time variation of water supply consumption and GHG emission (t-test) is show in table 4-12.

Table 4-12 School time variation of water supply consumption analyzed by t-test.

Comparison		Average	SD	t	sig
Items	School time				
Water supply consumption	School days School holidays	5569.50 6805.87	1256.18 1581.87	-1.354	0.206
GHG emission	School days School holidays	147.03 179.66	33.16 41.76	-1.353	0.206

School time variation of water supply consumption and GHG emission from water supply consumption in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in table 4-12. It was found that there was no statistically significant difference in water supply consumption between school days and school holidays in 2011. There was also no statistically significant difference in 2011GHG emission from water supply consumption between school days and school holidays in 2011.

4.4.4 Wastewater generated and GHG emission.

1) Seasonal variation of wastewater generated and GHG emission from quantity and quality of wastewater (One-Way ANOVA) in Tale 4-13

Table 4-13 Seasonal variation of wastewater generated and GHG emission analyzed by F-test.

Comparison		Average	SD	F	sig
Items	Season				
Wastewater generated	summer rainy winter	4810933.3 5306400.00 510.800.0	870232.83 1152007.4 1785587.5	0.127	0.883

Table 4-13 Seasonal variation of wastewater generated and GHG emission analyzed by F-test.(cont.)

Comparison		**Average**	**SD**	**F**	**sig**
Items	**Season**				
GHG emission	summer	747.39	135.19	0.127	0.883
	rainy	824.37	178.96		
	winter	792.89	277.40		
N_2O	summer	1.34	0.24	0.120	0.888
	rainy	1.47	0.32		
	winter	1.42	0.49		
CH_4	summer	13.84	2.50	0.127	0.882
	rainy	15.27	3.31		
	winter	14.69	5.14		

Seasonal variation (summer, rainy, and winter) in Table 4-13 of wastewater generated and GHG emission from wastewater generated in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in Table 4-13. It was found that there was no statistically significant seasonal variation of wastewater generated in 2011. There was also no statistically significant seasonal variation of GHG emission from wastewater generated in 2011.

2) School time variation of wastewater generated and GHG emission (t-test) in Table 4-14

Table 4-14 School time variation of wastewater generated and GHG emission analyzed by t-test.

Comparison		**Average**	**SD**	**T**	**sig**
Items	**School time**				
Wastewater generated	School days	4455600.0	1004946.4	-1.354	0.206
	School holidays	5444700.0	1265503.9		

Table 4-14 School time variation of wastewater generated and GHG emission analyzed by t-test.(cont.)

Comparison		Average	SD	T	sig
Items	**School time**				
GHG emission $kgCO_2e$	School days School holidays	692.19 845.85	156.12 196.60	-1.354	0.206
N_2O	School days School holidays	1.24 1.51	0.28 0.35	-1.347	0.208
CH_4	School days School holidays	12.82 15.67	2.89 3.64	-1.354	0.206

School time variation of wastewater generated and GHG emission from wastewater generated in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by t-test is shown in table 4-14. It was found that there was no statistically significant difference in wastewater generated between school days and school holidays in 2011. There was also no statistically significant difference in GHG emission from wastewater generated between school days and school holidays in 2011.

4.4.5 Quantity of paper used and GHG emission.

1) Seasonal variation of quantity of paper used and GHG emission (One-Way ANOVA) in Table 4-15

Table 4-15 Seasonal variation of quantity of paper used and GHG emission analyzed by F-test.

Comparison		Average	SD	F	sig
Items	**Season**				
Quantity of paper used	summer rainy winter	208.00 293.11 300.07	203.08 234.76 238.63	0.167	0.849
GHG emission	summer rainy winter	152.88 215.44 220.55	149.27 172.55 175.39	0.167	0.849

Seasonal variation of quantity of paper used and GHG emission from paper used in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by F-test is shown in Table 4-15. It was found that there was no statistically significant seasonal variation of quantity of paper used in 2001. There was also no statistically significant seasonal variation of GHG emission from quantity of paper used in 2001

2) School time variation of quantity of paper used and GHG emission analyzed by t-test is shown in Table 4-16.

Table 4-16 School time variation of quantity of paper used and GHG emission analyzed by t-test.

Comparison		Average	SD	t	sig
Items	**School time**				
Quantity of paper used	School days School holidays	174.07 324.19	179.16 218.76	-1.180	0.265
GHG emission	School days School holidays	127.94 238.28	131.68 160.79	-1.180	0.265

School time variation of quantity of paper used and GHG emission from paper used in 2011 for Mahidol Wittayanusorn School Public Organization analyzed by t-test is shown in table 4-14. It was found that there was no statistically significant difference in quantity of paper used between school days and school holidays in 2011. There was also no statistically significant difference in GHG emission from paper used between school days and school holidays in 2011.

4.5 GHG emissions reduction measures

Results from the application of five electricity saving measures for the 7th and 8th female residence halls from November 2012 to January 2013 were as follow.

Table 4-17 GHG emission reduction measures.

Measures	GHG emission reduction measures	Before applying measures
1st measure	Reduce the usage of air conditioner by rearranging the students who stay at the school during the weekend and holidays in the same air conditioning room (typical residence hall rooms capacity is 6 persons a room). For the rooms with less than 3 students, an alternative of ceiling fan is recommended over the air conditioning.	Air conditioners were used in every residence hall rooms.
2nd measure	Set the temperature for air conditioner at 25 degree Celsius and the operation time from 8.30pm to 5.00am.	Air conditioner were able to be turned on and off anytime.
3rd measure	Half of the hall way lighting, which are not close to each other, will be turned off after 11.00pm. Half of the restroom lighting, 3 lights, will also be turned off.	All hall way and restroom lighting were turned on.

Table 4-17 GHG emission reduction measures. (cont.)

Measures	GHG emission reduction measures	Before applying measures
4th measure	Turning off the light at midnight and encourage students to go to bed no later than midnight. No electronic devices such as laptops, lamps, and hair dryers, are allowed after midnight, except for the room air conditioners and ceiling fans.	No time limit for lighting and using electronic devices in residence hall rooms.
5th measure	Having the school announcement in the morning to have students turn off the light and electronic devices before leaving residence hall to create awareness for students.	No electricity saving awareness programs.

From the application of energy saving measures starting from December 2011, it was found that the electricity consumption for 7th and 8th female residence hall was reduced. The electricity consumption for 7th and 8th female residence halls from November 2012 to January 2013 are shown in figure 4-11.

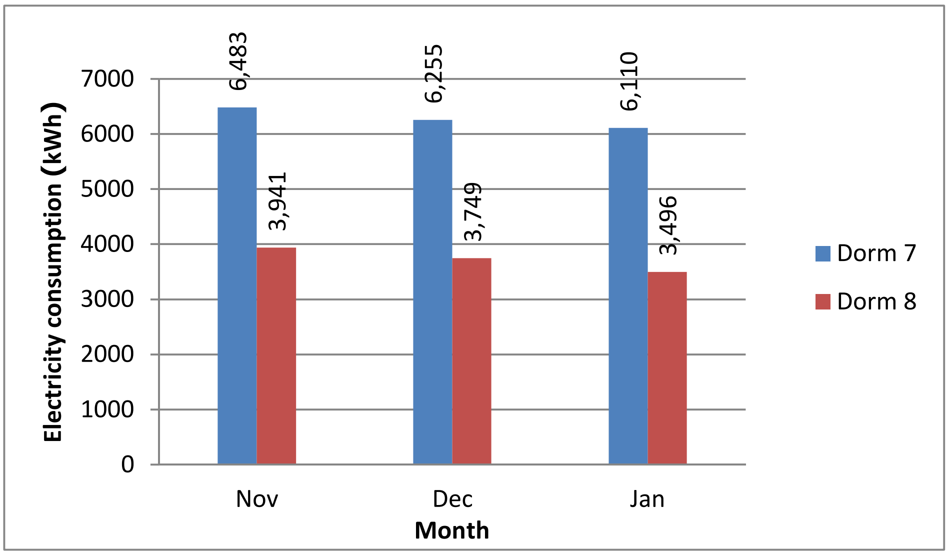


Figure 4-11 Electricity consumption for the 7th and 8th female residence hall from November 2012 to January 2013.

From figure 4-11, it was found that the electricity consumption for the 7th female residence hall during the month of December 2012, the first month that the electricity saving measures were applied, was 6,255 kWh which was 228 kWh less than the electricity consumption in November 2012 of 6,483 kWh. By continuously applying electricity saving measures, it was also found that the electricity consumption for the 7th female residence hall in January 2013 was 6,110 kWh which was 145 kWh less than the December 2012 consumption and 373 kWh less than the November 2012 consumption. For the 8th female residence hall, after applying the electricity saving measures in December 2012, the electricity consumption was 3,749 kWh which was 192 kWh less than November 2012 consumption of 3,941 kWh. By continuously applying electricity saving measures, it was also found that the electricity consumption for the 8th female residence hall in January 2013 was 3,496 kWh which was 253 kWh less than the December 2012 consumption and 445 kWh less than the November 2012 consumption.

CHAPTER V
CONCLUSION AND DISCUSSION

Results from the study of GHG emission from resource utilization and waste production of Mahidol Wittayanusorn School Public Organization in 2011 were from 2 phases of study which were the statistical analysis of the seasonal and academic time variation of the GHG emission from resource utilization and waste production and the study of GHG emission reduction approaches to develop GHG emission reduction measures. The study results can be concluded as follow.

5.1 GHG emission results for Mahidol Wittayanusorn School Public Organization in 2011

The results from the study of GHG emission for Mahidol Wittayanusorn School Public Organization in 2011 by collecting information from school activities including diesel fuel consumption from travel by school-owned vehicles, wastewater generated, electricity consumption, water supply consumption, quantity of paper used, waste generated, and cooking fuel consumption. It was found that GHG emission for Mahidol Wittayanusorn School Public Organization in 2011 was 1,277.59 tonCO_2e or 1.44 tonCO_2e per person which was calculated based on the total number of students and staffs of 883 persons. The major sources of GHG for the school were electricity consumption and production of waste which released GHG of 1,042.85 tonCO_2e and 209.42 tonCO_2e, respectively, or 81.63% and 16.39 % of the total emission from school, respectively. GHG from water supply consumption contributed as little as 2.02 tonCO_2e or 0.16% of the total emission from school.

It can be concluded that 3 major sources of GHG emission from the school were electricity consumption, production of waste, and production of wastewater, respectively. The first major source of GHG emission was electricity consumption, large number of electricity consumption in school was from the use of many electrical and electronic devices in residence halls, laboratories, and classrooms. The second major source of GHG emission was production of waste. Most of school waste was food scraps from the school cafeteria. Given that the school is residential school, most of waste was also from residential halls as well. The third major source of GHG emission was production of wastewater. GHG emission from wastewater was calculated from the school wastewater treatment process based on the values of BOD and nitrogen. Most of school wastewater was generated from residential hall, school buildings, and the school cafeteria. As for water supply consumption, it was the minor source of GHG emission. Water supply consumption released the least GHG when compared to other sources in the school.

5.2 Seasonal variation and academic time variation assessment results of GHG emission for Mahidol Wittayanusorn School Public Organization in 2011

Results for the assessment of seasonal variation and academic time variation of GHG emission for Mahidol Wittayanusorn School Public Organization in 2011 by statistical instruments were concluded that no statistical significant seasonal and academic time variation of GHG emission from the consumption of electricity, water, and paper and wastewater production were observed at a level of 0.05

From the total GHG emission of Mahidol Wittayanusorn School Public Organization in 2011, it can be concluded that the major source of GHG was electricity consumption which released 1,042.85 tonCO_2e or 81.63% of the total GHG emission. The electricity consumption for the school in 2011 were collected and were statistically compared to the 2012 data by using t-test which concluded that there was a statistically significant difference at a level of 0.05 between the electricity consumption in 2011 and 2012. There was also a statistically significant difference between GHG emission in 2011 and 2012. Therefore, it can be said that the electricity consumption and GHG emission in 2012 was more than the electricity consumption and GHG emission in 2011.

Given that the electricity consumption and GHG emission in 2012 was increased from 2011, electricity saving measures were developed to apply to the 7th and 8th girl residence halls. Five electricity saving measures were applied starting from December 2012 to January 2013. It was found that electricity consumption in December 2012 for 7th and 8th residence hall were 228 kWh and 192 kWh less than the consumption in November 2012. The electricity consumption in January 2013 for 7th and 8th residence hall were 145 kWh and 253 kWh less than the consumption in December 2012. For the electricity consumption in January 2013 for 7th and 8th residence hall were 373 kWh and 445 kWh less than the consumption in November 2012. The electricity cost saving as shown in table 5-1.

Table 5-1 Electricity consumption decreased for 7th and 8th residence halls of Mahidol Wittayanusorn School Public Organization.

Month	**Electricity consumption decreased**		**Electricity cost (Baht)**
	Residence hall	**kWh**	
December 2012 and November 2012	7th	228	488.19
	8th	192	411.11
January 2013 and December 2012	7th	145	310.47
	8th	253	541.72
January 2013 and November 2012	7th	373	798.67
	8th	445	952.82

Remark: Electricity cost was calculated from the multiplication of electricity consumption (kWh) by unit power rate of 2.1412 (Baht per kWh)
Source: Provincial Electricity Authority of Thailand, 2011.

5.3 Discussion

In 2011, GHG emission for Mahidol Wittayanusorn School Public Organization was 1,277.59 tonCO_2e or 1.44 tonCO_2e per person per year (the total number of students and staffs was 883 persons). Comparing to GHG emission from the department of chemical engineering, Kasetsart University, in 2011 of 1,036.43 tonCO_2e or 2.28 tonCO_2e per person per year, Mahidol Wittayanusorn School Public Organization total GHG emission was higher due to higher electricity consumption. However, the Mahidol Wittayanusorn School Public Organization emission per person per year was less than the department of chemical engineering, Kasetsart University.

5.2.1 Study results showed that GHG emission from electricity consumption was 81.63% of the total GHG emission. This was because of high electricity consumption. Given that Mahidol Wittayanusorn School Public Organization is a residential high school, high electricity consumption were observed from routine activities and the use of electronic devices in classrooms and residence hall rooms as well as from public services.

5.2.2 The second major source of GHG emission was production of waste which was 16.39% of the total emission. Given that Mahidol Wittayanusorn School Public Organization is a residential high school, most of waste was generated from consumption and services within the school.

Important GHG emission sources in the study were electricity consumption and production of waste. Therefore, to reduce GHG emission, Mahidol Wittayanusorn School Public Organization should reduce the consumption of electricity and the production of waste. Creating awareness, which will lead to the change of behavior in electricity consumption, waste management, waste separation, and waste reuse, is also an important activity. However, the GHG emission reduction activities are largely depend on the budget, technology specialists, human resource management, and the most important factor, the top level management policy to commit to the GHG emission reduction to mitigate the global warming.

5.2.3 GHG emission from other activities including fuel consumption for travel, wastewater generation, water supply consumption, use of paper, and cooking fuel was considered to be minor sources due to the top level management policy to conserve resource consumption.

However, GHG emission was not only depend on the resource consumption or waste generated but also depend on the emission factor. For example, electricity emission factor is 0.561 and water supply emission factor is 0.0264, even though the quantity of electricity and water supply consumed are similar, the GHG emissions are different. The GHG emission from electricity consumption is typically more than the GHG emission from water supply consumption at the same quantity consumed. Therefore, emission factors are considered as a critical factor to the GHG emission.

5.2.4 Types of activity, emission factors, and timing were also important factors for GHG emission especially for the residence halls that the academic term and vocation affects the consumption of electricity, water supply, wastewater generated, and waste generated. During academic vacation from March to April and October, GHG emission is typically less than the academic term from June to September and November to February. However, there was no statistically significant difference at a level of 0.05. There was also no statistically significant seasonal vacation at a level of 0.05.

5.4 Alternatives to GHG emission reduction and carbon offset

Total GHG emission for Mahidol Wittayanusorn School Public Organization was 1,277.59 tonCO_2e or 1.44 tonCO_2e per person per year. The study provided alternatives to GHG emission reduction and carbon offset as follow.

5.4.1 Alternatives to GHG emission reduction.

It was found that the application of 5 electricity saving measures for 7th and 8th girl residence halls clearly reduced the electricity consumption. The cooperation between students and person in charge was also an important factor in achieving the electricity consumption reduction. This was because during the application of electricity saving measures the head of student and the head of residence hall in each floor were asked to turn off restroom lights, hall way lights, and check the air conditioner temperature. The student committee was also asked to announce to students every morning to turn off the light and unnecessary electronic devices and to announce the energy saving tips to help creating awareness to students and staffs. Teachers from girl residence halls also cooperated in turning air conditioners on and off and warning students by knocking doors to have them turn their lights and electronic devices off after midnight as well as rearranging students to stay together in scheduled air conditioned residence hall rooms at full capacity (6 persons). Everyone in Mahidol Wittayanusorn School Public Organization is considered as an important part in GHG emission reduction by reducing the use of electricity.

5.4.2 Carbon offset

Phongwipa (2009) from Thailand Greenhouse Gas Management Organization Public Organization stated that teak trees were able to retain carbon at a value of 4.61 ton/Rai/year and earleaf acacia were able to retain carbon at a value of 9.08 ton/Rai/year. To offset carbon emission from Mahidol Wittayanusorn School Public Organization, plantation of teak trees of 277.13 Rai or earleaf acacia of 140.70 Rai is required. On the other hand, if students and staffs would like to offset their carbon emission, each of them need to plant teak trees of 0.31 Rai/person/year or plant earleaf acacia of 0.16 Rai/person/year.

Rawi Jearwipa et al. (2012) stated that rubber tree plantation area were an important source in the carbon dioxide absorption and retention. They studied the carbon offset values for rubber trees at the age of 25 years. Mass balance and organic carbon in soil relation equations were used to evaluate the values from rubber trees at the age of 2 5 12 16 and 26 years. Their results showed that rubber tree plantation area was able to retain carbon at a range of 50.68 - 193.72 ton/hectare or 8.11 - 30.99 ton/Rai. To offset carbon emission from Mahidol Wittayanusorn School Public Organization, plantation of rubber trees of 6.60 - 25.21 hectare or 41.23 - 157.53 Rai is required. On the other hand, if students and staffs would like to offset their carbon emission, each of them need to plant rubber trees of 0.05 - 0.18 Rai/person/year.

5.5 Research Limitations

5.5.1 Despite the period of the study in 2011, the waste generation information collected during 2012 was analyzed in the study instead of 2011 information. The actual waste generation information of 2011 may vary.

5.5.2 Given that no cooking fuel consumption records for the school cafeteria were documented, the cooking fuel consumption information was obtained from an interview with food store owners/staffs. These consumptions were therefore the approximation, not the actual information.

5.5.3 The actual wastewater generated may vary from the 80% estimation that was used in the study, given that there were no wastewater meters for the school.

5.5.4 Resource utilization and waste generation data for Mahidol Wittayanusorn School Public Organization in 2011 may be affected by the flood event occurred during November 2011 which caused the school to be closed during that time.

5.6 Suggestions for future Study

5.5.1 Data collection for the amounts of waste generated and cooking fuel used for school cafeteria should be conducted in the same period with other data.

5.5.2 The survey or the questionnaire for the consumption behavior of water, electricity, and other resources and waste production and management should be conducted to collect information for further result discussion, given that the behavior of staffs and students directly affects the GHG emission.

5.5.3 GHG emission should be calculated every 5 years to be used as a baseline for GHG emission reduction planning.

5.5.4 Given that the school green area, which was neglected in the study, is able to absorb carbon dioxide, therefore it should be included in furture study.

5.5.5 The campaign for reduction of resource utilization and waste generation for organization should be promoted to create awareness for everyone especially for the youths who are potential members for a society. The further study about the campaign results is also recommended.

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APPENDICES

APPENDIX A

ตารางบันทึกข้อมูลกิจกรรมการปลดปล่อยก๊าซเรือนกระจกของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน จังหวัดนครปฐม ปี 2554

ตารางที่ 1-ก ปริมาณการใช้เชื้อเพลิงและปริมาณก๊าซเรือนกระจกที่เกิดขึ้นจากการใช้เชื้อเพลิง (น้ำมันดีเซล) ของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

เดือน	ปริมาณการใช้เชื้อเพลิง (L)	GHG (kg CO_2e)
มกราคม	1,887	823.26
กุมภาพันธ์	792	345.53
มีนาคม	1,275	556.26
เมษายน	783	341.61
พฤษภาคม	895	390.47
มิถุนายน	1,723	751.71
กรกฎาคม	1,246	543.60
สิงหาคม	2,346	1,023.51
กันยายน	1,595	695.87
ตุลาคม	1,065	464.64
พฤศจิกายน	602	262.64
ธันวาคม	607	264.82
รวม	**14,816**	**6,463.92**

หมายเหตุ; ค่า Emission factor น้ำมันดีเซล = 0.52 หน่วย kg (D=0.839 kg/L)

ตารางที่ 2-ก ปริมาณการปล่อยน้ำเสียและปริมาณก๊าซเรือนกระจกที่เกิดขึ้นจากกระบวนการบำบัดน้ำเสียของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

เดือน	**จำนวนหน่วย (L)**	CH_4 **Emission (kg** CH_4**)**	N_2O **Emission (kg** N_2O**)**	**GHG (kg** CO_2e**)**
มกราคม	7,036,000	20.26	1.96	1093.07
กุมภาพันธ์	5,089,600	14.65	1.42	790.69
มีนาคม	5,114,400	14.72	1.43	794.54
เมษายน	3,829,600	11.02	1.07	594.94
พฤษภาคม	5,488,800	15.80	1.53	852.71
มิถุนายน	5,272,000	15.18	1.47	819.03
กรกฎาคม	6,029,600	17.36	1.68	936.72
สิงหาคม	6,342,400	18.26	1.77	985.32
กันยายน	5,498,400	15.83	1.53	854.20
ตุลาคม	3,389,600	9.76	0.94	526.59
พฤศจิกายน	2,732,000	7.86	0.76	424.42
ธันวาคม	5,557,600	16.00	1.55	863.40
รวม	**61,380,000**	**176.77**	**17.16**	**9,535.68**

หมายเหตุ; ค่า BOD = 16 ; ค่า N = 35.6

; ค่า Emission factor ของ CH_4 = 0.18 หน่วย **kg** CH_4/kg BOD

; ค่า Emission factor ของ N_2O = 0.005 หน่วย **kg** N_2O-N/kg N

; ค่า GWP ของ CH_4 = 25 และ N_2O = 298; ปริมาณน้ำเสียคิดจาก 80% ของน้ำประปา

ตารางที่ 3-ก ปริมาณการใช้น้ำประปาและปริมาณก๊าซเรือนกระจกที่เกิดขึ้นจากการใช้น้ำประปาของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

เดือน	**จำนวนหน่วย (m3)**	**GHG (kg CO_2e)**
มกราคม	8,795	232.18
กุมภาพันธ์	6,362	167.95
มีนาคม	6,393	168.77
เมษายน	4,787	126.37
พฤษภาคม	6,861	181.13
มิถุนายน	6,590	173.97
กรกฎาคม	7,537	198.97
สิงหาคม	7,928	209.29
กันยายน	6,873	181.44
ตุลาคม	4,237	111.85
พฤศจิกายน	3,415	90.15
ธันวาคม	6,947	183.40
รวม	**76,725**	**2,025.54**

หมายเหตุ; ค่า Emission factor น้ำประปา = 0.0264 หน่วย m3

ตารางที่ 4-ก ปริมาณการใช้ไฟฟ้าและปริมาณก๊าซเรือนกระจกที่เกิดขึ้นจากการใช้ไฟฟ้าของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

เดือน	ปริมาณการใช้เชื้อเพลิง (kWh)	GHG (kg CO_2e)
มกราคม	153,400	86,057.4
กุมภาพันธ์	166,000	93,126
มีนาคม	130,040	72,952.44
เมษายน	81,040	45,463.44
พฤษภาคม	148,360	83,229.96
มิถุนายน	202,600	113,658.6
กรกฎาคม	194,520	109,125.72
สิงหาคม	206,360	115,767.96
กันยายน	221,040	124,003.44
ตุลาคม	139,960	78,517.56
พฤศจิกายน	55,640	31,214.04
ธันวาคม	159,960	89,737.56
รวม	**1,858,920**	**1,042,854.12**

หมายเหตุ; ค่า Emission factor ไฟฟ้า = 0.5610 หน่วย kWh

ตารางที่ 5-ก ปริมาณการใช้กระดาษและปริมาณก๊าซเรือนกระจกที่เกิดขึ้นจากการใช้กระดาษของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

เดือน	กระดาษชำระม้วนใหญ่	กระดาษเช็ดปาก	กระดาษเทา-ขาว	กระดาษโปสเตอร์แข็ง	กระดาษโปสเตอร์อ่อน	กระดาษวาดเขียน 100 ปอนด์	กระดาษการ์ด 180 แกรม	กระดาษปก 120 แกรม	กระดาษถ่ายเอกสาร 80 แกรม (สี)	กระดาษถ่ายเอกสาร 80 แกรม	กระดาษถ่ายเอกสาร 70 แกรม
มกราคม	96	14	5.33	3.17	4.40	1.25	1.96	2.41	7.23	59.84	0
กุมภาพันธ์	96	0	0.67	3.08	0.20	10.75	2.5	5.61	3.61	34.54	366.97
มีนาคม	40	0	0.33	1.00	0.80	0.42	1.78	0.27	4.42	38.15	0
เมษายน	40	0	2.00	1.17	0.55	0	1.25	0.01	0.40	30.12	366.97
พฤษภาคม	40	1	0.25	0.50	1.75	0	2.14	6.15	4.02	38.55	0
มิถุนายน	80	15	1.92	0.42	1.85	17.17	1.78	5.08	0.80	34.94	366.97
กรกฎาคม	48	0	6.67	0.83	0.35	0.17	1.07	1.33	1.20	26.10	0
สิงหาคม	80	2	46.92	24.17	13.50	0	3.21	26.47	4.42	23.69	0
กันยายน	120	0	0	0	2.95	0.08	7.13	3.48	10.04	46.59	366.97
ตุลาคม	40	6	0	0	1.75	2.67	0.53	1.27	12.05	8.03	0
พฤศจิกายน	0	0	0	0	0	0	0	0.53	0.80	12.45	0
ธันวาคม	40	18	0	0	0.25	10.42	0.53	0.17	5.22	24.50	366.97
รวม	**720**	**56**	**64.08**	**34.33**	**28.35**	**42.92**	**23.89**	**53.68**	**54.22**	**377.51**	**1,834.86**

- รวมปริมาณการใช้กระดาษเท่ากับ 3,289.84 kg
- มีการปล่อยก๊าซเรือนกระจกจากจากการใช้กระดาษเท่ากับ 2,418.03 kg **CO_2e**

หมายเหตุ; ค่า Emission factor กระดาษ = 0.7350 หน่วย kg

ตารางที่ 6-ก ปริมาณขยะและปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์ในแต่ละวันที่เกิดขึ้นในโรงเรียนมหิดลวิทยานุสรณ์ ปีการศึกษา 2554 ช่วงเปิดเทอม

วัน	**น้ำหนักขยะ (kg)**	**GHG Emission (kgCO_2e)**
จันทร์	353	803.32
อังคาร	279	634.92
พุธ	247	562.10
พฤหัสบดี	269	612.16
ศุกร์	334	760.08
เสาร์	258	587.13
อาทิตย์	324	737.32
รวม (ต่อสัปดาห์)	2,064	4,697.03
ปริมาณขยะที่เกิดขึ้น ปล่อย GHG ทั้งหมด (35 สัปดาห์)		164,396.00

- ปริมาณขยะที่เกิดขึ้นในช่วงเปิดเทอมมีการปลดปล่อยก๊าซเรือนกระจกเท่ากับ 164,396.00 kg **CO_2e**

หมายเหตุ ; นำปริมาณรวมการปลดปล่อยก๊าซเรือนกระจกทั้งสัปดาห์คูณ 35 สัปดาห์ในช่วงเปิดเทอม

ตารางที่ 7-ก ปริมาณขยะที่เกิดขึ้นในช่วงสัปดาห์เปิดเทอมของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

ประเภทขยะ	**ร้อยละ**	**จันทร์**	**อังคาร**	พุธ	พฤหัสฯ	**ศุกร์**	**เสาร์**	**อาทิตย์**	**รวม**	**factor**
ขวดพลาสติก (PEP) ขวดใส	5.12	68.14	53.85	47.68	51.92	64.47	49.80	62.54	398.40	3.77
ถุงพลาสติก (PP) ถุงใส	2.7	22.86	18.07	16.00	17.42	21.63	16.71	20.99	133.69	2.399
ถุงพลาสติก (PE) ถุงขุ่น	3.02	16.20	12.81	11.34	12.35	15.33	11.84	14.87	94.75	1.52
แก้ว Glass	9.73	40.77	32.22	28.53	31.07	38.58	29.80	37.42	238.38	1.187
กระดาษ Paper	15.75	82.03	64.84	57.40	62.51	77.62	59.96	75.29	479.66	1.4755
ผ้าอนามัย	9.36	132.16	104.46	92.48	100.71	125.05	96.60	121.31	772.76	4
กล่องพลาสติก	2.15	12.80	10.11	8.95	9.75	12.11	9.35	11.75	74.83	1.6862
อลูมิเนียม (กระป๋อง)	4.17	65.23	51.56	45.64	49.71	61.72	47.68	59.87	381.41	4.4315
เหล็ก	1.03	6.40	5.06	4.48	4.88	6.05	4.68	5.87	37.42	1.76
โฟม	0.5	4.05	3.20	2.84	3.09	3.84	2.96	3.72	23.71	2.2971
อาหาร	35.2	314.37	248.47	219.97	239.56	297.45	229.76	288.54	1838.12	2.53
ใบไม้/กิ่งไม้	7.5	1.95	1.54	1.36	1.48	1.84	1.42	1.79	11.38	0.0735
หนัง/ยาง	2.44	26.96	21.31	18.86	20.54	25.51	19.70	24.74	157.63	3.13
สิ่งทอ	1.33	9.39	7.42	6.57	7.16	8.88	6.86	8.62	54.90	2
รวม	**100**	**803.32**	**634.92**	**562.10**	**612.16**	**760.08**	**587.13**	**737.32**	**4697.03**	

ตารางที่ 8-ก ปริมาณขยะและปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์ในแต่ละวันที่เกิดขึ้นในโรงเรียนมหิดลวิทยานุสรณ์ ปีการศึกษา 2554 ช่วงปิดเทอม

วัน	น้ำหนักขยะ (kg)	GHG Emission (kgCO_2e)
จันทร์	174	396.43
อังคาร	158	359.98
พุธ	165	375.93
พฤหัสบดี	169	385.04
ศุกร์	182	414.66
เสาร์	112	255.17
อาทิตย์	138	314.41
รวม (ต่อสัปดาห์)	1,098	2,501.62
ปริมาณขยะที่เกิดขึ้น ปล่อย GHG ทั้งหมด (18 สัปดาห์)		45,029.24

- ปริมาณขยะที่เกิดขึ้นในช่วงปิดเทอมมีการปลดปล่อยก๊าซเรือนกระจกเท่ากับ 45,029.24kg **CO_2e**

หมายเหตุ ; นำปริมาณรวมการปลดปล่อยก๊าซเรือนกระจกทั้งสัปดาห์คูณ 18 สัปดาห์ในช่วงปิดเทอม

ตารางที่ 9-ก ปริมาณขยะที่เกิดขึ้นในช่วงสัปดาห์ปิดเทอมของโรงเรียนมหิดลวิทยานุสรณ์ องค์การมหาชน ปี พ.ศ.2554

ประเภทขยะ	ร้อยละ	จันทร์	อังคาร	พุธ	พฤหัสฯ	ศุกร์	เสาร์	อาทิตย์	รวม	factor
ขวดพลาสติก (PEP) ขวดใส	6.42	42.11	38.24	39.94	40.90	44.05	27.11	33.40	265.75	3.77
ถุงพลาสติก (PP) ถุงใส	2.16	9.02	8.19	8.55	8.76	9.43	5.80	7.15	56.90	2.399
ถุงพลาสติก (PE) ถุงขุ่น	2.8	7.41	6.72	7.02	7.19	7.75	4.77	5.87	46.73	1.52
แก้ว Glass	7.35	15.18	13.78	14.40	14.74	15.88	9.77	12.04	95.79	1.187
กระดาษ Paper	14.75	37.87	34.39	35.91	36.78	39.61	24.38	30.03	238.96	1.4755
ผ้าอนามัย	7.5	52.20	47.40	49.50	50.70	54.60	33.60	41.40	329.40	4
กล่องพลาสติก	3.52	10.33	9.38	9.79	10.03	10.80	6.65	8.19	65.17	1.6862
อลูมิเนียม (กระป๋อง)	4.5	34.70	31.51	32.90	33.70	36.29	22.33	27.52	218.96	4.4315
เหล็ก	2.55	7.81	7.09	7.41	7.58	8.17	5.03	6.19	49.28	1.76
โฟม	2.8	11.19	10.16	10.61	10.87	11.71	7.20	8.88	70.62	2.2971
อาหาร	30.5	134.27	121.92	127.32	130.41	140.44	86.42	106.49	847.27	2.53
ใบไม้/กิ่งไม้	7.65	0.98	0.89	0.93	0.95	1.02	0.63	0.78	6.17	0.0735
หนัง/ยาง	3.7	20.15	18.30	19.11	19.57	21.08	12.97	15.98	127.16	3.13
สิ่งทอ	3.8	13.22	12.01	12.54	12.84	13.83	8.51	10.49	83.45	2
รวม	**100**	**396.43**	**359.98**	**375.93**	**385.04**	**414.66**	**255.17**	**314.41**	**2501.62**	

ตารางที่ 10-ก ปริมาณก๊าซเรือนกระจกที่เกิดจากปริมาณการใช้ก๊าซหุงต้มของโรงอาหาร โรงเรียนมหิดลวิทยานุสรณ์ ปี 2554

ร้านที่/ประเภทร้าน	ขนาดถัง (kg)	จำนวนถัง/เดือน		รวมน้ำหนัก (kg)	
		เปิดเทอม	ปิดเทอม	เปิดเทอม	ปิดเทอม
1 ร้านเครื่องดื่ม	15	1	0.5	15	7.5
2 ร้านผลไม้	15	1	0.5	15	7.5
3 ร้านขนมหวาน	15	2	1	30	15
4 ร้านข้าวแกง	15	5	2	75	30
5 อาหารว่าง ลูกชิ้นทอด	15	4	1	60	15
6 ข้าวแกง	15	5	2	75	30
7 ก๋วยเตี๋ยว	15	10	4	150	60
8 ข้าวมันไก่	15	4	2	60	30
9 ข้าวราดแกง	15	6	3	90	45
10 ข้าวราดแกง	15	8	3	120	45
11 อาหารอีสาน	15	4	1	60	15
12 ข้าวราดแกง	15	10	4	150	60
13 ก๋วยเตี๋ยว	15	8	3	120	45
รวมน้ำหนักก๊าซที่ใช้ต่อเดือน				1,020	405
Emission Factor ของก๊าซหุงต้ม (LPG) จากก๊าซธรรมชาติ (kg)				0.4980	0.4980
GHG Emission **(kgCO_2e)** ต่อเดือน				507.96	201.69
เปิดเทอม มิ.ย.-ก.ย. และ พ.ย.-ก.พ. (8 เดือน) ปิดเทอม มี.ค.-พ.ค. และ ต.ค. (4 เดือน)				4,063.68	806.76
GHG Emission **(kgCO_2e)** ต่อปี				4,870.44	

APPENDIX B

ตัวอย่างกิจกรรมที่มีการปล่อยและดูดกลับก๊าซเรือนกระจกแยกตามประเภทขององค์กร

ตาราง ข-1 องค์กรประเภทสถาบันการศึกษา

ประเภทของกิจกรรม	ตัวอย่างกิจกรรมที่มีการปล่อยหรือดูดกลับก๊าซเรือนกระจก	วิธีการคำนวณ
ประเภทที่ 1	การเดินทางภายในและภายนอก สถาบันการศึกษาด้วยยานพาหนะขององค์กร	1) ปริมาณน้ำมันเชื้อเพลิงที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของน้ำมันเชื้อเพลิง 2) ระยะทาง x น้ำหนักบรรทุก x ค่าแฟกเตอร์การปล่อย ตามประเภทของพาหนะที่ใช้ 3) (ระยะทาง/อัตราการสิ้นเปลืองเชื้อเพลิง) x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก แยกตามชนิดของน้ำมันเชื้อเพลิง
	การทำปฏิกิริยาเคมีและการเผาไหม้เชื้อเพลิงที่ก่อให้เกิด ก๊าซเรือนกระจกในกิจกรรมการเรียนการสอน	1) ปริมาณก๊าซเรือนกระจกที่เกิดขึ้นตามปริมาณมวลสารสัมพันธ์ของปฏิกิริยาเคมี 2) ปริมาณเชื้อเพลิงที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกตามชนิดของเชื้อเพลิง
	การใช้สารทำความเย็นของเครื่องปรับอากาศภายในองค์กร	ปริมาณสารทำความเย็น x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของสารทำความเย็น
	การใช้สารดับเพลิง	ปริมาณสารดับเพลิง x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของสารเคมีที่ใช้เป็นสารดับเพลิง

	การใช้ปุ๋ยเคมี	ปริมาณปุ๋ยเคมีที่มีการใช้จริง x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามประเภทและสูตรของปุ๋ยที่ใช้
	การบำบัดน้ำเสียที่องค์กรเป็นผู้ดำเนินการ	1) การคำนวณอ้างอิงตาม UNFCCC (2006) 2) การคำนวณอ้างอิงตาม IPCC (2006)
ประเภทที่ 2	การใช้พลังงานไฟฟ้าที่ซื้อจากภายนอก	ปริมาณไฟฟ้าที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก
ประเภทที่ 3	การเดินทางไปกลับระหว่างองค์กรและที่พักของบุคลากร	1) ปริมาณน้ำมันเชื้อเพลิงที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของน้ำมันเชื้อเพลิง 2) ระยะทาง x น้ำหนักบรรทุก x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามประเภทของพาหนะที่ใช้ 3) (ระยะทาง/อัตราการสิ้นเปลืองเชื้อเพลิง) x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกแยกตามชนิดของน้ำมันเชื้อเพลิง
	การเดินทางระหว่างคณะภายในองค์กรด้วยยานพาหนะส่วนตัว	1) ปริมาณน้ำมันเชื้อเพลิงที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของน้ำมันเชื้อเพลิง 2) ระยะทาง x น้ำหนักบรรทุก x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามประเภทของพาหนะที่ใช้ 3) (ระยะทาง/อัตราการสิ้นเปลืองเชื้อเพลิง) x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกแยกตามชนิดของน้ำมันเชื้อเพลิง
	การเดินทางไปราชการ	1) ปริมาณน้ำมันเชื้อเพลิงที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของน้ำมันเชื้อเพลิง 2) ระยะทาง x น้ำหนักบรรทุก x ค่าแฟกเตอร์

		การปล่อยก๊าซเรือนกระจก ตามประเภทของพาหนะที่ใช้ 3) (ระยะทาง/อัตราการสิ้นเปลืองเชื้อเพลิง) x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกแยกตามชนิดของน้ำมันเชื้อเพลิง 4) ระยะทางที่เดินทาง x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกของการเดินทางโดยเครื่องบิน(กรณีเดินทางด้วยเครื่องบินโดยสาร)
ประเภทที่ 3	การใช้สารเคมีเพื่อทำความสะอาดโดยบริษัทจ้างเหมาช่วง	ปริมาณสารเคมีที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามชนิดของสารเคมี
	การใช้น้ำประปา	ปริมาณน้ำประปาที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกของน้ำประปา
	การใช้วัสดุสำนักงาน และวัสดุสิ้นเปลือง เช่น กระดาษ	ปริมาณกระดาษที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกของกระดาษ
	การใช้พลังงานไฟฟ้า และก๊าซหุงต้มของร้านค้าและร้านอาหารที่มาเช่าพื้นที่ภายในองค์กร	ปริมาณก๊าซหุงต้มที่ใช้ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจกของการเผาไหม้ก๊าซหุงต้ม
	การกำจัดขยะ	ปริมาณขยะแยกตามองค์ประกอบ x ค่าแฟกเตอร์การปล่อยก๊าซเรือนกระจก ตามองค์ประกอบของขยะ

ที่มา : องค์การบริหารจัดการก๊าซเรือนกระจก องค์การมหาชน, 2554

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