Evaluation and Mitigation of Greenhouse Gas Emission from President's Office Buildings, Prince of Songkla University, Hatyai, Thailand

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ABSTRACT

The importance of carbon footprint for organization is to investigate the components and activities which are outstanding engagements involving high Greenhouse gases (GHG) emissions. Evaluation of the organizational GHG emissions from operational activities of administrative buildings of Prince of Songkla University (PSU), Hatyai campus was conducted in this study. The President's Office (PO) has a 6,988 m^2 functional area including executive, administrative, and meeting operations. The organizational scope was focused in terms of operational control. The amount of GHG emissions of about 548 ton CO_2 eq./yr was average released from PO operations during 2015 and 2016 (542 and 553 ton CO_2 eq, respectively). The highest GHG emissions was indirect emission (scope 2) which resulted from electricity consumption in PO buildings, emitting 334 and 358 ton CO_2 eq. in 2015 and 2016 respectively. More than half of whole electricity consumption arised from Air-conditioning (AC) system. Approximately 75% of the energy used in the building is attributed to administrative operations. Some effective solutions in reducing energy consumption of administrative building were suggested. The energy measures were divided into two different categories, reaching by internal and external factors. The scenarios were estimated for energy saving and GHG mitigation. Energy saving 11% was calculated by reduction AC work load to 5 hrs. Moreover, the most effective scenarios were identified of about 20% electricity comsumption reduction by mutualized Light-emitting Diode (LED) lighting retrofit with reduction operating time to 7 hrs and reduced operating time of AC system (5 hrs) and IT device (7 hrs). Furthermore, the energy saving model was appropriately considered for allocated support fund from external source. Therefore, the energy efficiency improvement requires holistic measures for sustainable energy building. The convergent association also reasonably brought about global warming mitigation.

Keywords: Carbon Footprint for Organization, Energy Efficiency, Energy Performance, Greenhouse Gases Emissions, Global Warming Mitigation

ชื่อวิทยานิพนธ์ แนวทางการประเมินและการลดการปล่อยก๊าซเรือนกระจกของอาคารสำนักงานอธิการบดี มหาวิทยาลัยสงขลานครินทร์ อำเภอหาดใหญ่ จังหวัดสงขลา

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บทคัดย่อ

ความสำคัญของการจัดทำคาร์บอนฟุตพรินท์ขององค์กร คือ การประเมินการปล่อยก๊าซเรือนกระจกจากกิจกรรมต่างๆ ของหน่วยงานในองค์กร งานวิจัยนี้มุ่งเน้นการประเมินการปล่อยก๊าซเรือนกระจกจากกิจกรรมการดำเนินงานของอาคารบริหารสำนักงานอธิการบดี มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่ ซึ่งอาคารสำนักงานอธิการบดี มีพื้นที่ 6,988 ตร.ม. แบ่งได้เป็น 3 ส่วน คือ ฝ่ายผู้บริหาร ฝ่ายธุรการ และฝ่ายจัดประชุม ขอบเขตองค์กรเป็นแบบควบคุม ซึ่งควบคุมโดยการดำเนินงาน ระหว่างปี ค.ศ. 2015 ถึง 2016 มีปริมาณการปล่อยก๊าซเรือนกระจกเฉลี่ย 548 ตัน ก๊าซคาร์บอนไดออกไซด์เทียบเท่า (543 และ 554 ตัน ก๊าซคาร์บอนไดออกไซด์เทียบเท่า ในปี 2015 และ ปี 2016 ตามลำดับ) ปริมาณก๊าซเรือนกระจกถูกปล่อยสูงสุดจากกิจกรรมการใช้ไฟฟ้าภายในอาคารสำนักงาน ซึ่งอยู่ในขอบเขต 2 การปล่อยทางอ้อม โดยคิดเป็น 334 และ 358 ตัน ก๊าซคาร์บอนไดออกไซด์เทียบเท่า ในปี 2015 และ ปี 2016 ตามลำดับ ส่งผลให้ค่าใช้จ่ายในการดำเนินการสูงสุด ปริมาณการใช้ไฟฟ้าส่วนใหญ่มาจากระบบเครื่องปรับอากาศ ซึ่งในการใช้พลังงานร้อยละ 75 มาจากสำนักงานธุรการ งานวิจัยนี้ได้เสนอแนวทางการลดการใช้พลังงานของอาคารสำนักงานธุรการ โดยมาตรการประหยัดพลังงานในอาคารมาจาก 2 ปัจจัย คือ ปัจจัยภายในและภายนอก แผนการประหยัดพลังงานและลดการปล่อยก๊าซเรือนกระจกถูกสร้างสรรค์จากหลายวิธี หากลดระยะเวลาการเปิดเครื่องปรับอากาศเป็น 5 ชม. คาดว่าจะสามารถประหยัดพลังงานได้ร้อยละ 11 ในขณะที่ การเปลี่ยนหลอดไฟเป็น Light-emitted Diode (LED) โดยมีระยะเวลาการเปิด 8 ชม. จะสามารถลดการใช้ไฟฟ้าได้ ร้อยละ 7 ยิ่งกว่านั้น หากสามารถใช้วิธีการเปลี่ยนหลอดไฟ LED ควบคู่กับการลดระยะเวลาการใช้งานเครื่องใช้ไฟฟ้า โดยใช้แสงสว่าง 7 ชม. เครื่องปรับอากาศ 5 ชม. และอุปกรณ์ด้านเทคโนโลยีสารสนเทศ 7 ชม. จะสามารถลดการใช้ไฟฟ้าได้มากถึงร้อยละ 20 รูปแบบการประหยัดพลังงานได้รับการพิจารณาทุนสนับสนุนงบประมาณจากหน่วยงานภายนอกอย่างเหมาะสม ดังนั้นการพัฒนาประสิทธิภาพการใช้พลังงานต้องคำนึงถึงมาตรการแบบองค์รวม เพื่อความยั่งยืนของการใช้พลังงานในอาคาร ทั้งยังนำไปสู่การลดสภาวะโลกร้อนเช่นกัน

คำสำคัญ: คาร์บอนฟุตพรินท์สำหรับองค์กร, ประสิทธิภาพพลังงาน, การประเมินพลังงาน, การปล่อยก๊าซเรือนกระจก, การลดสภาวะโลกร้อน

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CHAPTER 1

INTRODUCTION

1.1. Background

Nowadays, human activities have increasingly involved in anthropogenic greenhouse gases (GHGs) emission to the atmosphere such as fossil fuel combustion from coal, oil, natural gas, deforestation, agricultural activities, including release of aerosols. These greenhouse gases, mentioned in the Kyoto Protocol (Carbon Trust, 2012) are significantly concerned to be the major cause of climate change worldwide. Previous reports from the Intergovernmental Panel on Climate Change emphasized on the correlation between the increase of CO_2 emissions and climate change (IPCC, 2013). Providentially, the awareness of the environmental impact of this crisis including GHGs mitigation is intensively highlighted as global achievement.

Carbon footprint (CF) is a definition used to explain the measurement of GHGs emissions from an individual, product, or organization. Wiedmann (2007) described CF as the emissions of CO_2 which was directly and indirectly affected by an activity during the entire lifecycle of a product or service. However, not only CO_2 which was emitted from human activities, but other GHGs may also release. Therefore, CF should be included to account for these gases. Thus, to simplify CF assessments, GHGs emission was defined in terms of carbon dioxide equivalent (CO_2 eq). Equivalent means a quantity that describes, for a given mixture and amount of GHGs, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years) (Wikipedia, 2007) and included in the assessment (Tjandra et al., 2016).

A great number of organizations from educational to non-governmental institutes have been using CF evaluation for many purposes. A good example is the universities which have been using this evaluation to achieve many aims such as applying an educational support for students and researchers as well as to assess the sustainability of their work. Apart from this, higher educational institutes (HEI) also use this evaluation to promote green universities as well as monitor sustainability development (Lozano et al., 2013).

CF evaluation has been applied worldwide in a variety of organizations (non-governmental organizations, business, enterprise, public authorities, and educational institutions) and at the difference scale (personal, universities, cities, regional, countries and international) (Waas et al., 2012). University also calculated their carbon footprints for versatile approaches: e.g. to integrate sustainability into work performance, to perform a sustainability assessment of their operations, to use as educational tool with students and researches, to use for policy development. Performing a CF analysis is a strategy for HEI to practice what they teach, to monitor sustainability encouragement, and to raise public awareness for the university as a low carbon community. This project emphasize on evaluation of carbon performance calculation and mitigation of GHGs emission for administrative sector of university. Based on the results, the scenarios for sustainable environmental management were suggested. Sustainable development of university was discussed with adaptive educational research and proposed to university executive management team.

1.2. Rationale

One of the HEIs to calculate CF is the Prince of Songkla University (PSU), Hatyai campus, a Thai HEI located in Hatyai district, 30 km from Songkla province. PSU provides 19 professional bachelor programs in departments: Dentistry, Sciences, Nursing, Engineering, Agro-Industry, Natural Resources, Business Studies, Liberal art, etc. In 2007, PSU counted 34,000 students. During the past ten years, numerous educational, operational and management initiatives were started to integrate sustainable development within the organization, calculating the carbon performance was one of these initiatives (Lambrechts and Liedekerke, 2014). Administrative organization is the essential unit both in public, private and business organization including higher education institutions. This unit controls the important operations. For instance, finance, administrative, purchasing, transportation, conference and meeting, etc. For PSU, President’s Office served as support unit provided facility for education and administration. Therefore, it is the crucial unit to sustain university development both policy and education through low carbon operational approach. This research focuses on creative and innovative research carbon performance calculation and characterization of the current situation and determines the possibility to develop environment in university.

This project focuses on the calculation of the carbon emission and mitigation in PO, and the possibilities to use it for campus administrative operations, policy development and educational purposes. This research starts with the inventory used for carbon footprint elaborates on critiques on the use of carbon footprint and presents of results at PO, PSU. Section highlights discussion on the use of CF within campus operations, policy development and educational purposes. The result provides general conclusion on the application of low carbon operation in higher education as a sustainable operational strategies.

1.3. Research Questions

1) How much of the GHGs emission from President’s office buildings ?

2) How to mitigate GHGs emission from President’s office buildings ?

3) How much does it cost for electricity consumption in President’s office buildings ?

1.4. Expect Outcome

Since the study is in-depth calculating carbon emission from PO buildings in order to finding the number of carbon releasing and the main emission source that the most produced. So the expected outcome is finding possible approach to minimize carbon emission from the building and giving the scientific scenarios.

1.5. Research Scope

This study focused on GHGs emission and mitigation of President’s office, Prince of Songkla University in fiscal year 2015 and 2016 following the Thailand Greenhouse Gas Management Organization (TGO) guideline. The definition was explained in methodology (Chapter 2) and Appendix A as well. The boundary of research was operational control approach with geographical operation for activities in PO buildings. Finally, carbon footprint, mitigation scenarios, and policy suggestion were found out from this evaluation. Carbon footprint emission factors (EFs) applied the Intergovernmental Panel on Climate Change's 100-year GWP characterization factors to determine carbon dioxide equivalents (kg CO_2 eq) on a per person basis for each mode of activities (IPCC, 2007). The functional units used in this study were impact per year (CO_2 eq/yr), impact per person per year (CO_2 eq / capita / yr), and impact per area (CO_2 eq/ m^2). Scenarios were figured out in terms of electricity consumption per year (kWh/yr), and policy suggestion was explained through typical models.

1.6. Research Objectives

1. To investigate and calculate the carbon footprint of the President's Office buildings, Prince of Songkla University
2. To identify and quantify carbon emission mitigation possibility
3. To evaluate cost of administration and energy efficiency

1.7. Literature Reviews

1.7.1. Greenhouse Gas Emission

The accounting of Greenhouse gas (GHG) emissions has become a field of concern and growing interest for governmental and nongovernmental organizations agencies around the world by reason of the extending opportunities in GHG emission registries and emissions reporting, the growing pressure for GHG accountability in the public sector, and the prospective for carbon offsets generation. In the U.S., the GHG emissions accounting and reporting practice is rapidly becoming more streamlined and standardized, though it is still plagued with variations owing to the inconsistencies in reporting requirements for different public and private programs, and the diversity of emerging programs and policies in distinct jurisdictions.

The process of incorporating atmospheric carbon into forest, soils, ocean, or other natural environment is known as carbon sequestration. Those processes or resources that absorb carbon dioxide from the atmosphere are normally denoted as "carbon sinks" on account of their capacity to take up GHG emissions. Even though, calculations of carbon sequestration can be tough to execute because of estimation methodologies complexity and uncertainties, data requirements. Geographic location, humidity, temperature, and species dominance are among many important factors that can influence the carbon sequestered rate of forested land in an investigated area. The affects impacting factors calculation, which is indirectly related with the GHG effects or carbon cycle, indicate a more complex level of the calculation methods (Ravin and Raine, 2007).

1.7.2. Sources of GHG and Units of Measurement

1.7.2.1 GHG Types

The seven gases of the fifth assessment report (AR5) of the intergovernmental Panel on Climate Change (IPCC) on Climate Change 2014 (IPCC, 2014) are considered in the carbon footprint calculation. The gases are carbondioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and Nitrogen trifluoride (NF_3).

1.7.2.2 Equivalency Factors of Global Warming Potential

The Global Warming Potential (GWP) was established for comparison of environmental impacts of different gases. The time period generally provided for GWPs is 100 years from beginning. The evaluation of GHG emissions are determined in terms of mass of carbon dioxide equivalents (CO_2 eq) based on the transformation of other GHGs according to their respective equivalency factors for global warming potential over 100 years as per the latest version of IPCC report. GWPs could For instance, the equivalency factor for global warming potential of CH_4 over 100 years as compared to CO_2 is 25; this means that 1 kg of CH_4 impact on global warming equivalent to 25 kg of CO_2 over 100 years. In other words, the emission of 1 kg CH_4 is 25 kg CO_2 equivalent. Global warming potential factors for required GHGs, IPCC's Fourth Assessment Report (AR4) (IPCC, 2013) was examined as follow (Table 1.1).

Table 1.1 GHG and the Global Warming Potential

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

Source: IPCC (2013)

1.7.2.3 Sources of GHG Emissions

These following sources of GHG emissions are enumerated in carbon footprint:

- Raw material acquisition
- Electricity production and consumption
- Combustion processes
- Chemical reactions in industry
- Processing, manufacturing and operations
- Transportation of entire process
- Leakage of refrigerants and other fugitive gases
- Livestock, agricultural production and waste generation
- Waste and waste management

1.7.2.4 CO_2 Emissions from Fossil Fuel and Biogenic Sources

CO_2 emissions from fossil fuel are included in carbon footprint calculation but CO_2 emissions from biogenic sources are excluded.

1.7.2.5 Unit of Analysis

Unit for GWPs calculation could be obtained from common unit of measure and guide the policymaker to compare GHGs emission mitigation possibility with potential sectors and gases. The unit of analysis was set as per unit of product such as per kg, per liter, per piece, etc.

1.7.2.6 Carbon Offset

Carbon offset, both complusary[1] and voluntary[2], is excluded in carbon footprint calculation. (The National Technical Committee on Carbon Footprint of Product, 2010)

Note:

[1] Carbon offset from Joint Implementation (JI) or Clean Development Mechanism (CDM) or Emission Trading (ET)

[2] Carbon offset from CDM/JI but not certified by the competent body of the country to which the project belongs, or not registered with the UNFCCC management committee of CDM (The National Technical Committee on Carbon Footprint of Product, 2010)

1.7.2.7 Carbon Footprint Evaluation

The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Sprangers, 2011). Furthermore, "the 'total amount' of CO_2 is physically measured in mass units (kg, t, etc)". This is the definition for carbon emission evaluation in this thesis.

1.7.3. Carbon Footprint Standards, Protocols, and Principles

1.7.3.1 Standard and Protocol

Environmental information is required in order to make sustainable consumption decisions. In view of this, a new indicator, the carbon footprint has been developed over the last decade (Peters, 2010, Wiedmann and Minx, 2008). The goal of decreasing carbon footprint could be an important contribution for fascinating innovation while energizing politicians to promote sustainable consumption. Carbon footprint is an area of growing interest and becoming an active environmental research topic on which abundance of methodologies are currently underway in a number of countries (Peters, 2010, Wiedmann et al., 2011). To ensure the successful implementation of a Carbon footprint indicator, a single cut-off criterion and data source are required in both approaches in order to enable comparability. (Alvarez et al., 2014).

GHG emission accounting that has been practiced nowadays is following these important bases of standards and protocols:

- The technical reports and methodology guidelines of the Intergovernmental Panel on Climate Change (IPCC)
- ISO 14064

ISO 14064-1:2006 develops principles and requirements inventory at the organization level for quantification and reporting of GHG emissions and removals. It includes requirements for the design, development, management, reporting and verification of an organization's GHG inventory.

ISO 14064-2:2006 designs principles and requirements including provides GHG emission mitigation guidance for quantification, monitoring and reporting of activities which reducing GHG emissions or removal developments for organization project. It includes requirements for planning a GHG project, specifying and choosing GHG sources, sinks and reservoirs depend on the project performance of monitoring, quantifying, and reporting GHG project performance, baseline scenario, including data quality and reducing uncertainty.

ISO 14064-3:2006 provides fundamentals, requirements, and guidance for validation and verification of GHG affirmation. It is possibly applied to GHG project quantification including evaluating, and documenting conducted for organization level involved with ISO 14064-1 or ISO 14064-2 guidance.

According to ISO 14064 (2006), three different methodologies of quantifying greenhouse gases (GHGs) can be used: calculation, measurement and a combination of calculation and measurement. Measurement can either be continuous or intermittent. Calculation can be based on the following things (ISO, 2006):

- GHG activity data multiplied by GHG emission or removal factors
- The use of models
- Facility-specific correlations
- Mass balance approach

- According to Schaltegger & Burritt (2000), an environmental information system is significantly defined. Life-cycle Assessment (LCA) is an approach to account emvironmental impact. LCA evaluate the physical impact of a product, process, services, infrastructure, activities related to the environment. LCA monitors all environmental inventory and impact during entire life-cycle. Collecting the typical information for calculation of the life-cycle is not easily process. When a company decided to evaluate LCA, data from related corporate supplier, company, and other organizations is required to involve with reduction of environmental impact. Additionally, government and customer has the influence to initiate incentive and encorage for company in investigating environmental impact assessment. Therefore, LCA is an important tool to quantify environmental performance (Schaltegger & Burritt, 2000).
- PAS 2050 (BSI, 2008) is a notable standard for calculate carbon footprint of products.

The first step in calculating the carbon footprint of products is to present overall process flow according to PAS 2050 guidance (Carbon Trust & Crown, 2008). Process flow is a diagram that provide all of different materials, processes, and activities of the product’s life cycle related to emission impacts. For life cycle assessment of services and organization, an evaluation based on sources and activities involved in emissions was carried out.

The second step is identifying the scope and boundaries of the evaluation. In organizational life cycle assessment, boundary was indicated and explained in accordance with the scope and objective of the project. The organization chart could present structure of organization, operations, value chain, and their interrelationships.

The comprehensive life cycle assessment provided all input and output covering in organization's activities with validation.

The third step for carbon footprint evaluation was data collection. Data should be complied with 5 principles for calculation including complete, relevant, accurate, consistent, and transparent according to PAS 2050 (Carbon Trust & Crown, 2008).

- The Greenhouse Gas Protocol (GHG Protocol) of the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD).

The World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD) started to establish its corporate standard in 1998. The revised edition of the GHG Protocol Corporate Standard was published in 2004, a culmination of a two-year multi-stakeholder dialogue, designed to build on experience gained from using the first edition. It comprises of additional guidance, case studies, appendices, and a new chapter on setting a GHG target. The GHG Protocol Corporate Standard provides standards and guidance for companies and other types of organizations preparing a GHG emissions inventory. It includes the accounting and recording of the seven greenhouse gases covered by the Kyoto Protocol—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) (Chomkhamsri and Pelletier, 2011) including nitrogen trifluoride (NF_3) which was added in the fifth Assessment Report (AR5) of the intergovernmental Panel on Climate Change 2014 (IPCC, 2014).

Specifically, the Greenhouse Gas Protocol (WRI & WBSCD, 2003) and the Campus Carbon Calculator (Clean Air-Cool Planet, 2010) become the most usable methods for calculating the CO_2 emissions of a university (Chomkhamsri and Pelletier, 2011).

Sprangers (2011) presented a big difference among the Greenhouse Gas Protocol (GHGP) (WBCSD & WRI, 2003) and PAS 2050 is that the GHGP copes with the carbon footprint of organizations meanwhile PAS 2050 focuses on products or services. The GHGP provides a number of steps to assess the carbon footprint:

- Classify source of GHG emissions
- Define method for GHG emissions calculation
- Gather activity data and select standard emission factors
- Use calculation tools
- Summarize GHG emissions data to organization

There is the organization responsible for GHG management in Thailand called Thailand Greenhouse Gas Management Organization (Public Organization) or TGO which inventory in this report was applied from TGO guideline for carbon footprint for organization. The description will be identified in next section.

Although, there exist many programs for reporting, registering and trading emissions in many countries around the world, those programs are predominantly followed the standards and protocols of the IPCC guidelines and GHG Protocol, that are globally recognized as best practice in GHG emissions accounting. For example, an inventory of U.S. GHG national emission inventories and sinks from 1990 to 2005 was released by the USEPA in April 2007. The inventory is based on the IPCC guidelines including the updates guidelines for National Greenhouse Gas Inventories that were presented in 2006.

Figure 1.1, adapted from the WRI GHG Protocol, gives a summary on the three different groups, or “scopes”, including direct, indirect, and optional sources, of GHG emissions under the GHG Protocol. Data for direct emissions, including wastewater treatment, direct energy generation, travel in the company-owned vehicles, landfill gas, and fugitive GHG emissions, should be reported as a general rule. Indirect emissions from subscribed electricity and steam are also incorporated. Most of the programs do not report GHG emissions from optional source, such as from vehicles that not owned by the company, outsourced activities, waste disposal, purchased materials, and product use (Ravin and Raine, 2007).

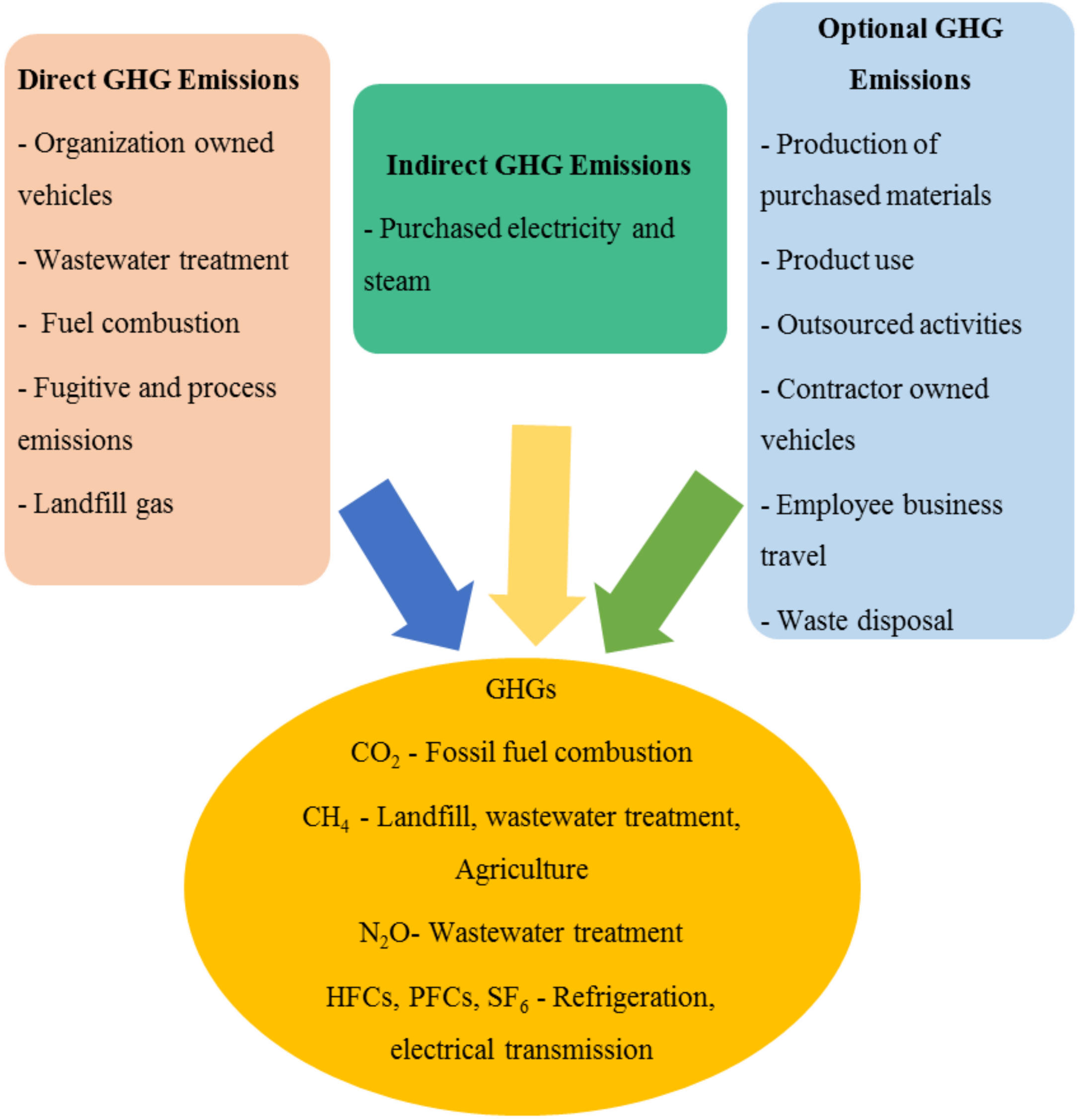


Figure 1.1 GHG Protocol Emissions Scopes

1.7.3.2 Principle of GHG Protocol

The five principles are relevance completeness, consistency, transparency, and accuracy (Figure 1.2).

1. Relevance

Select the GHG sources, GHG sinks, GHG reservoirs, data and methodologies appropriate to the needs of the intended user.

2. Completeness

Include all relevant GHG emissions and removals.

3. Consistency

Enable meaningful comparisons in GHG-related information.

4. Accuracy

Reduce bias and uncertainties as far as is practical.

5. Transparency

Disclose sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence. (Bureau of Indian Standards, 2009).

The first principle of relevance is important for providing available information to stakeholders both internal and external of company. The completeness of the GHG report is measured by how comprehensive and meaningful of the compiled information. Consistency in the organization’s reporting of GHG emissions will allow them to track emissions over time to identify trends. Transparency within the GHG report allows for a clear audit trail of the information presented. Accuracy, along with the four other accounting and reporting principles, will ensure the organization produces a true and fair representation of their GHG emissions. (TGO, 2015).

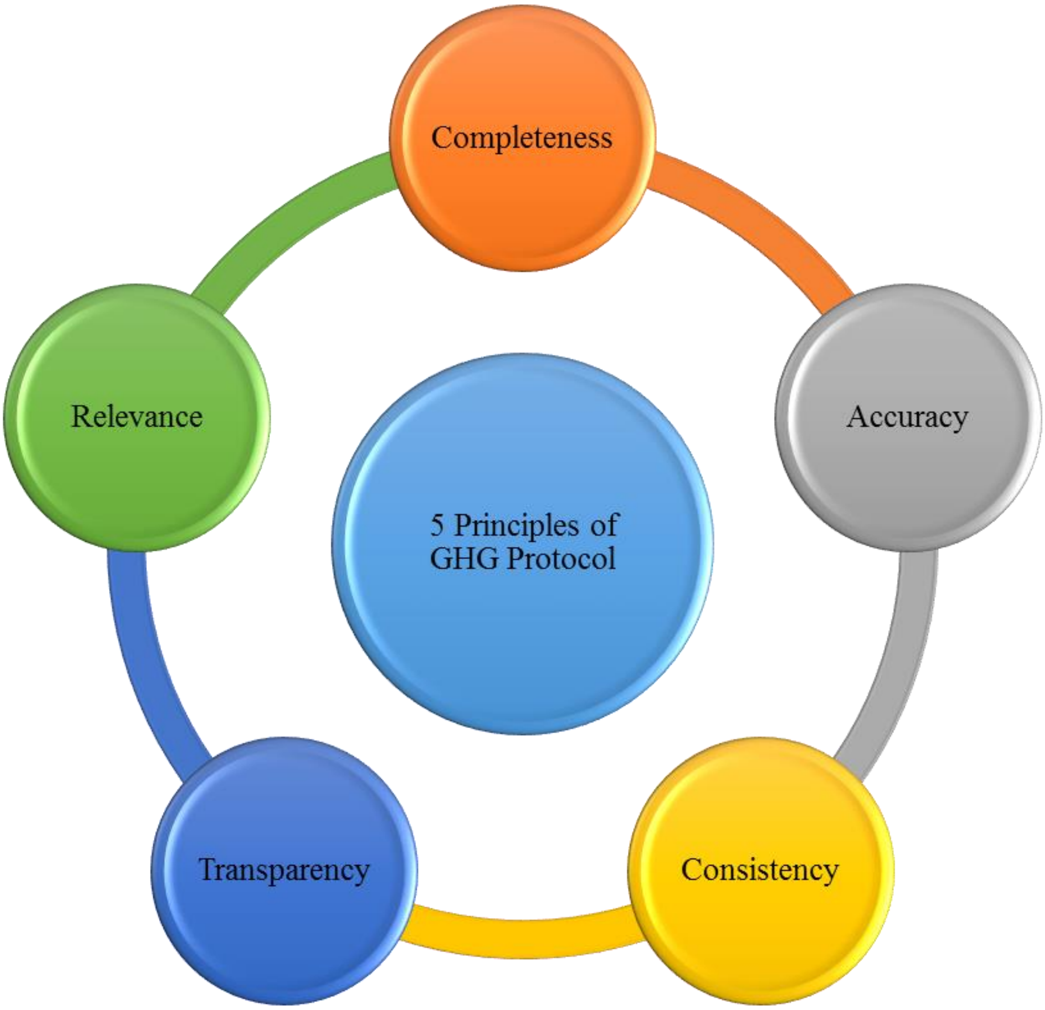


Figure 1.2 Principles of GHG Protocol

1.7.4. Scope of the GHG Emission Source

The Greenhouse Gas Protocol Corporate Standard (WRI and WBCSD, 2010) categorizes emission sources into three different ‘scopes’. Scope 1 accounts for direct emissions from sources that are controlled or owned by the organization; Scope 2 is indirect emissions that occur from the generation of subscribed electricity, steam or heat used by the organization; and Scope 3 accounts for all other indirect emissions resulting from the company activities, but emit from sources not controlled or owned by the company as presented in Figure 1.3.

The GHG inventories reporting have now considered all direct and indirect emissions embodied in the upstream supply chain, and/or emissions produced by the consumption and disposal of products. The consideration of these scopes in accounting GHG emissions highlights the necessity for a consumption-based approach (Larsen and Hertwich, 2009). Scope 3 emissions are particularly challenging to quantify, and a large number of sectors need to be analyzed in order to capture changes in consumption patterns. Downstream purchasing entities do not have access to detailed manufacturing information for each product purchased, nor the resources to investigate the supply chain of each product. Streamlined methods would therefore help to estimate scope 3 emissions (Thurston and Eckelman, 2011).

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

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

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

Scope 3 accounts for emissions of GHG emitted indirectly from sources, such as T&D losses associated with purchased electricity, employee travel and commuting, contracted solid waste disposal, and contracted wastewater treatment, that are not controlled or owned by the entity but associated to the entity’s activities. Those GHG emission sources are currently required for federal GHG reporting. Additional sources, such as GHG emissions from leased space, outsourced activities, vendor supply chains, and site remediation activities, are presently optional under federal reporting requirements, but they are substantial.

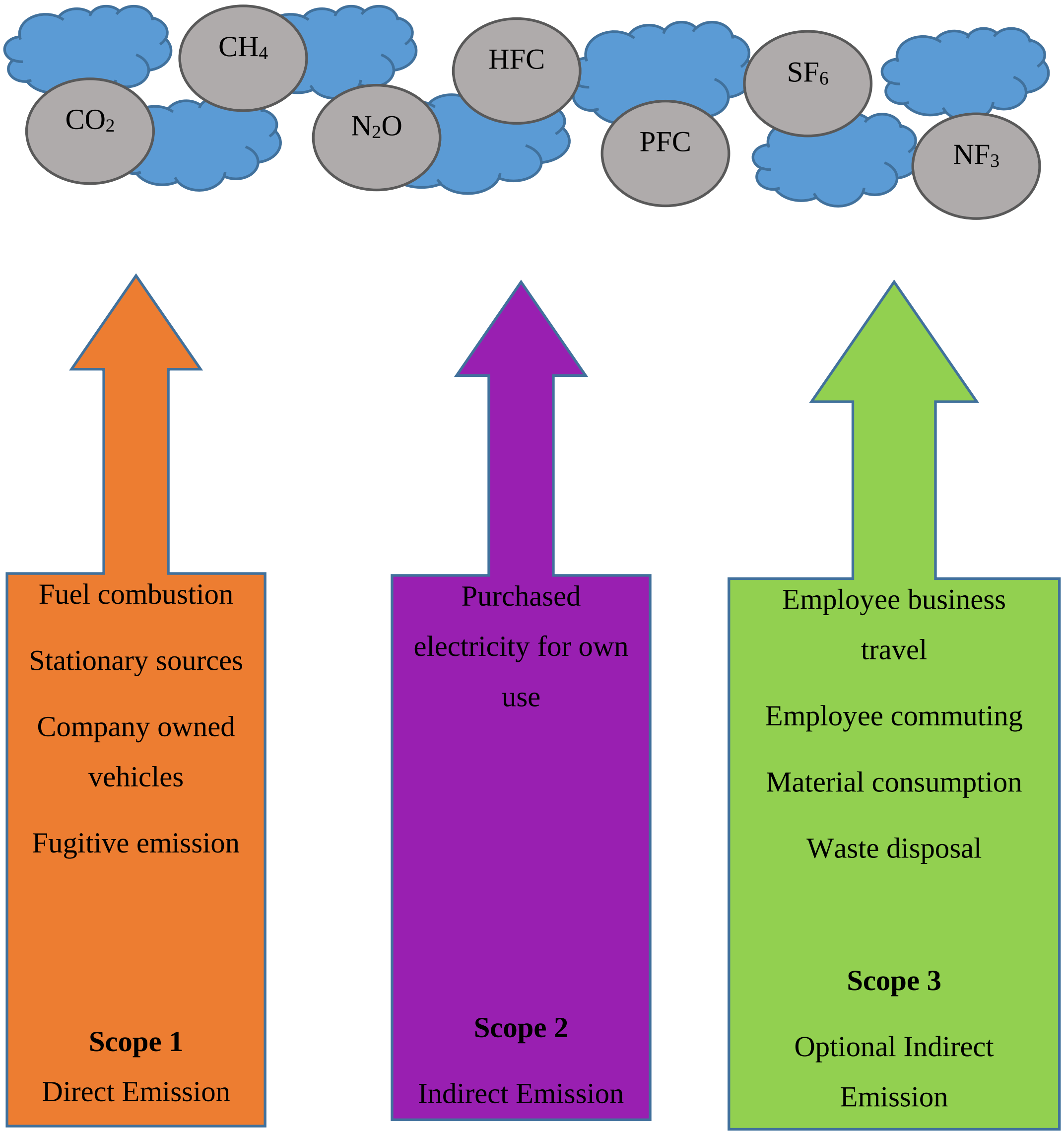
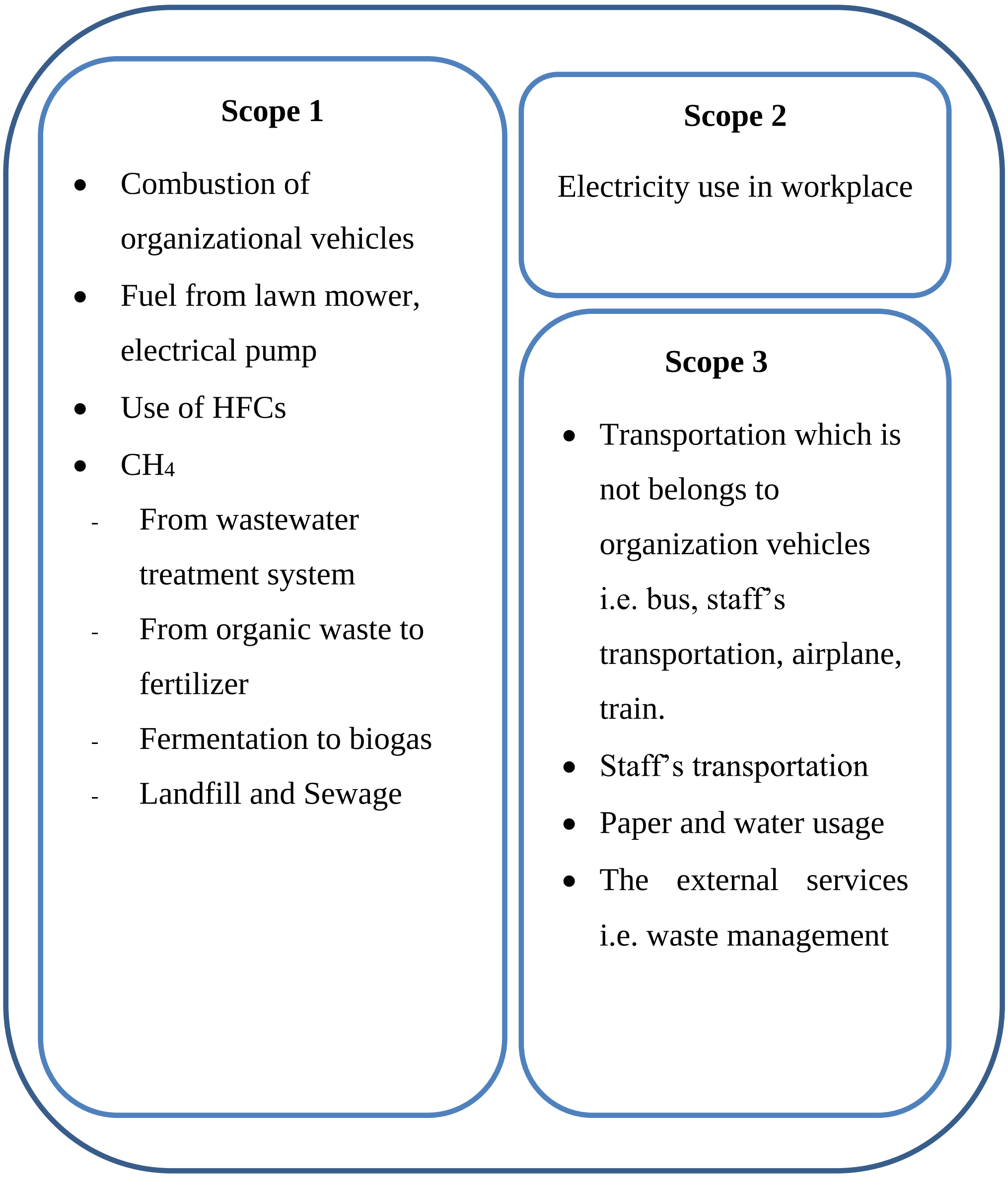


Figure 1.3 The Carbon Emission Sources in 3 Scopes

TGO defined scope of carbon footprint for organization in 3 scopes as illustrated in Figure 1.4.



Scope 1

- Combustion of organizational vehicles
- Fuel from lawn mower, electrical pump
- Use of HFCs
- CH_4
  - From wastewater treatment system
  - From organic waste to fertilizer
  - Fermentation to biogas
  - Landfill and Sewage

Scope 2

Electricity use in workplace

Scope 3

- Transportation which is not belongs to organization vehicles i.e. bus, staff's transportation, airplane, train.
- Staff's transportation
- Paper and water usage
- The external services i.e. waste management

Figure 1.4 The Scope of Carbon Emission Sources in Local Organization (TGO, 2012)

1.7.5. Step for GHG Accounting and Reporting

In order to measure the GHG emission and mitigation, step for GHG calculation and report is depicted as follow (Figure 1.5) (Charmorndusit, 2007).

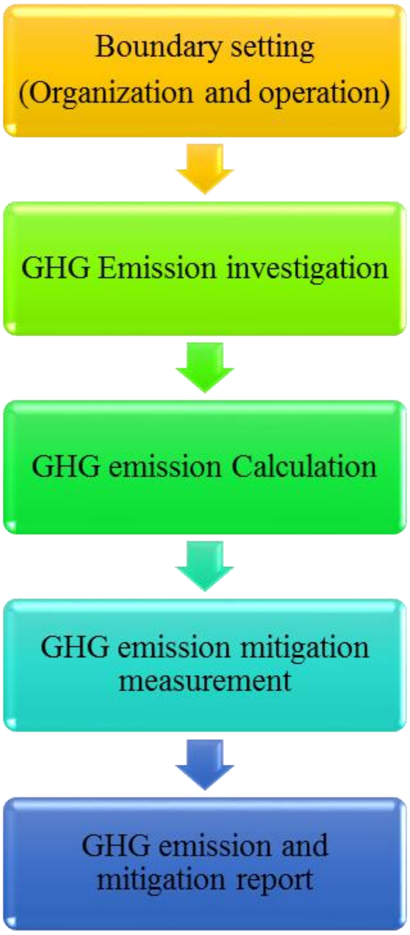


Figure 1.5 Step for GHG Accounting and Reporting

Source: Modified from Charmorndusit (2007)

1.7.6. Carbon Footprint and Sustainable Universities

Educational organizations and institutes are considered to be an important part of society which take an important role in education. In addition to education, they must also show social responsibility, especially concerning the environmental dimension relating to sustainable development. That is because activities operated by educational institutes can cause greenhouse gas emissions. Therefore, to understand the educational institute’s greenhouse gas emissions, it is necessary to evaluate the carbon footprint, which is the process of analyzing greenhouse gas emissions. (Puttiput et al., 2010). GHG emission from worldwide universities and GHG emission per capita for Asian countries were summarized in Table 1.2 and Table 1.3.

Table 1.2 GHG Emission per Capita in Worldwide Universities

University	Emissions per Capita (ton CO_2 eq)	References
University of Colorado at Boulder	1.2	Poohngamnil (2010)
Tufts University	2.2	Poohngamnil (2010)
College of Charleston	3.4	Poohngamnil (2010)
Tulane University	4.1	Poohngamnil (2010)
University of New Hampshire	4.8	Poohngamnil (2010)
California State University	6.0	Poohngamnil (2010)
University of Texas	5.8	Poohngamnil (2010)
Vermont University	6.2	Poohngamnil (2010)
Connecticut College	9.0	Poohngamnil (2010)
Carleton College	9.2	Poohngamnil (2010)
Florida	9.4	Poohngamnil (2010)
Eidgenössische Technische Hochschule (ETH) Zürich	9.3	Poohngamnil (2010)
Harvard University	10.0	Poohngamnil (2010)
Middlebury College	11.7	Poohngamnil (2010)
Yale University	12.6	Poohngamnil (2010)
City University of London	0.96	Letete et al. (2010)
University of Capetown	4.01	Letete et al. (2010)
University of Texas at Arlington	3.9	Letete et al. (2010)
University of Delaware	7.88	Letete et al. (2010)
University of Maryland	9.75	Letete et al. (2010)
Rice University	13.64	Letete et al. (2010)
University of Connecticut	9.78	Letete et al. (2010)

Source: Modified from Poohngamnil (2010), Letete et al. (2010), and Usubharatana and Phungrussami (2014)

Table 1.2 GHG Emission per Capita in Worldwide Universities (Continued)

University	Emissions per Capita (ton CO_2 eq)	References
Purdue University	17.10	Letete et al. (2010)
Hollins University	17.41	Letete et al. (2010)
University of Pennsylvania	13.13	Letete et al. (2010)
Vanderblit University	26.12	Letete et al. (2010)
Massachusetts Institute of Technology	36.40	Letete et al. (2010)
Thammasat University	1.62	Usubharatana and Phungrussami (2014)

Source: Modified from Poohngamnil (2010), Letete et al. (2010), and Usubharatana and Phungrussami (2014)

Table 1.3 GHG Emission per Capita for Asian Countries in 2008

Country	GHG Emission (ton CO_2)	GHG Emission (ton CO_2 eq)
Bangladesh	0.29	0.08
Brunei Darussalam	18.87	5.14
Cambodia	0.31	0.08
Chinese Taipei	11.53	3.14
India	1.25	0.34
Indonesia	1.69	0.46
Malaysia	6.7	1.82
Myanmar	0.24	0.06
Nepal	0.12	0.03
Pakistan	0.81	0.22
Philippines	0.80	0.22
Singapore	9.16	2.5

Source: Modified from Poohngamnil (2010)

Table 1.3 GHG Emission per Capita for Asian Countries in 2008 (Continued)

Country	GHG Emission (ton CO_2)	GHG Emission (ton CO_2 eq)
Sri Lanka	0.61	0.16
Thailand	3.41	0.93
Vietnam	1.19	0.32

Source: Modified from Poohngamnil (2010)

1.7.7. Sustainable Building and Energy Efficiency

Globally buildings are responsible for 40% of annual energy consumption and up to 30% of all energy-related greenhouse gas (GHG) emissions. The building sector has also been shown to provide the greatest potential for delivering significant cuts in emissions at low or no-cost or net savings to economies. With steadily increasing urbanization worldwide, building sustainably is important to achieving sustainable development (UNEP, 2011).

1.7.8. Energy Audit and Energy Measures

An energy audit (EA) is a process to monitor working problems, improve occupants comfort, and optimize energy use of existing buildings (Sterling et al., 1994; Rahman, 2009). Energy audits and monitoring energy use is indicated as the first step towards increasing energy efficiency within an organization. In addition, it identifies the opportunities for energy conservation. It was also described as a key element for decision making in energy management (Tim and Jutidamrongphan, 2016).

The focus on reducing building operational energy use through the last decades has distinguished that buildings are becoming more energy efficient, therefore increasing the relevance of the environmental and economic impact of the other life-cycle stages is mentioned (Oregi et al., 2017). Life-cycle assessment (LCA) is well recognized as a valid framework to assess the potential impacts of building projects. With regards to this tool, previous research findings presented that the majority of operational cost evidently from internal energy consumption. The operational energy involving the energy utilized by the building's operations and use (air conditioning, heating and lighting, office and kitchen equipment) (Biswas, 2014). In developing countries, retrofitting existing buildings at the optimal level is also a priority. In this regard, there is remarkable possibility for using this opportunity to update the heating and cooling technologies used in buildings, as well as implementing low cost but effective passive solutions to improve energy efficiencies such as thermal mass and sunshades (UNEP, 2009).

1.7.9. Energy Efficiency in Thailand

Energy is a major concern in Thailand, as continued economic development demands more consumption and production of electricity. Energy efficiency is key to achieving energy security and reducing greenhouse gas emissions. The building sector has been identified as an area where significant savings can be made because energy demand and consumption in this sector is considered to be rapidly growing. (UNDP, 2013).

Energy Conservation in Thailand's Energy Efficiency Development Plan focuses on two approaches: (1) Economical use or reduced expendable use of energy, and (2) Energy efficiency improvement such as reducing energy in doing the same activities, involving, among others, lighting, hot water production, cooling systems, transportation or running machines in the manufacturing process. Energy conservation plays a significant role in strengthening energy security, alleviating household expenditure, reducing production and services costs, reducing trade deficit and increasing the competitive edge, including reduction of pollution and greenhouse gases (GHG) which cause global warming and climate change. Therefore, energy conservation has been an important policy of the government, particularly since the enforcement of the Energy Conservation Promotion Act, B.E. 2535 (1992) (EPPO, 2011). It also was frequently emphasized as the context of the energy efficiency development plan of Thailand 2015-2036 as strategies to achieve the target in compulsory measures by enforcement of energy conservation standards in designated factories and buildings (EPPO, 2015)

1.7.10. Importance of Energy Conservation

Governments have a responsibility to provide effective energy security across the country. In many developing countries there is normally very little margin between existing power supply and electricity demand. With increasing electricity use from existing consumers and new connections, new generation needs to be brought on line to meet increasing demand. In addition, due to changing climate patterns and the increasing risk of drought, countries that are highly dependent on electricity from hydro as their main source of electricity are losing much of their generation capacity resulting in intensive power rationing (UNIDO, 2010)**.** With energy management in buildings, it is essential to understand the status of energy consumption; where and how much energy is being used.

The key to achieving these savings is a whole-building approach. View each building as an energy system with interdependent parts (Figure 1.6). One component in the building can greatly affect other components, which in turn affects the overall energy efficiency of the building. For example, an efficient heating system is not just a high efficiency gas furnace, it is heat-delivery system that starts at the furnace and delivers heat throughout the building using a network of ducts. If the ducts are not sealed and the walls, attic, crawlspace, windows, and doors are not well insulated, even the most energy efficient furnace will not prevent energy loss. Taking a whole-building approach to saving energy and water ensures that the money property owners invest to save energy and water is cost-effective.

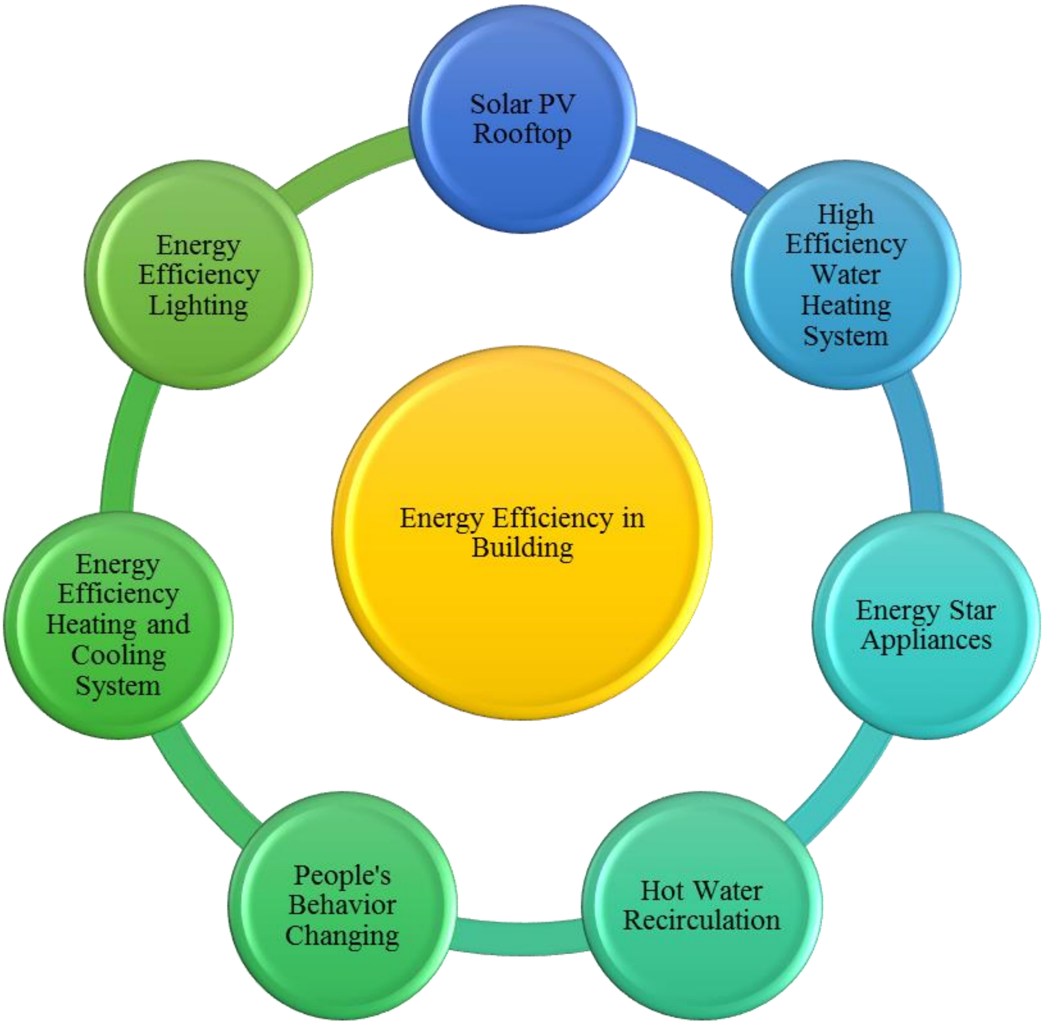


Figure 1.6 Energy Efficiency in Building

Source: Modified from PowerHouse Service Inc (2009)

1.7.11. Operational Energy Reduction

1.7.11.1 Energy Audit Program

An energy audit (EA) is a process to monitor working problems, improve occupants comfort, and optimize energy use of existing buildings (Sterling et al., 1994, and Rahman, 2009). Energy audits and monitoring energy use is indicated as the first step towards increasing energy efficiency within an organization. In addition, it identifies the opportunities for energy conservation. It was also described as a key element for decision making in energy management. The process is periodic in nature, and it assesses changes in building use, the condition of existing equipment, and the applicability of new energy-efficient technologies.

1.7.11.2 Energy Efficiency

The focus on reducing building operational energy use through the last decades has distinguished that buildings are becoming more energy efficient, therefore increasing the relevance of the environmental and economic impact of the other life-cycle stages is mentioned (Oregi et al., 2017). Life-cycle assessment (LCA) is well recognized as a valid framework to assess the potential impacts of building projects. With regards to this tool, previous research findings presented that the majority of operational cost evidently from internal energy consumption. The operational energy involving the energy utilized by the building's operations and use (air conditioning, heating and lighting, office and kitchen equipment) (Biswas, 2014). In developing countries, retrofitting existing buildings at the optimal level is also a priority. In this regard, there is remarkable possibility for using this opportunity to update the heating and cooling technologies used in buildings, as well as implementing low cost but effective passive solutions to improve energy efficiencies such as thermal mass and sunshades (UNEP, 2009).

In Thailand, the Ministry of Energy has also implemented projects to encourage energy conservation and efficient energy consumption, and has worked with local administrative organizations to enhance communities' energy capacity. The campaign to reduce 10% energy consumption in government administration offices was applied since March 2012 to promote energy conservation and cost saving (Tim and Jutidamrongphan, 2016).

1.7.12. Case Studies

From the study of carbon footprint analysis of student behavior for a sustainable university campus in China shown that survey responses, combined with utility data and emissions calculations, indicated that the average annual carbon footprint was a relatively modest 3.84 tons of CO_2 equivalent per student. In terms of GHG emissions, university – wide analysis also fits within a broader trend of designing, operating, and in some cases regulating low carbon organizations and communities. Such initiatives require methods for allocating emission. The carbon footprint is simply the sum of GHGs emitted that can be attributed to an activity, process, organization, or entity. The idea is flexible, and depends heavily on specification of both scope and methods (Li et al., 2015).

From the study of calculating carbon footprint of the university summarized the carbon footprint in Erasmus University Rotterdam (Spranger, 2011) which focuses on CO_2 emissions only, rather than CO_2 equivalents. Finding of this study is the total CO_2 emission of the EUR is 12,6 million kg CO_2 in 2010. Commuting is responsible for the majority of the emissions of Erasmus University, with student commuting being responsible for 61,6% of the total emission, and employee commuting is responsible for 13,2% of the total CO_2 emission. Other important sources of emissions are purchased heat (12,6%), purchased electricity (7,3%) and employee travels (2,7%). Guereca et al. (2013) demonstrated the implementation of low carbon action plans with regards to personal commuting. They proposed commuting pattern as reduction of attending time (3 days per week), promote public bus use including carpool system which could reduce emission.

From the study of the evaluation and the search of methods in decreasing the volumes of GHGs of the Faculty of Engineering, Chiang Mai University shown that evaluation of the organizational greenhouse gases emissions resulting from the Faculty of Engineering’s activities could be, then, a factor which demonstrates the faculty’s responsibility. As well, the data of the measurements in decreasing the emissions of GHGs could be guidelines for controlling or reinforcing a future operation. Operational control was used to consider the organizational scope (Puttiput et al., 2010).

From the study of the quantification of carbon footprint for an office in Singapore reported that the organization has carbon footprint of 2.3 ton CO_2 eq / month with major emissions obtained from the air-conditioning system contributing almost 65%. It was also found that lighting system turns out as a significant contributor in office carbon footprint from main working area. Therefore, continue the practice of turning off the lights and air conditioners when the room is not in use was suggested via considering in proper lighting and temperature with regards to impact on working environment prior to spending into new lighting and air conditioning systems (Tjandra et al., 2016).

From the study of analyzing the thoughts of ecological footprints of university student: A preliminary research on Turkish students shown that exploring the carbon, food, goods and service and consumption level of people to realize probable damage of consumption habits which are essential to decrease ecological destruction and increase consciousness of people in our planet. Data collection was online survey questionnaire among of 420 students who live in the dormitory and rent house. To reach the sustainable development, the result should be focused on technology, behavior and policy. (Sudas and Ozelturkay, 2015).

From the study of investigating the carbon footprint of Norwegian University of Science and Technology (NTNU) presented that carbon footprint of NTNU is versiy significant with an average contribution of 4.6 ton CO_2 eq. per student. The large amounts of equipment and consumable investment for scientific use is the significant contributor to this carbon footprint. To reduce carbon footprint related to energy and buildings are responsibility of property management. In existing buildings, reducing energy actions could be performed such as opening hours reduction, turn off light in unoccupied offices, diminishing the need for building related services i.e. working and cleaning (Larsen et al., 2013).

Song et al. (2016) reported that reading papers contributed the most to the generation of the carbon footprint by consuming 24.68 MJ of energy and emitting 2 kg CO_2 eq. Therefore, it was also investigated that policy makers at the university should not promote the substitution of e-reading for print reading for reducing the carbon footprint but should encourage replace desktops with laptops (Song et al., 2016).

From the study of carbon footprint analyses of student behavior for a sustainable university campus in China shown that Student’s carbon footprint estimation can serve two roles, both increasing student consciousness of the GHG emission due to their activities and providing a comprehensive basis for campus-wide university sustainable development and decision maker. The research used questionnaire that divided in 5 categories, background information, daily life, academics, transportation and green campus. Result showed annual CF of about 3.84 ton per capita. The top individual used was dining room. (Li et al., 2015)

From the study of energy saving: View and attitudes of students in secondary education shown that in this part the importance of education was highlighted as 1) The awareness of the students 2) The information on the difference types of renewable energy 3) To undertaking of action, in order to suggest solution and alternative strategy 4) To develop of positive attitude and values toward energy resources. The solution is promotion, education and motivation. (Eirini et al., 2015)

From the study of carbon footprint of science: More than flying shown that university tended to take action to reduce their environmental impact. The objectives of this study were showing out the impact, evaluation and mitigation. Recommendation to reduce carbon emission such as using green electricity, reduction of energy consumption and promoting commuting by bicycle were suggested (Wouter, et al., 2013).

To accurate carbon footprint evaluation, universities should use an advanced information system for calculating their carbon footprint, looking at the issue from an environmental viewpoint. However, universities should decide whether investing in such an expensive tool would be worth the money and time.

CHAPTER 2

RESEARCH METHODOLOGY

This chapter discussed detail of research including step of the research, study area, conceptual framework, data collection and data analysis. The concept of this study is to estimating the current situation of GHGs emission of PO buildings following the Thailand Greenhouse Gas Management Organization (TGO) guideline.

2.1. Study Area

2.1.1. Location

PSU map that shows detail of main part in the university was illustrated in Figure 2.1 which has the memorable statue of Prince of Songklanakarin at the front of buildings (Figure 2.2).

Figure 2.1 Map of PSU Hatyai Campus (http://w08.psu.ac.th/en/hatyai-exploring)

1) Statue of HRH Prince Mahidol Adulyadej
2) Office of the President
3) Front Gate (Kanjanavanich Road Gate)
4) Songklanagarind Hospital
5) Soccer Field
6) Main Soccer Field
7) Faculty of Dentistry
8) Faculty of Medicine

9) Faculty of Nursing
10) Physician/Nurse Dormitories
11) Faculty of Science
12) Graduate School/ Central Facility
13) Khunying Long Learning Resources Center
14) Faculty of Pharmaceutical Sciences
15) Faculty of Natural resources
16) Faculty of Engineering
17) Faculty of Agro-Industry
18) Faculty of Liberal Arts
19) Faculty of Management Sciences
20) Computer Center
21) Faculty of Law
22) Information Technology Building
23) Sports Complex/ Gymnasium
24) Student Union/ Food Center
25) Student Dormitories
26) Reservoir
27) Srisarp Gate (Punnakan Road Gate)
28) Prince of Songkla University International Convention Center
29) Mor-Or Withayanusorn School
30) Faculty and Staff Residential Area

Figure 2.2 The Front Area of President’s Office Buildings

2.1.2. President’s Office Administration

President’s office comprises of three buildings; building 1, building 2, and building 3. Both building 1 and 3 have three floors, building 2 has four floors. Totally all of three buildings divided into 124 small parts and consists of the following divisions by 7 functions (Figure 2.3) as mentioned below (PSU, 2000).

1. General affairs division was further divided into clerical services, welfares (including buildings and ground), finances and personnel sub-divisions.

2. Financial division is responsible for overall management of financial and monetary affairs of the university, including book keeping of disbursement, purchasing of materials and supplies and inventory of equipment.

3. Personnel division responsible for support and improvement of the administration of personnel of the university so that it can be carried out efficiently and fairly according to the existing rules and regulation.

4. Building and ground division is responsible for the construction works and utilization of usable area of the Campus, managing and maintaining services regarding transport, accommodation, public utilities, landscaping works of the Campus.

5. Student affairs division has consisted of three sub-divisions and one unit, namely, counseling and job placement, Student Services and Welfares, Student Affairs sub-divisions and Clerical Service unit.

6. Planning division is providing necessary information to support the decision making of university executives, to coordinate and give advices to the faculties and organizational units of the university in devising policies and plans, and in utilization of resources, and to follow up and make the assessment of the results systematically.

7. Education service division is the central unit which provides necessary support in working out the policy and intention of the university according to its primary mission in the management of education, research, academic services and international relation.

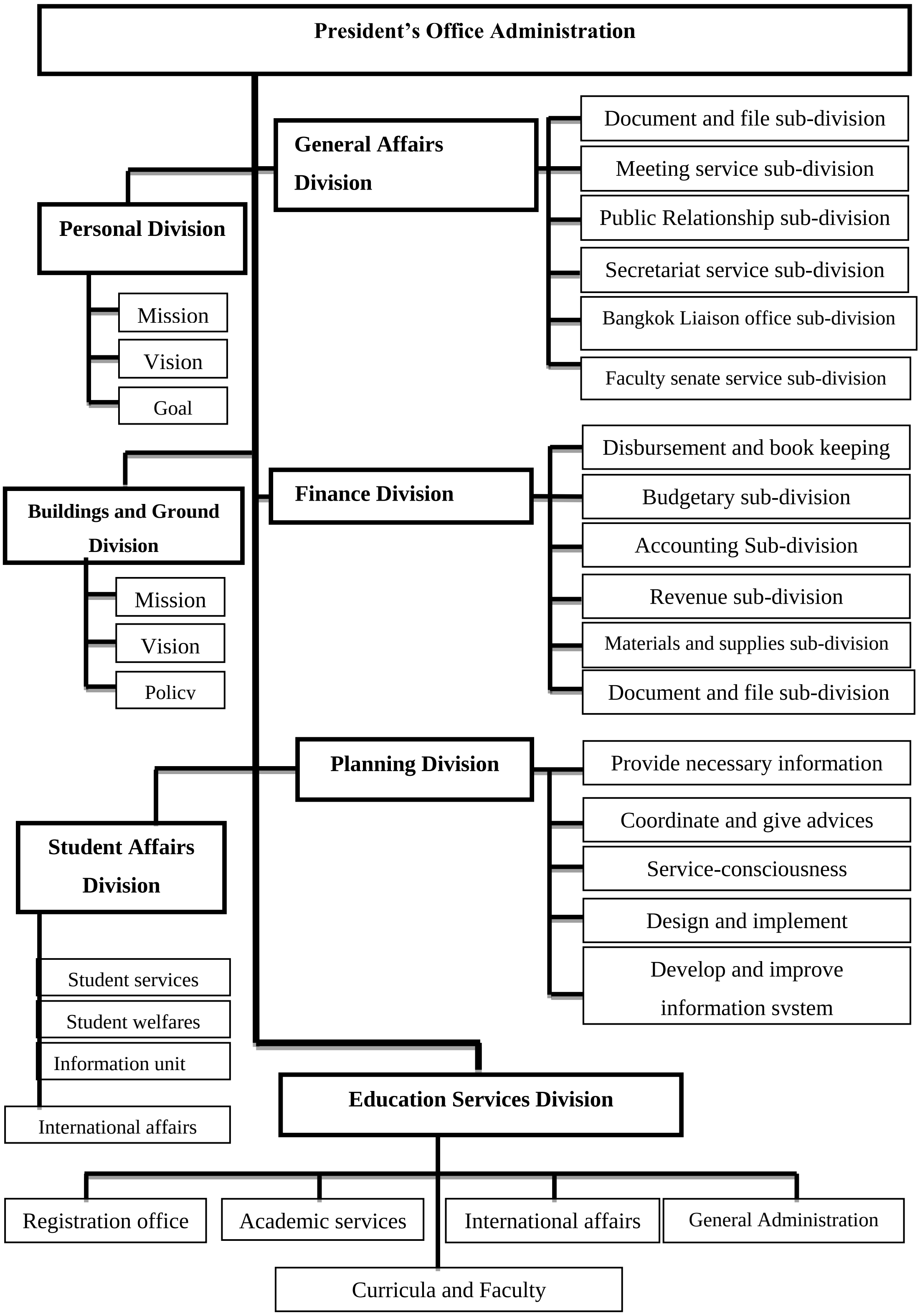


Figure 2.3 The System Organization of President's Office

2.2. Methodology

The carbon footprint was evaluated following by the TGO guideline of carbon footprint for organization. The summary of data collection, GHG calculation and analysis are described in the flow chart below (Figure 2.4).

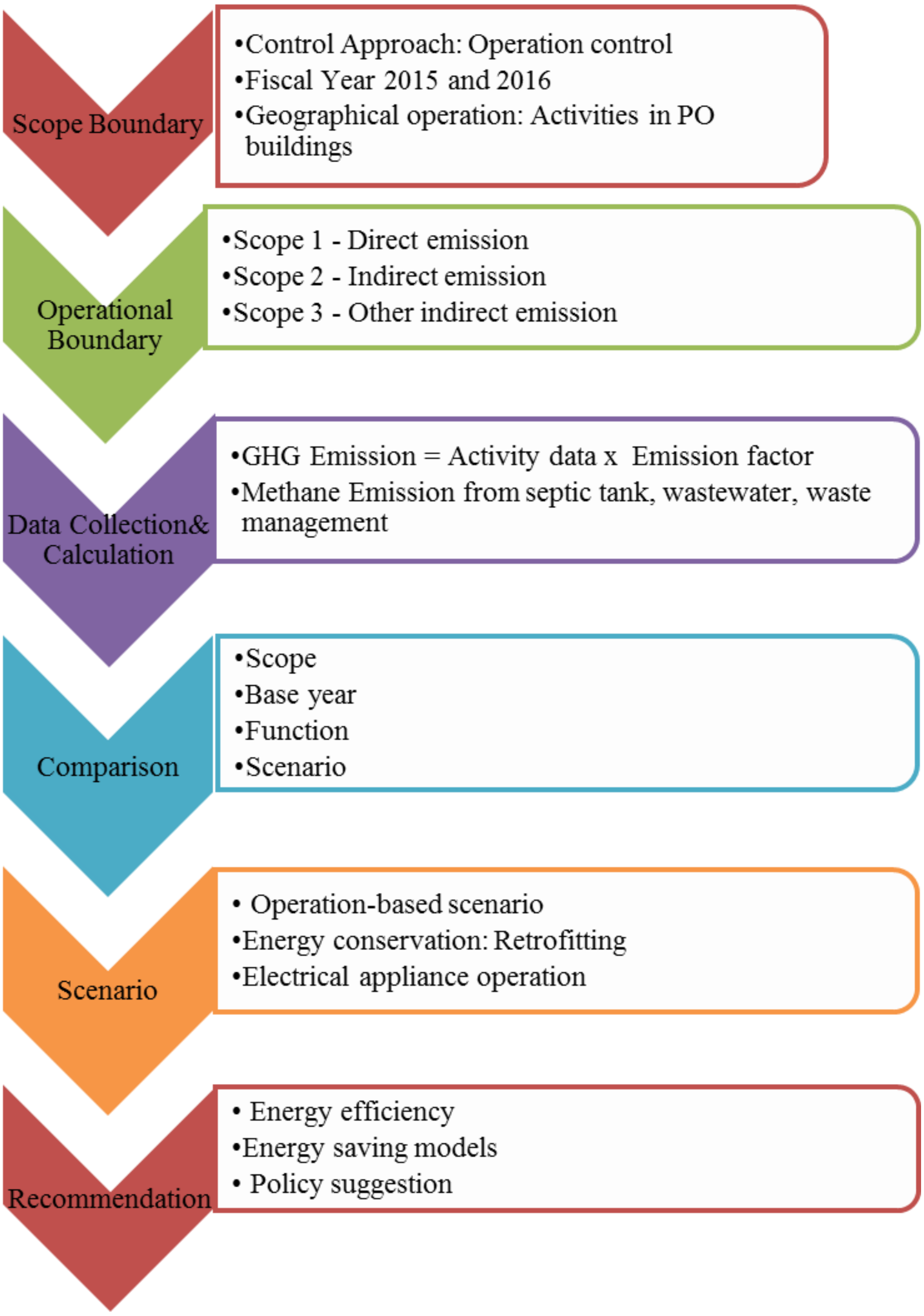


Figure 2.4 Research Methodology

2.2.1. Scope and Boundary

Summary of scope and boundary could be presented in terms of

1. Organization boundary: Control approach, Operational control

2. Base year: Single base year approach (Fiscal year 2015 and 2016)

Fiscal year 2015 (October 2014 – September 2015) and fiscal year 2016 (October 2015 – September 2016) were utilized in carbon footprint calculation.

3. Geographical operations: Activities from President's Office buildings

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

- Layout
- Organization structure
- The area and amount of staff
- Organization type: management function of PSU
- Process flow of service

4. Operational boundary

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

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

1) GHG emissions from stationary combustion units

1.1 Electricity production for organization use
1.2 Fossil fuel combustion from stationary machine which controlled or owned by organization

2) GHG emissions from mobile combustion

3) Fugitive GHG emissions

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

Scope 3: All other indirect emissions which is not covered in scope 2 including upstream and downstream emissions, emissions resulting from the extraction and production of purchased materials and fuels, transport-related activities in vehicle not owned or controlled by the reporting organization, use of sold products and services, outsourced activities, recycling or used products, waste disposal, etc. (TGO,2015)

5. GHG from operational activities

The research is carried out to measure GHG emission from the operation control of PO buildings for the purposes of consolidating and reporting GHG emissions.

In this study, 7 GHGs which are the target for the first commitment period of the Kyoto Protocol cover emission of the seven main GHGs namely; Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbon (HFCS), Perfluorocarbon (PFCs), Sulphur hexafluoride (SF_6), and Nitrogen trifluoride (NF_3) were investigated

With the TGO's guideline, all of human activities are taking account to GHG emission. So the assumption and estimation of the GHG were analyzed baseline annual calculation on PO building in fiscal year 2015 and 2016.

6. Facility for consideration in GHG emissions calculation

- Facility including;

1) Administrative divisions: General affairs, finance, planning, personnel, building and ground, education service, and student affairs

2) Executive rooms: 14 rooms

3) Meeting rooms: meeting 1, meeting 2, 210, 211, 212, 214, 215, and 303

- Facility excluding;

1) Coolant R-22 with regards to the R-22 replacement was not recorded as GHG in Kyoto Protocol

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

2.2.2. Assumption and Limitation

2.2.2.1 This research mainly used emission factor of Thailand from Thai LCI database which collected and managed by National Metal and Materials Technology Center (MTEC) and TGO including international database from IPCC for data which is not collected in Thailand for carbon footprint evaluation.

This study calculate carbon emission from scope 1, 2 and 3 excluding following issues;

Scope 1

1) Coolant R-22 with regards to the R-22 replacement was not recorded as GHG in Kyoto Protocol

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

Scope 3

1) Staff transportation with regards to lack of data in PO staff's petrol payment.

2) Business travel of executive committee due to limitation in personal reimbursement collection.

3) Visitor transportation according to unable to accurately measure individual distance and petrol consumption.

Carbon capture and storage by green area with regard to limitation of geographical boundary

2.2.2.2 Electricity consumption and cost were collected from central electricity meter of President's office which is not divided for each electricity system. Therefore, assumption of electricity parameters was analyzed from measurement, allocation, and calculated data for evaluate electricity consumption and cost including protect the overestimation from calculation.

2.2.3. Data Collection

In order to accomplish data collection, data analysis and report are required to make sure that the process is following principle guideline of the GHG protocol by TGO, which provided a direction to implement GHG protocol corporate standard and the GHG emissions report. Data flow (Figure 2.5) was analyzed and evaluation criteria was established before primary data was collected by means of measurement, evaluation, and interview. Secondary data could be achieved from calculation, statistical data, exploration, literature review etc.

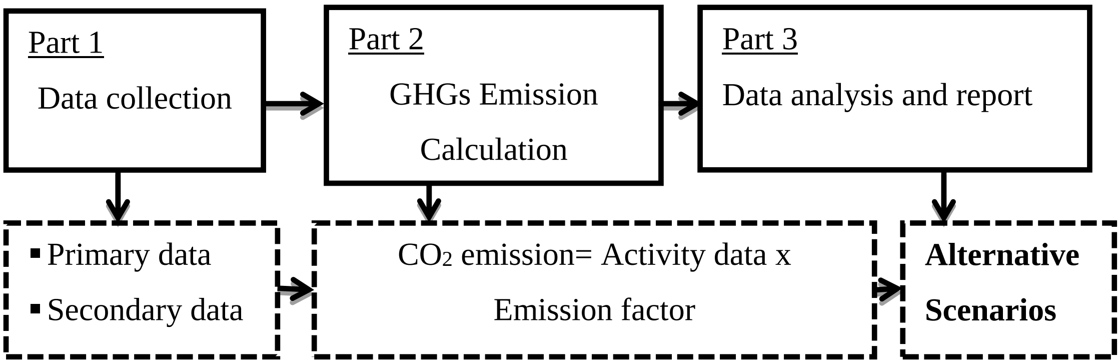


Figure 2.5 Step for Data Collection and Analysis

2.2.4 Data Calculation

To archive the first objective, “Identify and quantify carbon mitigation possibility”, all data collected from scope 1, 2 and 3 was calculated by Eq. 2.1.

$$CO_2\ Emission = Activity\ Data \times Emission\ Factor \qquad \text{(Eq. 2.1)}$$

2.2.4.1 Emission Factor

The emission factors were chosen from reliable data sources i.e. IPCC, Thai LCI Database, and TGO

2.2.4.2 Activities Data

Activity data evaluation (Table 2.1) was gathered from each building follow by the scope below:

Scope 1 Direct GHG emissions normally from fossil fuels or other man-made chemical. There are four types of sources:

- Stationary combustion of fuels in any stationary equipment
- Mobile combustion of fuels in transportation sources such as motorbike, cars, van, bus, and trucks
- Fugitive sources, such as releases of SF_6 from electrical equipment, HFC release from used of refrigeration and air conditioning equipment
- Waste and wastewater management by organization’s operation

Scope 2: Indirect GHG emissions from use of purchased electricity

Scope 3: Other indirect emissions are classified into the following categories:

- Emission from paper use in operation
- Water supply for office operation
- Wastewater from operation
- Methane emission from waste management

Consequently, scope 3 emission activities were listed for GHG reduction and mitigation.

Activity data and source of GHG emission were summarized in Table 2.1 and Table 2.2.

Table 2.1 Activity Data

Scope	Activity
Scope 1	1.1 Stationary combustion 1.1.1 Gasoline combustion from mower 1.1.2 Diesel combustion from foggy machine and power supply 1.2 Mobile combustion 1.2.1 Gasoline combustion from organization’s vehicles 1.2.2 Diesel combustion from organization’s vehicles 1.3 Septic tank
Scope 2	Electricity consumption
Scope 3	3.1 Paper A4 consumption 3.2 Water consumption 3.3 Wastewater treatment 3.4 Solid waste management

Table 2.2 Source of GHG Emission by Scope

Resource	GHG	Pollution Source	Data Quality		EF Source
			Source	Type	
Scope 1					
Stationary combustion	CO_2 CH_4 NO_2	Mower, Mosquito spraying machine, power supply	Petrol record	R	IPCC Vol. 2 table 2.3 DEDE
Mobile Combustion	CO_2 CH_4 NO_2	Organization vehicles	Petrol record	R	IPCC Vol.2 table 3.2.1, 3.2.2, DEDE
Septic tank	CH_4	Wastewater from septic tank	Data sheet	C	IPCC 4th Assessment Report, 2007
Scope 2					
Electricity	GHG	Electricity appliances	Meter	R	Thai national database
Scope 3					
Paper A4	GHG	Working documents, meeting documents	Annual record	R	Ecoinvent 2.2, IPCC 2007 GWP 100a :Paper, woodfree, coated, at regional storage/CH U
Water consumption	GHG	Faucets, sanitary wares	Annual record	R	IPCC Vol. 5 Table 6.2, 6.8
Wastewater treatment	CH_4	Wastewater	Annual record	C	IPCC Vol. 5 Table 6.2, 6.8
Solid waste management	CO_2 CH_4 NO_2	Waste from human activities	Data sheet	C	Thai national database

Remark:

R = Record or Evidence (e.g. petrol bill, water supply bill)

C = Calculated (emissions factors, mass balance)

2.2.4.3 Specific Calculation from Typical Activities

- Methane emission from septic tank as calculated in Eq. 2.2 and Eq. 2.3

$$CH_4\ Emission = [U \times T \times EF] \times (TOW - S) - R \qquad \text{(Eq. 2.2)}$$

Where;

U = 1 (According to the database of population in Thailand 2003: choosing the proportion of population living in Hatyai Municipality)

T = 1 (According to Urban-high income, IPCC Vol. 5, Table 6.5 ([using the data of Indonesia, which is a country in the same region and has the same BOD per population])

S = 0 (No sludge removal)

R = 0 (No reusing of methane gas)

$$TOW = P \times BOD \times 0.001 \times I \times W \qquad \text{(Eq. 2.3)}$$

P = The number of staff who work under President's office operation

BOD = 40 g/person/day

I = 1 (Default value for Asia)

W = Working days in a year (2015 = 242 days, 2016 = 241 days)

- Wastewater

The calculation of wastewater produced by the PO was estimated from the calculation of 90% of the volume of water supply. Generally, the wastewater volume was, then, calculated for evaluate the methane emissions as calculated via Eq. 2.4.

$$CH_4\ Emission = \{(W \times COD).S\} \times B\text{o} \times MCF \qquad \text{(Eq. 2.4)}$$

Where;

W = the volume of waste water (m^3)

COD = 5 kg/ m^3 (According to IPCC Vol.5, Table 6.9, Vegetable, Fruit & Juices)

S = 0 (No sludge removal)

B_0 = 0.25 kg CH_4/kg BOD

MCF = 0.3

However, wastewater with aerated treatment system was not emitted methane to the atmosphere. Therefore, there is no GHG emission from wastewater.

With regards to municipal waste from PSU sent to Hatyai municipality incinerator, therefore, carbon emission from waste management was calculated in terms of GHGs emission from incineration presented in Appendix C.

2.2.5 GHG Mitigation Comparison

In order to reach second objective of the study, "Identify and quantify carbon mitigation possibility", all recommendations, possible mitigation strategies, including support operational policy to reduce carbon emission were discussed.

After the data gathering, CO_2 emission was calculated then the cost analysis was estimated to evaluate the impact on total cost of operation (Figure 2.6).

2.2.6 Operational Cost Analysis and Energy Efficiency Evaluation

The operation cost of administration was analyzed in order to find out possible energy conservation and cost reduction from routine staff working.

Energy was investigated in terms of electricity cost as recorded in electricity bill monthly. Water supply was determined by water meter prior to concluded in monthly invoice, and material and supplies were collected by annual issue of material from material disburse procurement. Entire materials and supplies cost was recorded in disbursement department account from each division. Total cost was considered with regards to energy and cost minization in buildings.

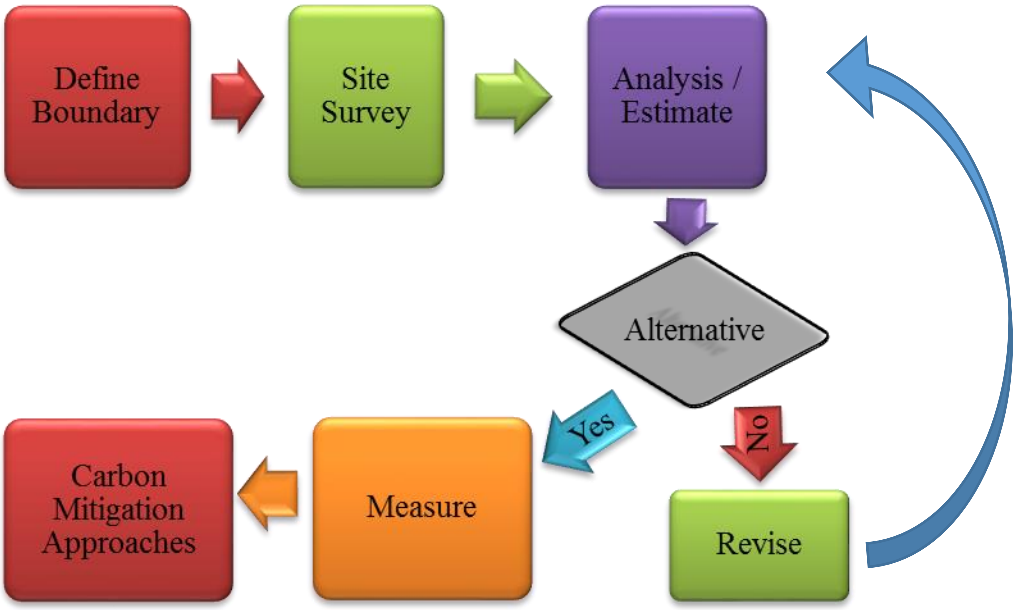


Figure 2.6 Operational Framework for Cost Analysis

2.3. Evaluation Criteria

The criteria for evaluation in each parameter was classified in Table 2.3.

Table 2.3 Evaluation Criterias

Area of Investigation	Acquisition Data
1. Building characteristics	1. Construction layout 2. Organization chart 3. Function of operational layout
2. Carbon Emission	1. Direct GHG emission 2. Indirect GHG emission from use of purchased electricity 3. Other indirect GHG emission
3. Operational cost	1. Process flow 2. Cost of operation
4. Energy performance	1. Type and key appliances system - Air conditioning (AC) system, - IT devices, - Lighting system, - Auxiliary appliances 2. Operational hour
5. Energy breakdown	- Annual operational energy for different end-use appliance
6. Energy efficiency	- Action taken into account for energy reduction

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Building Characteristic

3.1.1. Background of Study Area

President's office (PO) was separated in three connected buildings; building 1, building 2, and building 3 as illustrated in Figure 3.1. It has a 6,988 m^2 functional area including executive, administrative, and meeting operations (Table 3.1). Both building 1 and 3 have three floors, building 2 has four floors (Figure 3.2-3.5). The expand layouts were illustrated in A3 (Appendix I). Totally all of three buildings divided into 124 small parts.

Figure 3.1 President's Office Buildings Layout

Table 3.1 Total Area of President's Office Buildings

Area	Floor 1	Floor 2	Floor 3	Floor 4*	Total (m^2)
Building 1	936	936	216	-	2,088
Building 2	1128	624	408	408	2,568
Building 3	828	784	720	-	2,332
Total (m^2)					**6,988**

* Only building 2 has 4 floors

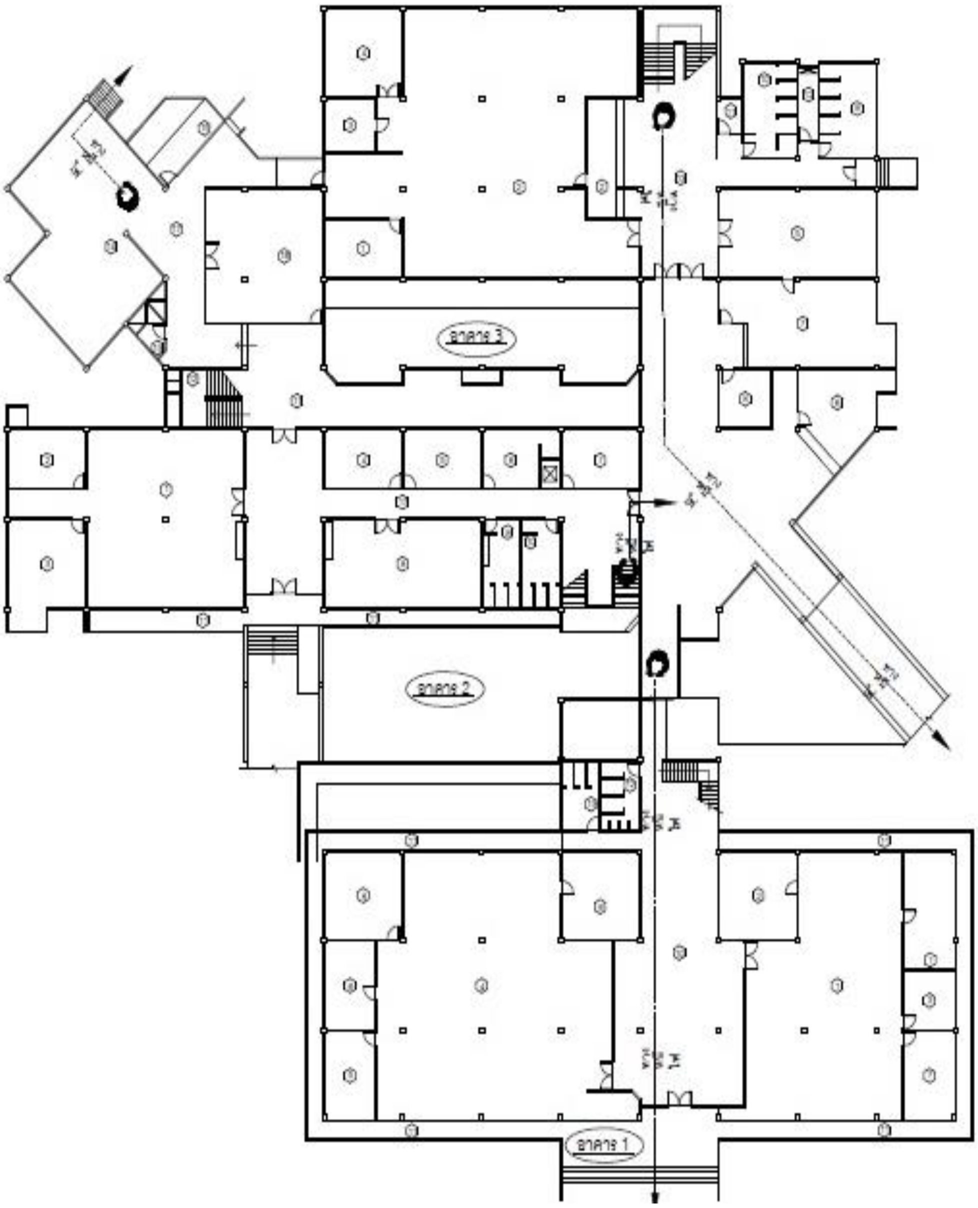


Figure 3.2 The 1st Floor of President’s Office Buildings

Building 1

1. General division
2. Storage 1
3. Storage 2
4. General staff office
5. General staff director office
6. Confidential document
7. General division director office
8. Storage room 1
9. Storage room 2
10. Hallway
11. Walkways
12. Men’s restroom
13. Women’s restroom

Building 2

1. Education service
2. Education service director service
3. Computer room
4. Photo copy room
5. Photo copy room
6. Storage room
7. Office
8. Education information center
9. Men’s restroom
10. Women’s restroom
11. Light
12. Men’s restroom
13. Women’s restroom
14. Faculty senate canteen
15. Management office
16. Faculty senate office
17. Walkways

Building 3

1. Financial division director
2. 103 Financial division
3. Mankong room
4. Document room
5. Packages distribution
6. Post office
7. Packages distribution
8. Small packager room
9. Men’s restroom
10. Women’s restroom
11. MDB room
12. Storage room
13. Walkway

Figure 3.2 The 1st Floor of President’s Office Buildings (Continued)

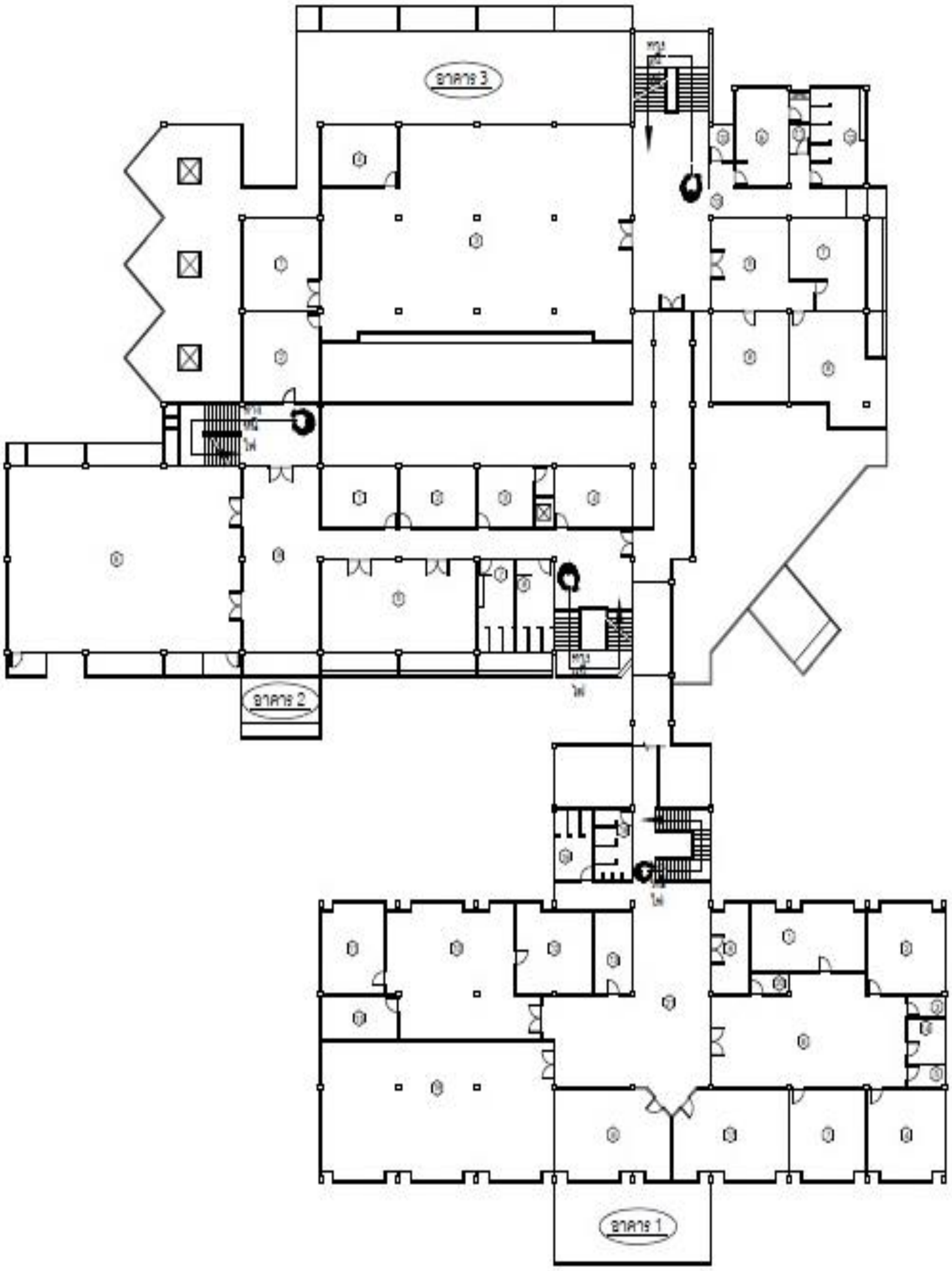


Figure 3.3 The 2nd Floor of President’s Office Buildings

Building 1

1. Document storage
2. Meeting room 1
3. Student affair
4. Office of Director of student affair
5. Room
6. Vice president for student development and alumni affairs
7. Vice president for information technology and physical structure
8. Vice president assets and outreach
9. Office of assistant for student development
10. PB-2A room
11. Restroom
12. Women’s restroom
13. Walkway

Building 2

1. Meeting room 1
2. Meeting room 2
3. Lounge
4. Meeting room 3
5. Meeting room
6. Men’s restroom
7. Women’s restroom
8. Meeting room
9. Walkway

Building 3

1. President
2. Vice president
3. Restroom
4. Vice president for planning and finance
5. Restroom
6. Hallway
7. Vice president for academic affaire
8. Advisor to the president for finance and procurement management
9. IMT room
10. Planning division
11. Director of planning division office
12. Master planning division
13. Common room
14. Storage room1
15. Storage room2
16. Meeting room 1
17. Meeting room 2
18. Men’s restroom
19. Women’s restroom
20. Restroom
21. Walkway

Figure 3.3 The 2nd Floor of President’s Office Buildings (Continued)

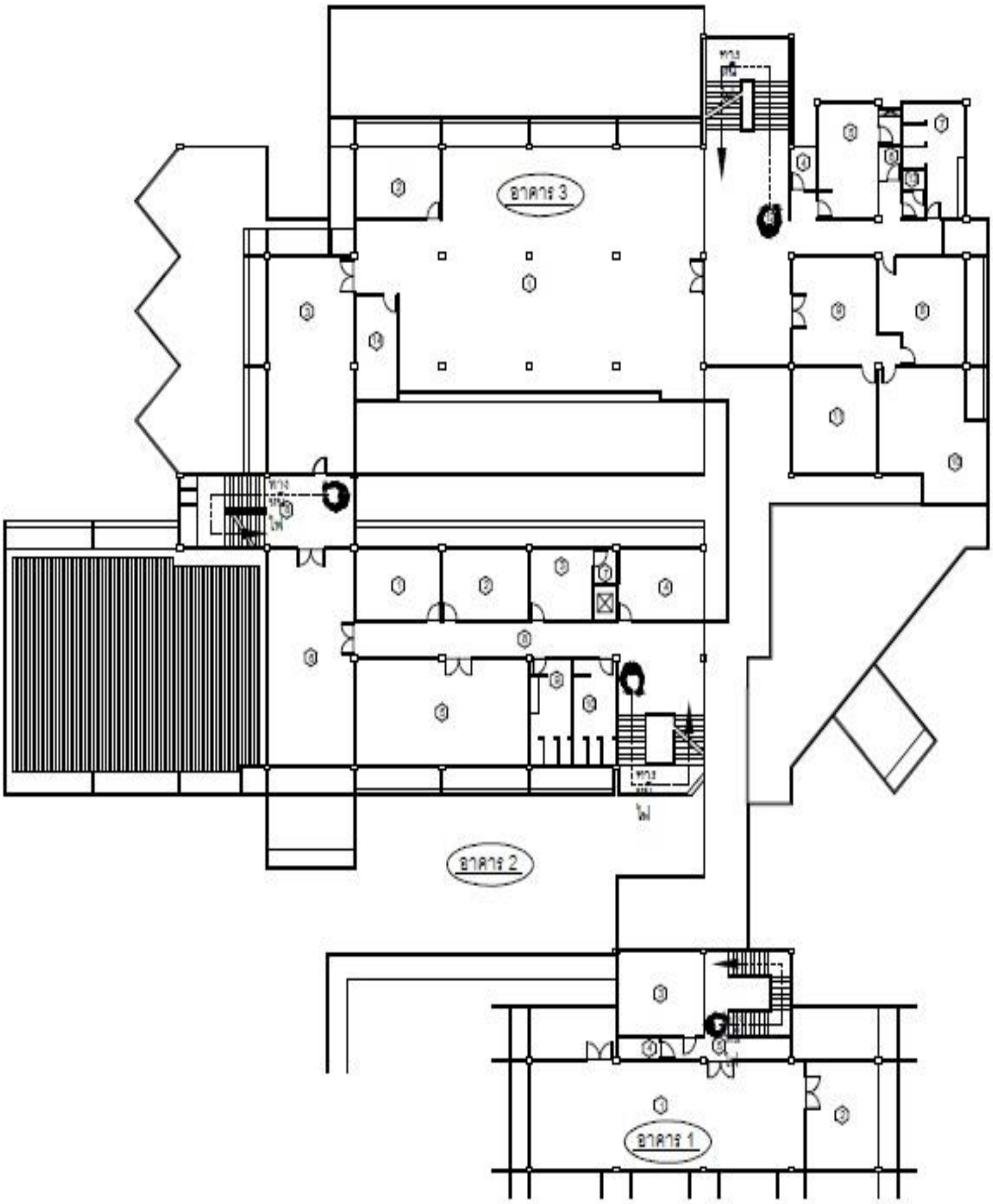


Figure 3.4 The 3rd Floor of President's Office Buildings

Building 1

1. Planning division
2. Meeting room
3. Common room1
4. Common room2
5. Walkway

Building 2

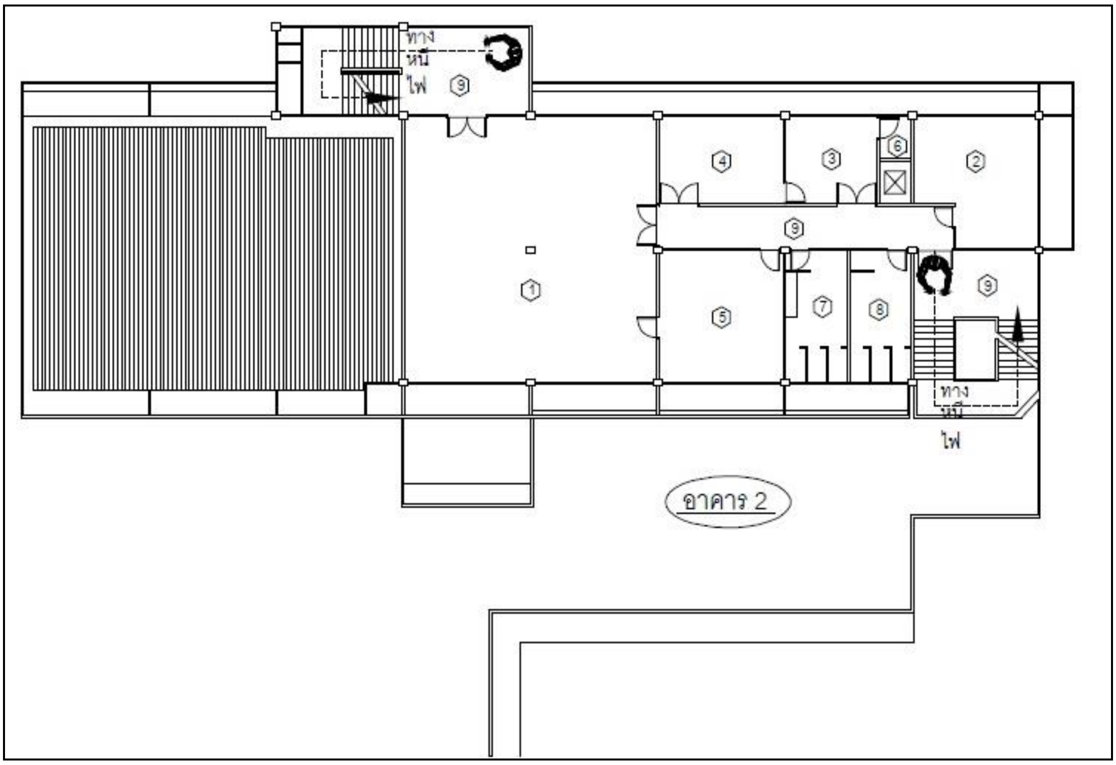
1. Government office association
2. Meeting room
3. Room
4. Art Center
5. Office of internal audit
6. Office of internal affair
7. Room PB 2B
8. Walkway
9. Men’s restroom
10. Women’s restroom

.

Building 3

1. Physical plant services and security
2. Office of director for physical plant service and security
3. Meeting room
4. PB-3 room
5. Advisor to the president for budgeting
6. Restroom
7. Men’s restroom
8. Advisor to the president for external relations
9. Vice president
10. Vice president for international affair
11. Vice president for research system and graduate study
12. Walkway
13. Women’s restroom
14. Document room

Figure 3.4 The 3rd Floor of President’s Office Buildings (Continued)



Building 2

1. Entrance unit
2. Computer room
3. Room 403
4. 404 lounge
5.405 office
6. Room PB-4B
7. Men’s restroom
8. Women’s restroom
9. Walkway

Figure 3.5 The 4th Floor of President’s Office Buildings

3.1.2 Occupancy Profile

The operational units in PO buildings can be separated based on its 3 function - executive, administration, and meeting. The executive board was divided into 3 levels: president, vice presidents, and assistant presidents. In PSU, Hatyai campus, there is a president, 8 Vice presidents, and 16 assistant presidents. The administrative function was classified into 7-units based on its responsibility as shown in Figure 3.6. Considerably, conventional meeting is another important function of PO building in moving campus forward by leading the university management.

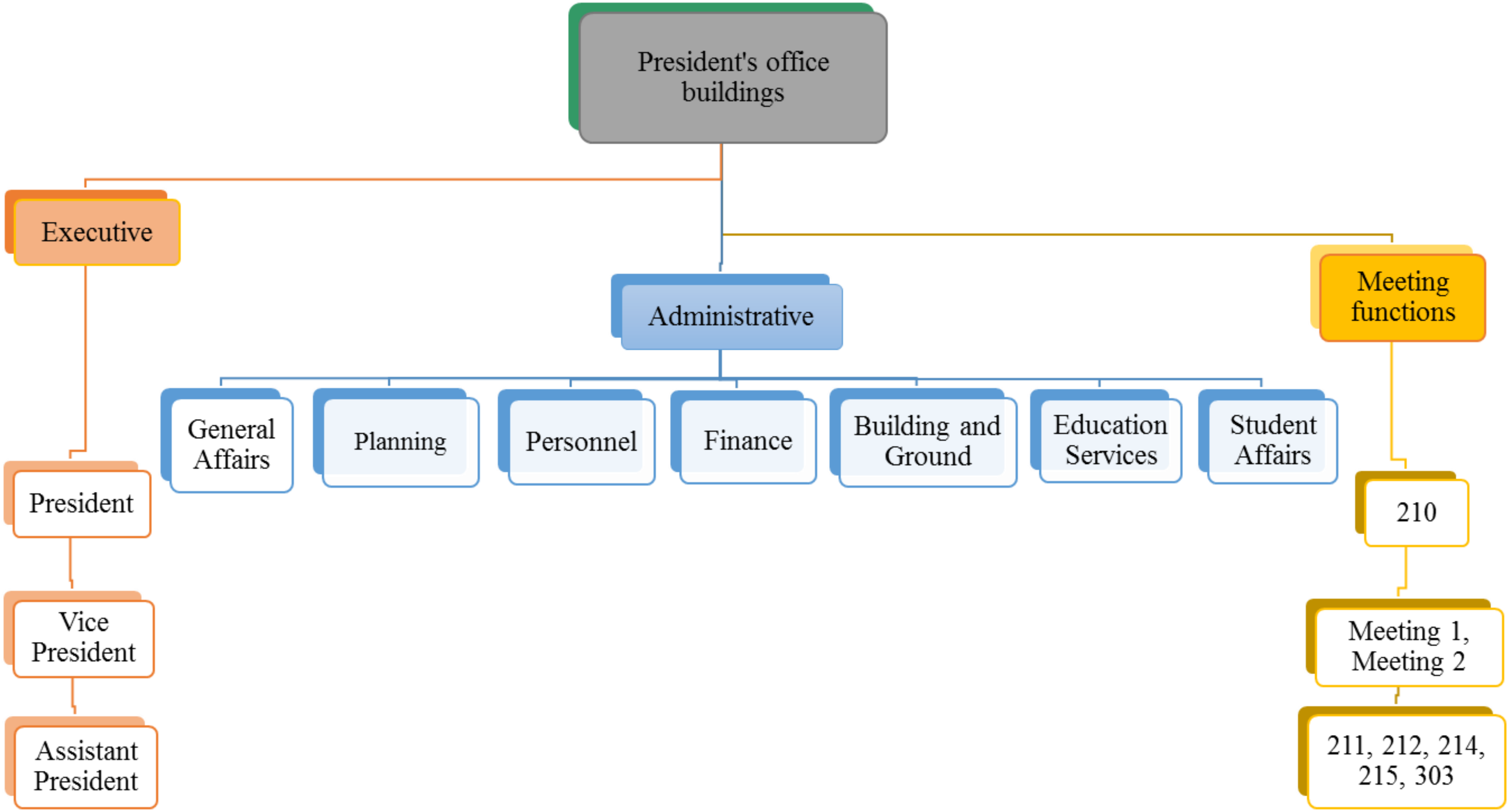


Figure 3.6 Functional Chart of President’s Office Buildings

According to the individualities of the building and the difficulty of identifying sub-operational locations for each of them, general profiles have been designed depending on the functional units of the building, that the building was divided into 3 buildings: Building 1, 2, and 3. The function of administration in PO building was separated in 7 divisions as aforementioned (Figure 3.7). Each division is responsible for campus management. According to this classification, Figure 3.7 illustrated the occupancy profiles of PO buildings which has an operation schedule from 8.30 am to 4.30 pm in a full operation mode on weekdays (Monday to Friday) and from 4.30 pm to 8.30 am in a setback mode on weekdays including Saturday and Sunday. The full operation time assuming 7 hrs a day excluding lunch time from 12 pm to 1 pm. The conventional usage of the buildings could be considered for 3 sections as 1) Fourteen executive rooms served for 25 executive committees related to daily use of 1-2 hours before and after meeting; 2) Seven administrative divisions which is significant part of the building. The entire staff of PO operation is increasing from 630 to 707 staff in 2015 to 2016. These amount were taken into account for carbon footprint evaluation. However, the amount of staff who worked in 7 divisions in these buildings of about 242 persons including 25 executive members was measured for their operational activities (Energy use and carbon footprint emission); and 3) Eight meeting rooms (daily use from 9 am to 4.30 pm). These operations are determined based on access control of workers, executive activities and meeting schedules. There are 2 meetings throughout the day from 2 hrs to 4 hrs. The occupancy profiles exemplified in Figure 3.7 are considered constant throughout the year due to the fact that during academic breaks, they still work and have meetings. However, it’s closed on weekend and official holidays (16 days/year). Approximately, PO has 242 working days per year in 2015 and 241 working days in 2016.

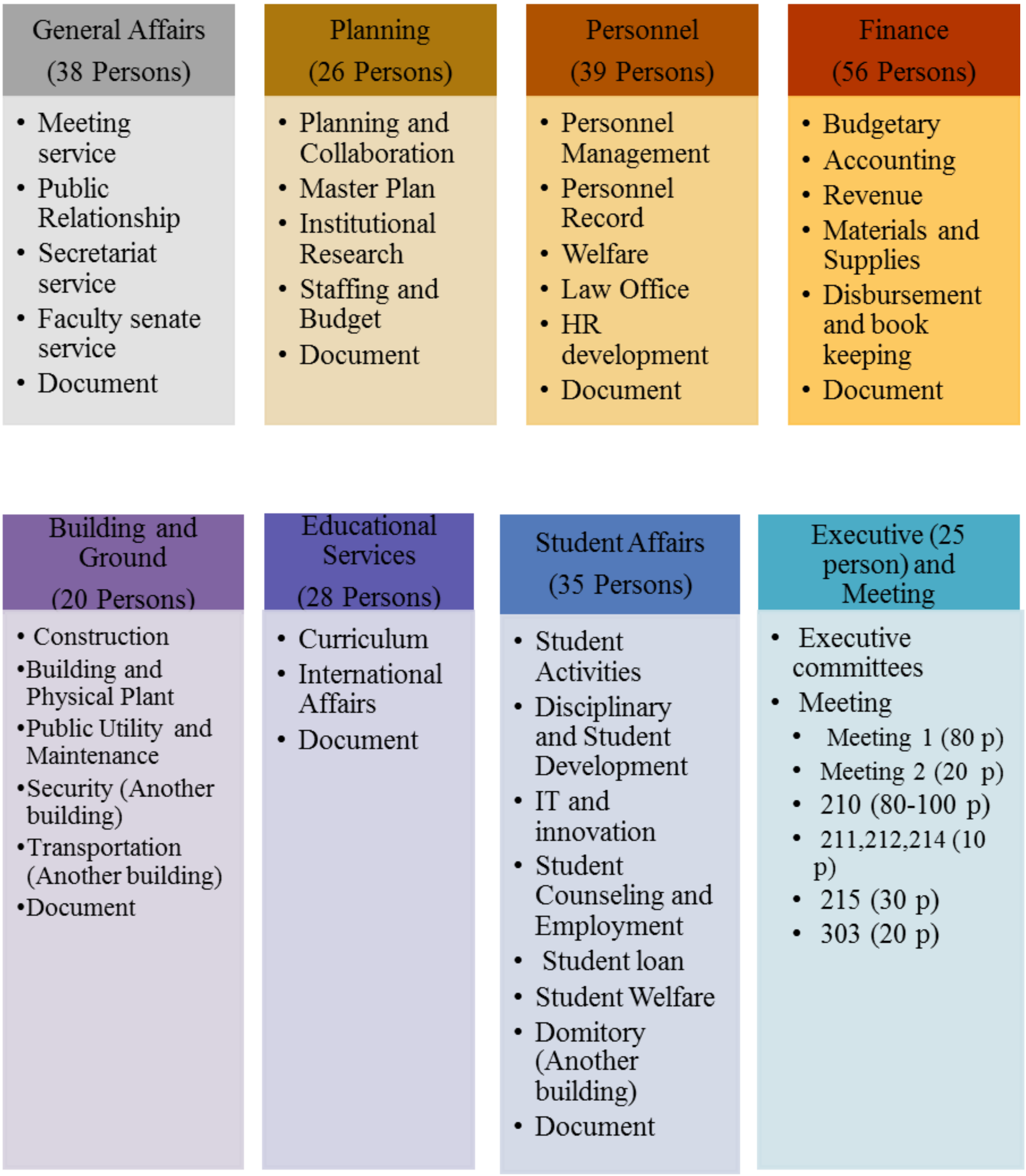


Figure 3.7 Operational Structure in President's Office

3.2 Carbon Footprint

The current state of carbon emission from operational activities in PO was investigated. The facilities which were considered in this study was constituted from executive function, administration section, and meeting function (Figure 3.7). The activities which involved in GHG emission can divide in 3 scopes.. Each scope has the different sources of emission. To obtain the carbon footprint of organization, each scope was determined by source of emission and data provided from responsible units in PO e.g. Finance division responsible for budgetary and materials and supplies record. There are 2 facilities which were not included in this scope; 1) Coolant R-22 with regards to the R-22 replacement was not recorded as GHG in Kyoto Protocol and 2) Dry chemical in extinguisher according to its application was not impact on GHG emission. Summary of carbon footprint inventory was clarified in Appendix C with emission factor sources in Appendix D.

3.2.1. Data Flow

In order to access the data collection, data flow was depicted in each category divided by scope as below

Scope 1: Stationary combustion, mobile combustion, fugitive emission from waste management and septic tank

Stationary combustion from the combustion of fossil fuels

Worker on

- Mower (Gasoline)
- Power supply (Diesel)
- Mosquito spraying machine (Diesel)

Cash card → Petrol station → Record

Mobile combustion from the combustion of fossil fuels

Driver on

- Motorbike (Gasoline)
- Van (Diesel)
- Car (Gasoline /Diesel)
- Bus/Truck (Diesel)

Cash card → Petrol station → Record

Fugitive emission from septic tank

The fugitive emission from septic tank could calculated by Eq. 3.1 and Eq. 3.2.

$CH_4\ Emission = [U \times T \times EF] \times (TOW - S) - R$ (Eq. 3.1)

Defining $S = 0$ according to without sludge removal, $R = 0$ according to without methane recovery, $U = 1$ based on population database from Chiangrai municipality, $T = 1$ based on urban-high income, IPCC Vol. 5, table 6.5 (applied from Indonesia reference as same region and same BOD value per person)

$EF = B_0\ x\ MCF$ (Eq. 3.2)

EF = Emission Factor (kg CH_4/kg BOD), B_0 = maximum CH_4 producing capacity (kg CH_4/kg BOD) from IPCC Vol. 5 table 6.2, MCF = Methane correction factor (fraction) from IPCC Vol. 5 table 6.3

Whereas, $B_0 = 0.6$ for default maximum CH_4 producing capacity, $MCF = 0.5$ with regards to septic system treatment. Therefore, $EF = 0.3$

Total organically degradable carbon in wastewater (TOW) could be calculated from Eq. 3.3.

$TOW = P \times BOD \times 0.001 \times I \times W$ (Eq. 3.3)

P = The number of staff who work under President's office operation

BOD = 40 g/person/day

I = 1 (Default value for Asia)

W = Working days in a year (2015 = 242 days, 2016 = 241 days)

Scope 2: Indirect GHGs emission from consumption of purchased electricity (Electricity consumption and/or electricity purchased from electricity authority)

Electricity consumption of PO buildings was measured every month in terms of electricity bill. Building and ground service division is responsible unit for electricity consumption measurement. Therefore, data flow was accomplished by record of electricity consumption from building and ground service division.

Scope 3: Alternative other indirect emissions which are selected for possibility in GHG reduction and mitigation. The description of each activities was described below.

Paper consumption

This study focuses on A4 paper with regards to the majority of paper use in every offices in PO buildings

Data was collected by material and supplies section in finance division. The users had to take the paper reams from distribution unit in material and supplies section and the distributed amount was recorded each time. Therefore, the data was obtained from record of paper distribution by material and supplies unit.

Emission from water consumption

The water consumption was recorded every month in terms of summary of water supply for each unit. The recorded was monthly collected by water supply unit in building and ground service division. The emission from water consumption was calculated from directly water consumption (m^3) record.

GHG emission from wastewater treatment

Wastewater treatment plant located outside President's office boundary. The wastewater treatment is aerated lagoon which not emit GHGs to the atmosphere (Emission Factor = 0) as examined in Appendix C. Therefore, emission from wastewater treatment was considered but it was not included in result according to zero emission.

GHG emission from waste management

Waste from PO was disposed to Hatyai municipality landfill which has incineration treatment. Therefore, waste management from PO was calculated based on waste incineration method (Appendix C)

3.2.2. Carbon Emission of President's Office Buildings

GHG emissions arising from combustion and fugitive release of fuels were the direct emission (Scope 1) which could take into account for 1) Stationary combustion from the combustion of fossil fuel which PO organization owned i.e. mower, fogging machine, pump, etc. In this case, there are mower, mosquito fogging machine, and power supply defining as stationary machines which PO owned. 2) Mobile combustion from the combustion of fossil fuels used in the operation of vehicle or other forms of mobile transportation which PO controlled. The vehicles which PO controlled comprise of bus, truck, car, van, and motorbike. The fuel used in these vehicles was recorded in terms of gasoline and diesel consumption. Data of both fuel used in mobile combustion could collect from petrol bill which reported by PSU service co-operative division from October 2014 to March 2015 and petrol station in PSU which is Bangchak company franchise after April 2015 according to service co-operative division had already finished contract for 20 years. In 2016, the record was carried on cash card which provide for driver of each vehicle. All record from gasoline and diesel was gathered from vehicle section in building and ground service division. 3) Direct emission produced from septic tank. This part was calculated in datasheet based on the amount of staff and working days in fiscal year 2015 and 2016, and 4) Direct fugitive emissions from refrigeration, air conditioning, fire suppression, and industrial gases was included in scope 1 as well. In this study, data was collected from air conditioning coolant and fire extinguishers. However, air conditioning in PO used R -22 which is not included in this type of fugitive emission (R-22 is not GHG in Kyoto protocol agreement). Fire extinguisher was also monitored. However, there is no leakage or usage record during this period. Therefore, fugitive emission was investigated from septic tank and waste management.

The indirect emission (Scope 2) was measured by electricity purchased from Provincial Electricity Authority (PEA) which could obtained from electricity meters in every monitoring point in university. The usage of electricity of PO was monthly reported and presented in payment bill from electricity unit in building and ground services division.

The optional indirect emissions (Scope 3) are a consequence of the activities of a PO organization but occur from sources which not owned or controlled by the organization. This includes emissions associated with waste, water consumption, business travel, commuting, and procurement. In this case, there were 3 sources of emission which could be collected including paper from procurement, water consumption, and wastewater. These activities were selected based on significant potential and possibility for GHG mitigation. Paper type A4 was used as working document and meeting documents for PO administration and could be collected in terms of annual bill. Water consumption was measured by water meter. Both of data were data from evidence which were directly recorded by PO’s administrative units (Material and supplies unit in finance division and water and wastewater unit in building and ground division). However, data for the business travel and staff owned vehicle could not represent as the evidence or billing with regards to they are an individual cost and different original affiliations payment.

Table 3.2 Carbon Emission in President's Office Buildings in 2015

Description	Unit	Amount	Emission Factor	CO_2 Emission (CO_2 eq)
Scope 1				
- Gasoline (Mower)	L	2,020	2.1896	4,423
- Diesel (Spraying machine)	L	222	2.7079	601
- Gasoline (Vehicle)	L	12,226	2.2376	27,356
- Diesel (Vehicle)	L	37,772	2.7446	103,667
- CH_4 from septic tank	kg CH_4	1,830	25	45,738
Total				**181,785**
Scope 2				
- Electricity	kWh	574,560	0.5821	334,451
Scope 3				
- Paper	kg	3,380	1.1800	3,989
- Water consumption	m^3	5,209	0.7043	3,669
- Waste management	kg	91,476	specified	18,205
Total				**25,863**
Total				**542,099**

As presented in Table 3.2 and Table 3.3, total direct GHG emissions from combustion and fugitive release equal to 182 and 170 ton CO_2 eq in 2015 and 2016, respectively. The fuel combustion from diesel in organization owned vehicle are the major part of carbon emission for scope 1. This ratio is slightly decreased in 2016. Scope 2 emissions physically occur at the facility where electricity is used. Electricity which consumed by PO occupies the chief GHG emission ratio. The least emissions come from scope 3 which were counted for 26 and 24 ton CO_2 eq in 2015 and 2016, respectively as depicted in Figure 3.8. Therefore, total emission from PO operational activities was calculated to be 542 ton CO_2 eq in 2015 and slightly increase to 553 ton

CO_2 eq in 2016 from increasing in electricity consumption or increasing 2% from 2015. The average for carbon emission of about 548 ton CO_2 eq was calculated from total emission during 2015 and 2016.

Table 3.3 Carbon Emission in President's Office Buildings in 2016

Description	Unit	Amount	Emission Factor	CO_2 Emission (CO_2 eq)
Scope 1				
- Gasoline (Mower)	L	2,400	2.1896	5,255
- Diesel (Spraying machine)	L	1,100	2.7079	2,979
- Gasoline (Vehicle)	L	11,278	2.2376	25,236
- Diesel (Vehicle)	L	30,580	2.7446	83,928
- CH_4 from septic tank	kg CH_4	2,111	25	52,779
Total				**170,177**
Scope 2				
- Electricity	kWh	615,592	0.5821	358,336
Scope 3				
- Paper	kg	3,044	1.1800	3,592
- Water consumption	m^3	692	0.7043	487
- Waste management	kg	102,232	Specified	20,346
Total				**24,425**
Total				**552,937**

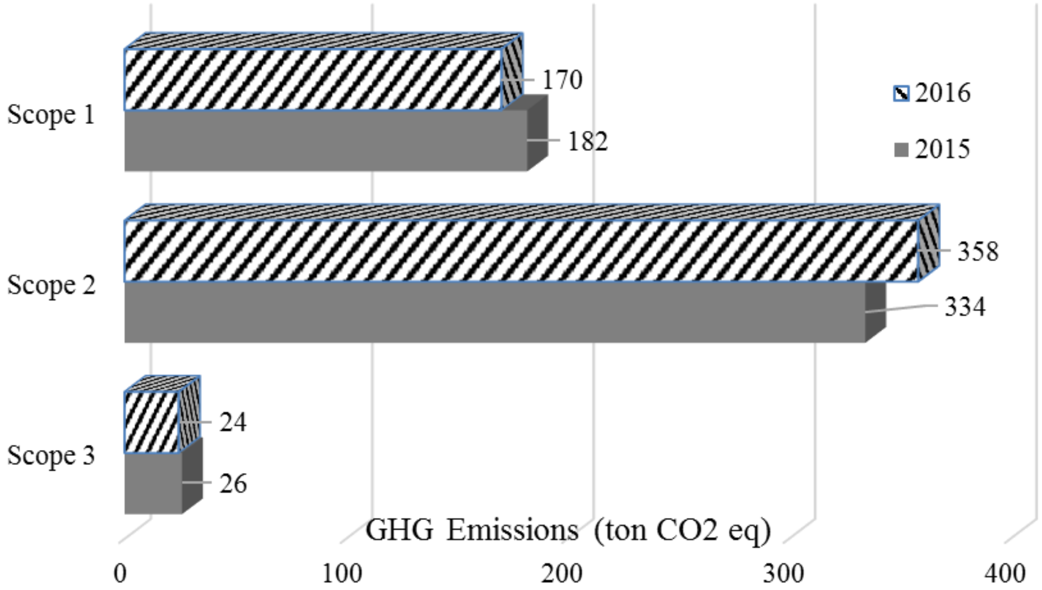


Figure 3.8 GHG Emission from President’s Office in 2015 and 2016

The average GHG emission was reported in terms of GHG emission per capita which reduced from 886 CO_2 eq/capita in 2015 to 808 CO_2 eq/capita in 2016. However, GHG per area of buildings slightly increased from 2015 to 2016 as exhibited in Table 3.4.

Table 3.4 Total GHG Emission from President's Office in 2015 and 2016

Description	Unit	2015	2016
Total GHG emission	ton CO_2 eq / yr	542	553
GHG Emission per capita	kg CO_2 eq / capita / yr	860	782
GHG Emission per area	kg CO_2 eq / m^2	78	79

Moreover, it could be identified that hot spot for carbon emission is electricity consumption. The options for GHG mitigation could be emphasized on consumption reduction and renewable energy contribution. High energy consumption not only increase GHG emission but also increase cost of operation including environmental impact. The GHG emission mitigation with operational cost reduction were comprehensively discussed which will be analyzed in next step.

3.3. Assessing and Reducing Uncertainty

The qualitative influences of uncertainty in this project were investigated in order to reduce uncertainty in future management. Uncertainty was considered as score weight, data reliability, and emission factors from carbon footprint evaluation. The data quality was scored in 3 groups and quality of emission factor was separated in 4 groups as following tables. Setting of data score was illustrated in Table 3.5-3.7.

Table 3.5 Level of Reference Score of Data Quality

List	Level of Data Quality				
Activities Data	X = 6 points		Y = 3 points		Z = 1 point
	Continuous data collection and automatic measurement[1]		Data collection from meter and receipt[2]		Data collection from secondary data and estimation[3]
Emission Factors (EF)	C = 4 points	D = 3 points	E = 2 points	F = 1 point	
	EF from qualified measurement[4]	EF from producer[5]	EF from national level[6]	EF from international level[7]	

[1] Continuous data collection from actual quantification record which quantification record could provide from measurement and qualified equipment or instrument i.e. fossil fuel consumption which measure from oil dispenser

[2] Data collection from receipt of reliable and verifiable references i.e. electricity consumption from organizational electricity receipt

[3] Data assumption for evaluation from case studies, secondary data

[4] Factor obtained from primary data collection by qualified measurement and certified instrument

[5] Factor from supplier

[6] Initial factor defined for national level i.e. TC common data

[7] Initial factor defined for international level i.e. IPCC

The uncertainty was calculated following TGO guideline of carbon footprint (2012) by Eq. 3.4. The unceratainty score could be estimated by activities data multiply by emission factor as described in Table 3.5

$$\textit{Uncertainty Score} = \textit{Level of Data Quality}_{\text{Activities Data}} \times \textit{Level of Data Quality}_{\text{EF}} \quad \text{Eq. 3.4}$$

The finding of score of data quality or untertainty score was determined in Table 3.6. High score presents high data quality with low uncertainty. The result of overall data quality was evaluated in each scope as presented in Table 3.7.

Table 3.6 Qualitative Analysis of Data Quality

Level	Overall Score of Data	Description
1	1-6	High uncertainty Low data quality
2	7-12	Medium uncertainty Medium data quality
3	13-18	Low uncertainty Good data quality
4	19-24	Low uncertainty Excellent quality

Table 3.7 Overall Data Quality Level

Scope	List	Data Collection Score	EF Score	Result	Level
1	Stationary combustion	3	1	3	1
	Mobile combustion	3	1	3	1
	Septic tank	1	1	1	1
2	Electricity	6	2	12	2
3	Paper use	3	1	3	1
	Water consumption	3	2	6	1
	Wastewater treatment	1	1	1	1
	Waste management	1	2	2	1

From level of data quality, organization could apply for uncertainty planning in carbon footprint inventory and improvement in next evaluation.

To improve data quality, data is cross-checked with energy consumption estimates based on activities to reduce errors, omission, and double accounting.

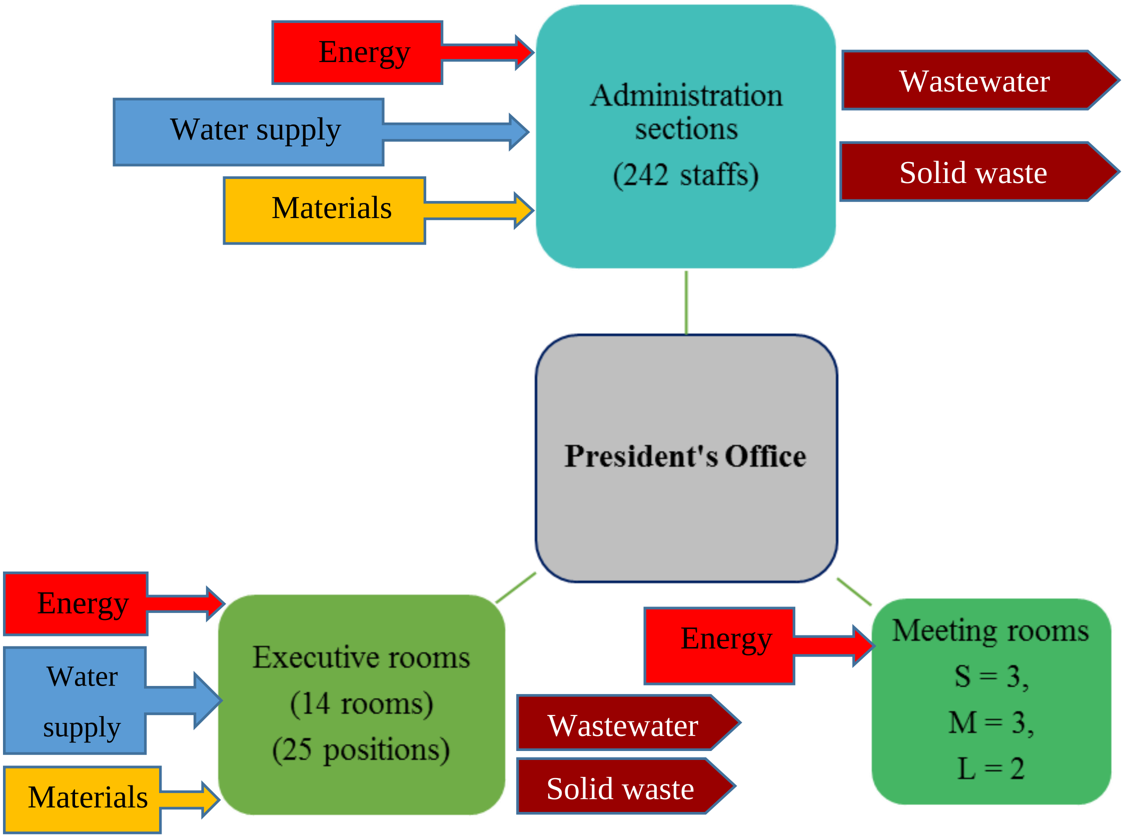
3.4. Operational Cost Analysis

3.4.1. Material Flow Analysis

To evaluate the operational cost of administration, material flow is a recognized quantitative procedure to measure material throughput for all economic activities including environmental burden it creates. Material Flow Analysis is used to identify and quantify the consumption of natural resources based on the mass balance principle (Frohling et al., 2013; Hoque et al., 2012), which could be used to evaluate energy consumption performances on industrial or sectoral levels (Sendra et al., 2007; Tanimoto et al., 2010). In this research, it accounts for all materials and energy used in services and consumption including administration (Figure 3.9). Generally, it is a method for evaluating the efficiency of using material resources. The throughput actually transformed into administration and management activities including documents then finally turned to the natural system in terms of waste and wastewater.

The identification of wastes is necessary as the purpose of conducting an action plan to diminish the flow of materials and energy. Its methodology allows the monitoring of wastewater and solid waste that are typically accounted for conventional life cycle analysis.

Focusing on the administration sector, the largest constituent in PO buildings, it also possesses the largest amount of material use and energy consumption serving for 242 routine working staff. The occupancy profile of meeting and executive is different from administration. However, these casual users account for a significant proportion of total energy use and material consumptions. This composite profile including many types of work pattern ranging from routine officer, temporary members, and executive committees which are representative for four-year term of management. The executive office is served for these executive members. The meeting rooms are provided for meeting and discussion in several management function.



S = 5-10 persons,

M = 20-30 persons,

L = 80 -100 persons

Figure 3.9 Material Flow by Function

3.4.2. Cost of Administration

The cost of operating activities in PO building, as mentioned in previous section, is estimated in the figure below. The data represents annual cost of operation including a constant throughput of energy, water supply, and material and supplies that served for administrative activities in PO building, assuming regular condition was predicted for energy consumption and waste production evaluation in routine activities.

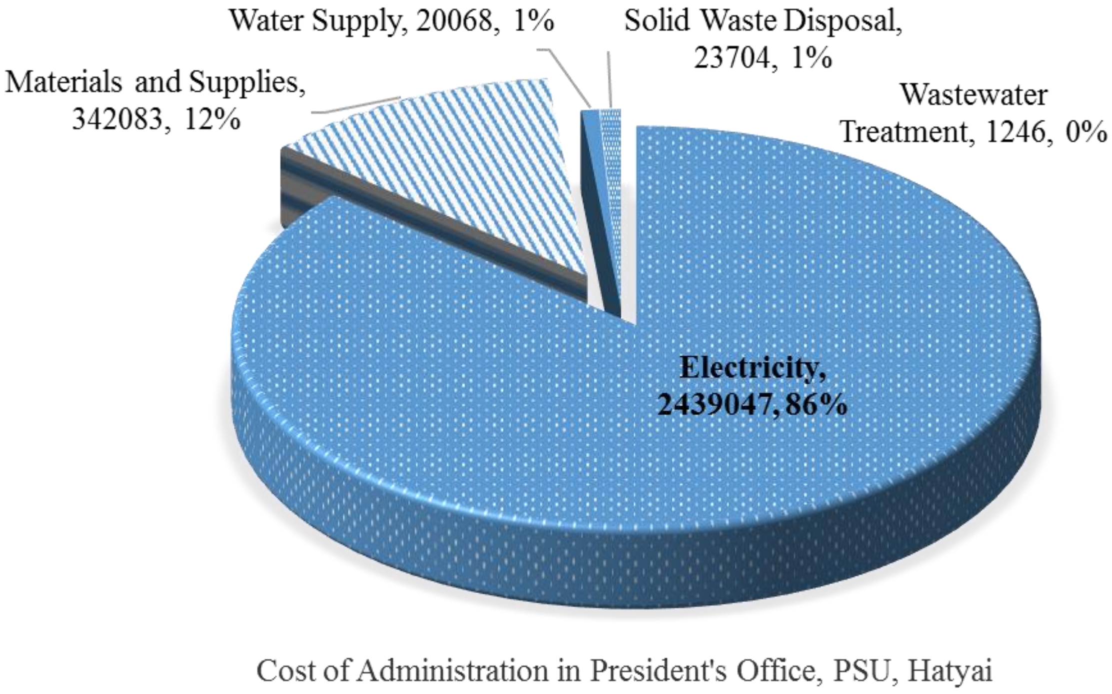


Figure 3.10 Cost of Administration in President’s Office Buildings

Cost of each constituent was provided by source as presented in Figure 3.10. The cost of administration was gathered from 3 documents in fiscal year 2016 and 242 working days according to updated continuing research data. Electricity was charged from average rate in Fiscal year 2016 at 3.96 THB per unit (kWh). Water supply appraised for 29 THB per unit (m^3) and wastewater was estimated to be produced from 90% of water supply with the treatment cost 2 THB per unit (m^3) and the solid waste disposal will be charged before transport to Hatyai Waste to energy gasification power plant at the rate of 0.319 THB per kg. An estimated value of about 1.15 kg per capita per day for solid waste generation coefficient in urban area has been used in solid waste generation cost calculation. Total cost of operation in PO building of about 80,748 USD (2,826,147 THB) in 2016 was summed from each constituent. Noticeably, the highest cost of operation comes from electricity consumption (86%) estimated to be 2,439,047 THB or 69,687 USD (Exchange rate of Bank of Thailand in Fiscal year 2016 equaled to 35 THB per USD). Electricity consumption of PO buildings has obviously increased from 485,092 to 574,020 units

(Watt) in 2013 to 2014 and rising to 615,592 units in 2016. This growing energy consumption results from routine activities in administrative division.

3.5. Energy Performance

As aforementioned, the highest cost of operation resulted from electricity consumption. To evaluate energy reduction measurement, energy performance is required. The energy performance focused on the operational activities. Average operation period was obtained from interview and observation. It also was assumed that 242 working days in administrative building were regular operation time a year. The cost for each electricity appliance was estimated for predict energy trend and cost reduction.

3.5.1 Energy Consumption Trend

Annually, electricity consumption was growing from 2013 to 2016 of about 26.9% as presented in Figure 3.11. Electricity consumption rapidly raised up from 2013 to 2014 prior to slightly increase in 2014 to 2015 then significantly reached to 615,592 kWh/yr in 2016 which tended to continually increase energy use as trend in Figure 3.11. The cost of electricity in PO buildings was increasing from 2.06 Mil. THB in 2013 to 2.44 Million THB in 2016.

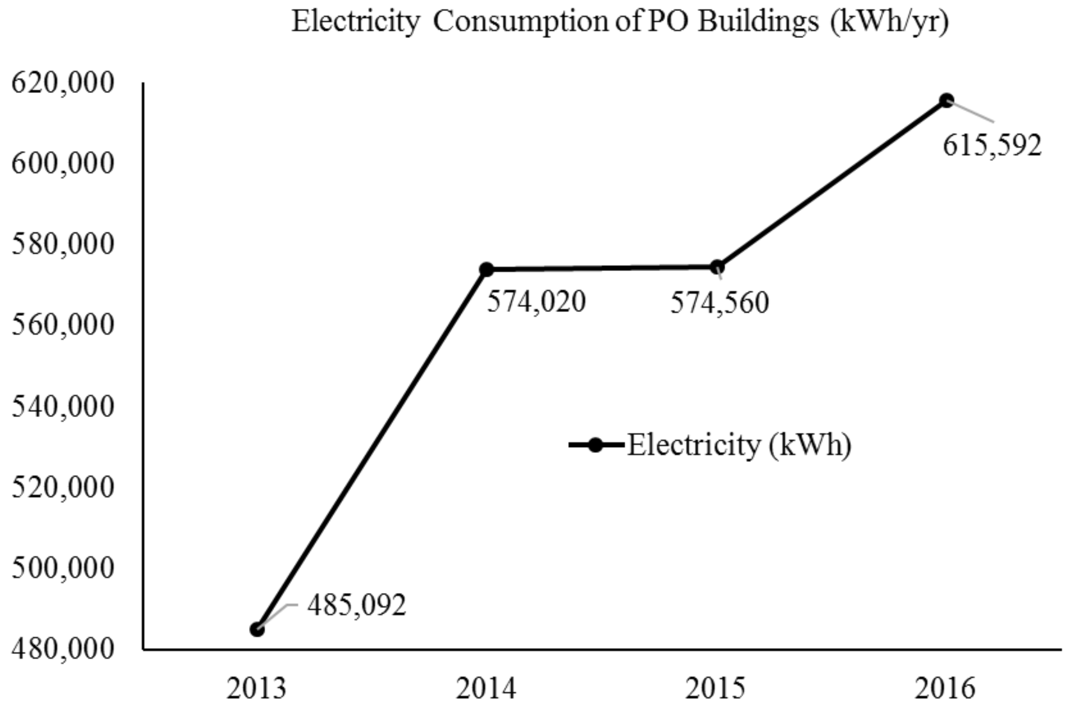


Figure 3.11 Electricity Consumption of President’s Office from 2013 – 2016

3.5.2. Energy Audit

Operational energy is the energy requirement of the building during its lifetime. An energy audit program has been investigated from several operational activities e.g. financing, accounting, budgetary planning, reporting, documenting, meeting, academic supervision (guidance) as well as concrete objects such as databases and support services. The evaluation was held in fiscal year 2016. Although there will be a lot of detail planning to be carried out later, developing the significant energy audit plan at an early stage is required. In this study, the primary building operation was considered in four types of energy usage - cooling (Air-conditioning, AC), lighting (Fluorescent lamp), Information Technology (IT) devices (Computer and support devices), and auxiliary appliance (Electric appliance). By monitoring the four key components as the basic operators responsible for the specified tasks, the building supervisor can plan for the maintenance schedule. The calculation of power consumption and cost estimation of AC, lighting system, IT device and auxiliary appliance were examined in Appendix F. The electricity provided for whole PO buildings was not separated by appliance system (Appendix G), thereafter, direct work load and load factor investigation was not possibly measured from each system. Poonpratin (2012) suggested that electricity consumption could determine from appliance monitoring and work load assumption. In practical, this research evaluated energy consumption on appliance monitoring from surveillance and staff interview including assuming differentiated operating time as described in Appendix F.

Primarily, AC system in PO building was surveyed. The total number of AC in each section was summed up in Table 3.8. AC is the greatest section of energy use in PO building for cooling room space. Operation time of each section is differentiated. AC provided for administration (8-9 hrs/d), meeting function (6-7 hrs/d), and executive room (2-3 hrs/d) were estimated from staff interview for energy consumption calculation.

Table 3.8 AC System Monitoring in President's Office Buildings

AC Size	Capacity	No. of AC			Consumption	Cost
(BTU/h)	(kW)	Meeting	Adminis-tration	Executive	(Unit/d)	(THB/yr)
9,000	0.77	1			3.08	3,031.08
12,000	1.03		1	1	6.68	6,567.35
12,500	1.07		2	1	12.32	12,103.28
18,000	1.54	1	4	4	46.27	45,466.24
20,000	1.71	1	4	2	46.27	45,466.24
24,000	2.06	3	1	3	44.22	43,445.52
25,000	2.14	5	3	3	84.62	83,144.28
28,000	2.40		2		23.99	23,575.09
30,000	2.57	2	4		71.98	70,725.26
33,000	2.83			1	4.24	4,167.74
36,000	3.08	7	5	8	200.51	197,020.38
37,000	3.17	1	2		44.39	43,613.91
40,000	3.43			1	5.14	5,051.80
48,000	4.11	8	12	6	415.42	408,185.81
60,000	5.14		24		616.97	606,216.56
130,000	11.14	1			44.56	43,782.31

The lighting system in operation is depicted in Table 3.9. The lighting survey was illustrated in Appendix E. The major of light in PO building is T5 fluorescent lamp that changed from T8 bulb since 2013. This could reduce energy from 36 W to 28 W for bulb type 1198 mm and reduce from 18 W to 14 W for small bulb type (588 mm).

Table 3.9 Lighting System in President's Office Buildings

Lighting - Bulb Type	Capacity(W)	No. of Lamp	Cost (THB/yr)
T5 1198 mm Ft 1 * 28 W	28	100	21,998.59
T5 1198 mm Ft 3 * 28 W	28	1359	298,960.87
T5 588.7 mm Ft 1 * 14 W	14	43	4,729.70
Compact-Fluorescent bulb 9 W	9	111	7,848.78
T5 1198 mm Ft 2 * 28 W	28	442	97,233.78
T5 588.7 mm Ft 3 * 14 W	14	63	6,929.56
T5 1198 mm Ft 2 * 28 W	28	442	97,233.78
T5 588.7 mm Ft 2 * 14 W	14	8	879.94
T8 Ft 2 * 18 W Surrounding	18	16	2,262.71
LED bulb 12 W	12	29	2,734.11
T8 588.7 mm Ft 2 * 18 W	18	8	1,131.36
Ceiling bulb 32 W	32	2	502.82

The electricity used for IT device and auxiliary appliance was monitored using survey questionnaire (Appendix E). Table 3.10 presents information of appliance usage in administration operation. IT device shown the significant ratio of energy consumption cost of about 399,588.71 THB/yr with regards to routine staff's operation. Meanwhile, auxiliary appliance was taken into account for 190,581.57 THB/yr.

Table 3.10 IT Device and Auxiliary Appliances in President’s Office Operation

Appliance Type	Appliance	No. of Appliances	Capacity (W)	Operation Time (hr/d)	Cost (THB/yr)
IT Devices	Computer - Desktop	235	200	8	369,262.08
	Computer - Laptop	24	65	4	6,128.18
	Printer	72	40	8	22,627.12
	Scanner	10	20	8	1,571.33
Auxiliary Appliances	Photocopier	3	1100	6	19,445.18
	Projector	5	210	0.5	515.59
	Fax machine	10	10	8	3,468.96
	Telephone	104	10	24	36,077.18
	Microwave oven	6	800	0.5	2,356.99
	Refrigerator	12	125	24	52,034.40
	Pot	12	700	8	65,995.78
	Fan	39	75	0.5	1,436.29
	Television	10	90	0.2	176.77
	Blower	38	30	8	8,956.57
	Rice cooker	1	600	0.2	117.85

Total electricity consumption ratio was summarized and used as index to describe overall energy use. Figure 3.12 indicates that air conditioning (AC) system accounts for 55% of the total operating energy of a PO building. Meanwhile, lighting equipment require 23% of the operating energy and IT equipment demands tend to require about 15%. Finally, auxiliary demands completed the energy profile, requiring only 7% of the total operational energy. According to the highest electricity cost of PO is paying for AC system. Therefore, reducing electrical cost on AC will greatly impact on cost of operation.

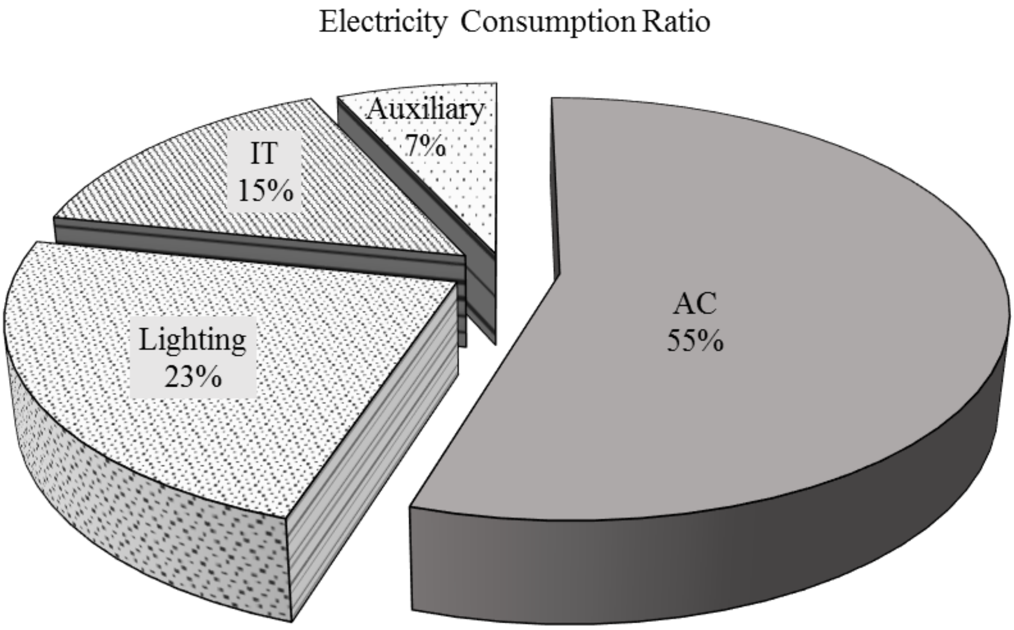


Figure 3.12 The Annual Electricity Consumption Ratio

Approximately, three-fourth of the energy consumed in buildings is attributed to administrative operations (Figure 3.13) followed by meetings function. The executive function is the smallest part of total energy consumption. Looking at the administration sector, the largest component of energy use are also space AC system consumed 42% of total energy consumption. Therefore, it is important to recognize that reduction of space AC could reasonably decrease the entire electricity consumption as operational energy. The findings show the impact of focusing on fundamental areas of administration (i.e. finance, educational service, personnel, etc.) to minimize the required energy prior to develop them. It means that the potential for energy saving is huge including appliance retrofit and operation time reduction. Occupant behavior changing is alternative in sustainable energy consumption. The challenges of implementing changes in operational energy performance improvement of PO buildings are addressed in the recommendations that could bring about energy efficient results.

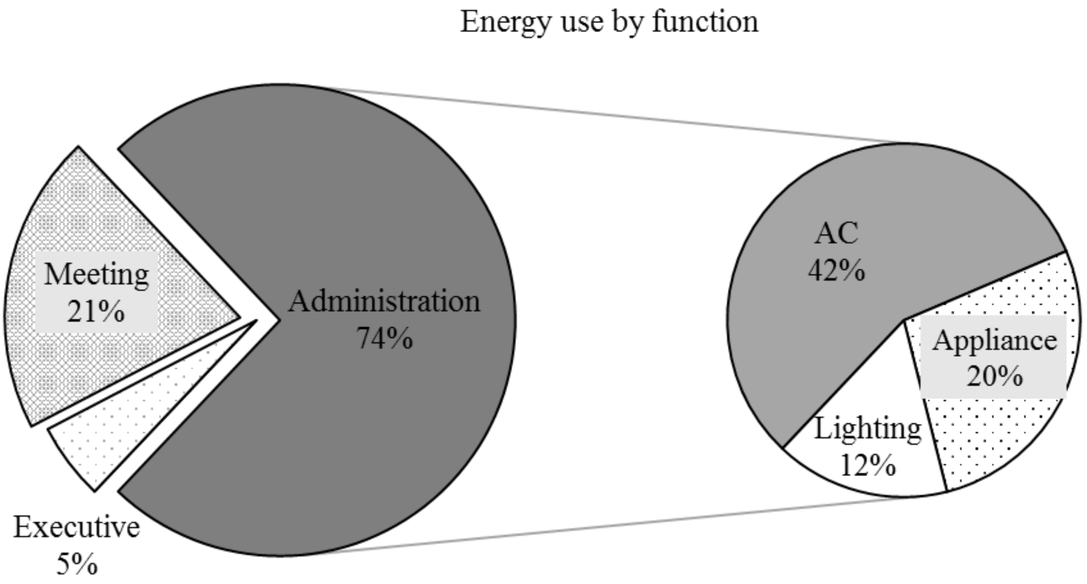


Figure 3.13 Energy Use by Function

3.6. Energy Efficiency Measures

Energy breakdown represented that almost 75 percentage of energy use is provided for administrative section. This is hotspot of electricity consumption in PO buildings. Therefore, steps to saving energy in the building is significantly deliberated on among stakeholders in administrative divisions. University executive, representative of building and ground subdivision, and administrative staff play a crucial role in energy performance development for PO building.

3.6.1. Energy Conservation Guidance

From basic principle in electricity calculation, it was found that the cost of electricity consumption depends on 2 parts; 1) Capacity (Watt), and 2) Operating time (hrs). Therefore, energy consumption of a building by means of occupancy can be reduced while maintaining or improving the level of comfort in the building by capacity reduction of appliances and outlet and/or decrease operating time. They can typically be categorized into

- Reducing cooling demand;

- Reducing the energy requirements for ventilation;
- Reducing energy use for lighting;
- Reducing electricity consumption of office equipment and appliances;
- Good housekeeping and people solutions.

This study was emphasized on reducing energy use for operation of administrative divisions. Therefore, energy conservation should apply for administrative divisions.

For lighting system, this can be accomplished through:

- Making maximum use of daylight while avoiding excessive solar heat gain;
- Using task lighting to avoid excessive background luminance levels;
- Installing energy-efficient luminaires with a high light output to energy ratio;
- Selecting lamps with a high luminous efficacy;
- Providing effective controls that prevent lights being left on unnecessarily.

Retrofitting of appliances and electrical devices is another approach in energy saving. Operational time reduction is conventional strategies which require continuing support from both executive and staff cooperation

From the energy audit result, AC system was found to be the highest proportion of energy consumption. Therefore, energy conservation was recommended as below

1. Rearrange the furniture that obstructs air conditioning ventilation

2. Using supplemental fans to initially cool air in the room

3. Setting temperature 25-26 degree celcius

4. Regularly monitoring and maintenance, for instance, coolant checking and AC cleaning

5. Installation new AC instead of old existing AC system

However, some constraints must be carefully consideration by operations, techniques and investment cost. In order to save energy efficiency, cost of investment and retrofit should be clarified. For the lighting system, cooling system, IT equipment, and auxiliary equipment. The cost for retrofit was exhibited in Table 3.11.

Table 3.11 Estimation Cost of Equipment Retrofit

Cost System	Acquisition	Installation	Operation and Maintenance
Lighting	V	2.29 USD/set	-
Air conditioning	V	71.43 USD/unit	D
IT equipment	V	-	D
Auxiliary equipment	V	-	-

Remark: V = Vary with specification and power,

D = Depend on equipment and maintenance retrofit

3.6.2. Energy Efficiency Involvement

From the aforementioned instruction, the suggested measures were divided into 2 different categories, reaching by internal and external factors (Figure 3.14). The most mutual recommendations were identified as lighting and air conditioning retrofits. They could get grant support from the outsource fund in efficient appliance installation. The most cost-effective solution is not always the most environmentally sound choice. For instance, renewable energy implication might consume very little energy but cost more to install than it saves in energy cost. However, renewable energy installation was planned for renovating PO building as a smart building in the future. Solar roof is an interesting alternative. Even though it is not easy to install solar roof on the rooftops of the old building because of the heavy weight of the roofing material. Furthermore, there is still potential for improving energy performance not only influenced by its physical characteristics but also by many other factors such as occupant’s behavioral change, and control of indoor environmental conditions.

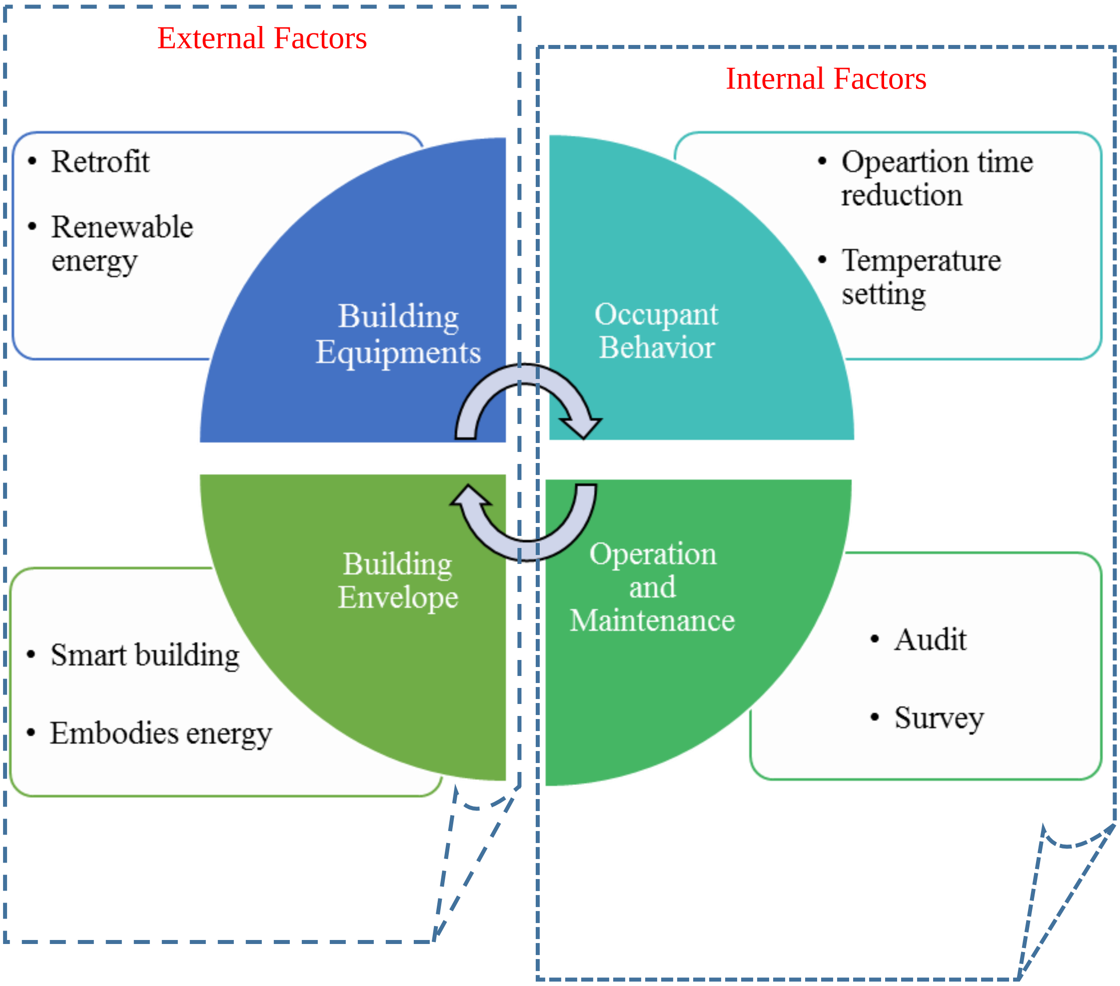


Figure 3.14 Energy Efficiency Measures for President's Office Operations

3.6.3. Energy Conservation and GHG Emission Reduction Scenario

To promote energy saving and GHG emission reduction in PO buildings, scenarios from energy consumption reduction were figured out for policy maker consideration. Baseline scenario was control treatment for compare with modified energy scenario. Baseline case was the normal operation carried on general operation time with existing electricity equipment and appliance. The energy conservation was possibly proposed in 5 options as explained in Table 3.12.

Table 3.12 Options for Energy Conservation

Option	Description
A	AC - Operation time reduction: Turn on from 9-11.30am and 1.30 – 4.00pm (5 hrs operation)
B	Lighting – Turn off during lunch time (Reduce 1 hr operation)
C	IT devices – Switch off during lunch time (Reduce 1 hr operation)
X	LED installation instead of fluorescent at normal operation (8 hrs)
X1	LED installation instead of fluorescent at 7 hrs operation

Eight scenarios were considered from five options in administrative office which is the major part in electricity consumption and it was daily service and routine works. All scenarios were described as below:

A) By means of reduction of AC operating time as turn on from 9-11.30am and 1.30-4.00pm to reduce compressor work load

B) By means of reduction of operation time in lighting system during lunch break (Turn off from 12-1 pm)

C) By means of reduction of IT devices operation time during lunch break (e.g. Switch off computer monitor from 12-1pm)

X) By means of the Light-emitting Diode (LED) installation which is lighting system improvement. This means that the LED lamps will be entirely installed instead of T5 fluorescents which existed in PO buildings. This project was supported from DEDE and it is in bidding process for LED supplier. The installation was completed by June 2017.

X1) By means of the LED light installation with operation time reduction during lunch time (12-1 pm)

Scenario X + A: the replacement of LED with AC operation time reduction

Scenario A + B + C: Fully occupancy saving by reduction operation time of lighting, IT devices, including space AC

Scenario X + A + C: The retrofitting equipped with occupancy behavior change (Switch off AC and IT devices during lunch time for an hour). This scenario will be effective when all LED were installed

Scenario X1 + A + C: After LED installed, extreme energy saving would be occurred when operation time reduction for all electricity use with developed energy efficient lighting system

The A and B options present the insignificant scenarios (III, IV). Therefore, they was considered in supporting with significant options which are AC control (A) and LED installation (X) (Table 3.13). LED is recommended by Electricity Generating Authority of Thailand (EGAT) that it can saving 80% more than fluorescent (EGAT, 2013)

Table 3.13 Scenarios for Energy Conservation and GHG Reduction

Scenario	Option
Baseline	Control condition at normal operation
I	X
II	A
III	B
IV	C
V	X + A
VI	A + B + C
VII	X + A + C
VIII	X1 + A + C

Reduction of electricity consumption and GHGs mitigation was illustrated in 2015 (Appendix F) to initiate energy efficiency (Table 3.14). The significant energy conservation methods are explained in scenario demonstration (Figure 3.15). For AC work load reduction, it could reduce 11% electricity consumption. Matching between operation time reduction and appliance retrofit could maximize energy reduction. Also, enhancement of GHGs mitigation relates to energy conservation (Figure 3.16). LED installation with reducing operation time of AC, lighting system, and IT devices presents one-fifth reduction in energy consumption and GHGs emission as exhibited in Table 3.14. However, investment cost and promotion campaign are required for energy conservation promotion. The possible effective scenario for investment was LED installation. In addition, to choose the optimize scenario, possibility and potential of energy saving were deliberately considered through each scenarios.

Table 3.14 Electricity Consumption and GHG Reduction Scenarios

Scenario	Electricity Consumption (kWh/yr)	GHG Emission (ton CO_2 eq)	Reduction (%)
Baseline	574,560	334	0
I	530,183	310	7.7
II	511,013	296	11.1
III	571,319	334	1.0
IV	574,304	333	0.0
V	466,637	272	18.8
VI	507,516	295	11.7
VII	466,380	271	18.8
VIII	456,540	266	20.5

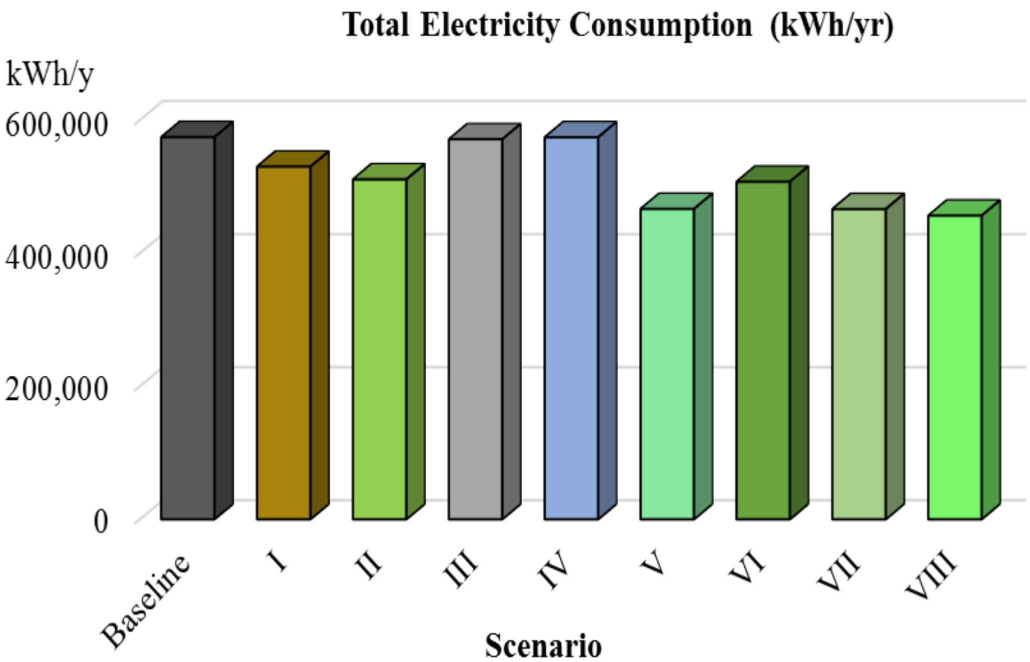


Figure 3.15 Energy Saving Scenarios in 2015

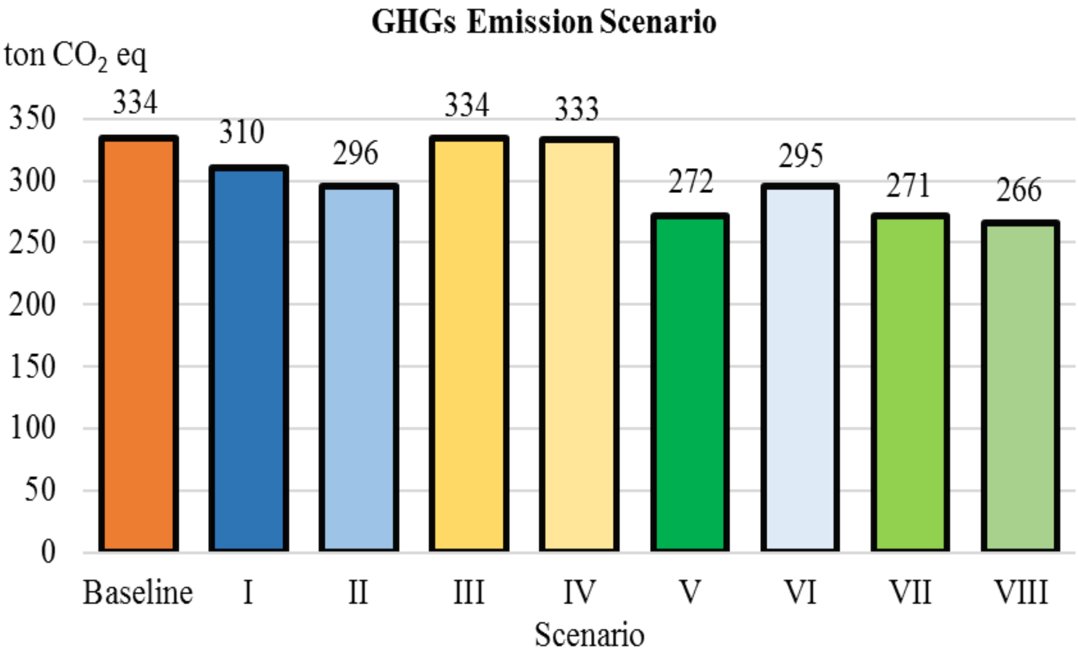


Figure 3.16 GHG Mitigation Scenarios in 2015

These scenarios were proposed to university executive representative who is the pacesetter of green university team responsible for convert strategies involved in green university project (Appendix H) to implementation. This research will be one of the database support for green university approach.

3.6.4. Solar Rooftop Contribution

Currently, the energy saving projects are applying on PO buildings, for instance, smart building, LED retrofitting, and solar rooftop installation, etc. As recommendation in IPCC (2007), solar PV integrated with active solar design contributed for mitigation technology and practices for buildings. Solar panel could be installed for PO with rooftop renovation. The energy required is estimated to be 2.54 kW/day assuming from 242 working days per year and electricity consumption in 2016 (615,592 kWh/yr). A solar panel could produce 225 Watt in an hour at 90% efficiency from maximum capacity (250 Watt). It requires 1.68 m^2 per panel with assuming 4 hrs/day sunlight approach. A solar panel could substitute 0.9 kW/day electricity consumption from fossil fuel production. Therefore, PO buildings could be contributed from 30 solar arrays for electricity cost saving. Even the solar lighting is renewable energy and eco-friendly energy source, its contribution also equipped with support accessories, for example, solar charge controller, inverter, battery, circuit breaker, etc. These accessories cost is comparative high which has to consider for investment.

3.6.5. Energy Saving Models

One of several options to support the energy efficiency is to use subsidies as an implementing instrument. If subsidies can be applied, the adequate amount of subsidy needs to be estimate by target sector, taking into account for the university variable conditions. The effect of the subsidy can be very sensitive to its level. Too small subsidy does not really activate the demand side but will only be picked up by those who would order an energy audit in any case. Too high subsidy percentage might reduce the cost-effectiveness of the programme. A clear fact is that the higher total cost of the programme requires the higher subsidy. The basic question is to find out the level where the trigger effect really starts. This level has to be evaluated separately in each of the chosen target sectors (Vaisanen et al., 2004).

The commitment of the clients will depend on the amount of money they are investing on the audits themselves. Free might not be valued. However, the private owned model is quite sensitive to apply for university sector more than private processing companies with regards to cost of investment. The cost effectiveness of the programme is connected to the question of the subsidy level. In some sectors, the trigger effect may start with a 30 % subsidy. On the other hand e.g. in the residential sector, the cost of an energy audit may be 3 to 4 times as high as what the building owners are willing to pay, which means that the level has to be 75 to 80 %. From the viewpoint of the cost-effectiveness of the programme the level of the percentage should be evaluated against the output of the programme - the generated savings per sector (Vaisanen et al., 2004).

Therefore, the energy saving model for university could be considered in 3 models (Figure 3.17). In case of university owned whole retrofit and installation cost, the energy saving cost will appear in terms of electricity cost reduction. As of subsidy fund model, university received subsidy support from outsource organization. For instance, changing new air conditioner with more than 15 years operating AC including lamp changing. This model could be funded under energy saving project from ministry of energy, Thailand (Energy Policy and Planning Office – EPPO, and Department of Alternative Energy Development and Efficiency - DEDE). This type of support could be explained in 2 projects as LED installation and AC retrofitting and cleaning. This model is applying by DEDE grant for LED changing in university. In 2017, LED lights will be fully installed in PO instead of existing fluorescent lamps. In the third model, private owned energy efficient project. This model would be carried out by private company by auditing electricity use and appliances in offices, the investment cost including retrofit, acquisition, installation and maintenance costs will be afforded by private company. The energy saving cost will be calculated from baseline situation compared to modified system then saving cost will be paid to private sector. This model, the private company will sign energy saving purchase agreement with prospect organization for electricity compensation in operation years. The energy consumption r educes from retrofit will be gained by company. However, this model is not suitably applied for public organization such as university. It might be matched with medium and large private company in terms of flexible management.

Figure 3.17 Energy Saving Models

Remark: + Saving cost which could be saved from energy consumption reduction. It might be allocated into 2 alternatives to motivate and challenge for behavior changing by economic demand;

1) Pay back to staff in responsible offices,

2) Charity money to charity or foundation (e.g. orphanage, elder care centers, or homeless centers) in the name of responsible divisions

3.6.6. Lesson Learned of Energy Conservation Measures

In order to significantly reduce energy consumption, AC work load reduction is required. Serveral campaigns were initiated and cancelled (Appendix H). The lesson learned of energy reduction from AC was summarized as follow;

- PO Buildings lie on sun movement and there is no tree nearby the buildings. Therefore, application of green shadow from garden trees

- Adjustment of AC opening time was applied to turn on during 9-11.30am and 1.30 – 4pm. However, the measure was shortly implemented according to staff could not torelate to hot weather effected on working efficiency. Especially, season variation effected on environmental temperature made public area concern. Therefore, comprehensible reduction of AC Operation should be continually and intensively revised.

- Temperature setting was adapted from 25 °c to 26 °c. This campaign was proposed for energy conservation. However, it was cancelled according to impact on staff working.

- Stop overtime (OT) working was requested for cooperate to reduce AC and electricity consumption after normal working time. However, several divisions have necessity to do OT for work on duty.

However, all measures were implied as requested and voluntary activities. Intensive compulsory measures might effective for organization which measure would impact on benefit of organization. In addition, economic motivation would be considered to imply for public benefit. The committee for energy conservation would be interesting team and could establish effective measures from brainstorming.

3.7. Recommendation for Sustainable University

The integrated approaches must be concreted policy before distributed to every sector in university to maintain the sustainable organization. This strategy should not be one time campaign but it should be real time monitoring and improvement. The vision of university must be provided for benefit of mankind including environmental friendly learning for future generation. Carbon Footprint of PO buildings is one of the initiatives to motivate green campus programme. It shows the representative of symbolic sign from PSU executive sector to move PSU forward to sustainability academic in Southern part of Thailand. It will also be representative showcase to visiting academic guest as green building to promote social responsibility of university with creative environmental friendly activities, for instance, waste separation, waste bank, and reforestation. These projects are the concrete evidences which support development of economic, social and environment as sustainability for PSU. The carbon footprint project will be implied to potential organization as database on GHG emission and mitigation. For instance, BSC building which obtain many activities including learning, and laboratory. PSU Historical hall is the next building which involve energy saving through renovate AC system.

CHAPTER 4

CONCLUSION AND SUGGESTION

4.1. Conclusion

This study estimated the GHG emission in President's office (PO) buildings, Prince of Songkla University (PSU), Hatyai, Thailand in the fiscal year 2015 and 2016. The sources of GHG involved in this study are direct and indirect emissions. Data analysis and report following principle guideline of the GHG protocol by Thailand Greenhouse Gas Management Organization (TGO), which provided a direction to implement GHG protocol corporate standard and the GHG emissions report. The required data input could collect from measurement and secondary data including estimation and calculation which consumed long time to obtain the entire data from relevant documents.

The GHG emission sources were monitored follow by TGO guideline. These sources were divided into 3 scopes as follow;

Scope 1 – Direct emission from stationary combustion, mobile combustion of gasoline from vehicles which controlled by organization, and septic tank system

Scope 2 – Indirect emission from electricity consumption

Scope 3 – Other indirect emission including paper use, methane emission from wastewater treatment

The results exhibited that total emissions from PO operational activities were calculated to be 542 and 553 ton CO_2 eq. in 2015 and 2016, respectively. It was found that the highest GHG emission was indirect emission from electricity consumption, emitting 334 ton CO_2 eq. in 2015 and 358 ton CO_2 eq. in 2016 equal to 62% and 65% of total emission in 2015 and 2016, respectively. The least emissions come from scope 3 which were counted for 26 and 24 ton CO_2 eq in 2015 and 2016. The average for carbon emission of about 548 ton CO_2 eq was calculated from total emission during 2015 and 2016.

Total cost of operation in PO building of about 80,748 USD (2,826,147 THB) in 2016 was summed from each constituent. Noticeably, the highest cost of operation comes from electricity consumption (86%) estimated to be 2,439,047 THB or 69,687 USD. Electricity consumption of the PO buildings has increased from 485,092, 574,020, to 574,560 units (Watt) in 2013-2015 (Tim and Jutidamrongphan, 2016) and rising to 615,592 units in 2016. This growing energy consumption results from routine activities in administrative division.

The result of cost of operation was also correspondingly presented that electricity consumption gained the highest cost of operation which are mainly from Air conditioning system (55%). Third-fourth of electricity was provided for administrative division activities, follow by meeting and executive function, respectively. Therefore, energy efficiency development is crucial by means of electricity consumption reduction especially in AC system with operation time control. For instance, using supplement fans to cool air in the room including setting the moderate temperature in the room between 25-27 degree celcius.

The scenario of energy conservation was listed for energy efficiency development. The results from scenarios estimation was suggested that convergence of internal and external factors displayed the most effective energy saving by means of LED installation equipped with reduction of operation time in every electricity appliance which could reduce one-fifth energy consumption including mitigate GHGs emission. However, some constraints must be carefully consideration by operations techniques and investment cost. Therefore, the integrated approaches must be deliberately implemented for GHG mitigation and energy efficiency development in order to move forward the sustainable university.

The most cost-effective solution is not always the most environmentally sound choice. For instance, renewable energy implication might consume very little energy but cost more to install than it saves in energy cost. However, renewable energy installation was planned for renovating PO building as a smart building in the future. Solar roof is an interesting alternative. Even though it is not easy to install solar roof on the rooftops of the old building because of the heavy weight of the roofing material.

A solar PV panel could substitute 0.9 kW/day of electricity consumption from fossil fuel production. Therefore, PO buildings could be contributed from 30 solar arrays for electricity cost saving. Even the solar lighting is renewable energy and eco-friendly energy source, its contribution also equipped with support accessories, for example, solar charge controller, inverter, battery, circuit breaker, etc. Therefore, these accessories cost is comparative high which has to consider for investment.

The lesson learned from AC reduction campaign was summarized. Voluntary activities were requested for energy conservation. However, limitation effected on working efficiency is the most concern for energy reduction campaign. To reduce constraint in energy conservation, compulsory measures and incentive benefit would be interesting alternatives.

Therefore, the energy saving model for university could be considered in 3 models. In case of university owned whole retrofit and installation cost, the energy saving cost will appear in terms of electricity cost reduction. As of subsidy fund model, university received subsidy support from outsource organization. For instance, changing new air conditioner with more than 15 years operating AC including lamp changing. This model could be funded under energy saving project from ministry of energy, Thailand (Energy Policy and Planning Office – EPPO, and Department of Alternative Energy Development and Efficiency - DEDE). This type of support could be explained in 2 projects as LED installation and AC retrofitting and cleaning.

The integrated approaches must be concreted policy before distributed to every sector in university to maintain the sustainable organization. This strategy should not be one time campaign but it should be real time monitoring and improvement. The vision of university must be provided for benefit of mankind including environmental friendly learning for future generation. Carbon Footprint of PO buildings is one of the initiatives to motivate green campus program. It shows the representative of symbolic sign from PSU executive sector to move PSU forward to sustainability academic in Southern part of Thailand. It will also be representative showcase to visiting academic guest as green building to promote social responsibility of university with creative environmental friendly activities, for instance, waste separation, waste bank, and reforestation. These projects are the concrete evidences which support development of economic, social and environment as sustainability for PSU.

4.2. Suggestion for Further Study

1. Some sources of GHG emission are not taking into account in the study and crucial in further study e.g. exact measurement on fuel consumption in transportation by individual PO officer cars should be recorded for other indirect emission including fugitive emission from existing sources.

2. Data collection for carbon emission might detect error from human or equipment, for instance, meter for water supply which quite different in 2015 and 2016. The water gauge have deviation then unit for water consumption has error.

3. The carbon footprint should be continually evaluated to monitor the GHG reduction and energy conservation measures.

4. Advance technologies in GHG mitigation should be applied or installed with existing conditions and equipment.

5. The limitation of the study should be reduced, for instance, database for carbon footprint calculation should be online established and possibly updated in soft copy version.

6. The carbon footprint evaluation should be applied as a significant project in improvement for environmental friendly activities of whole university.

7. The energy conservation would be achieved not only from advance technological development but the people intentional consciousness is also reached. Therefore, behavioral research to enhance public engagement in energy conservation is reasonable study required.

8. Executive committee board of PSU should be the main driving force to support and involve public participation from PSU’s staff and students in GHG mitigation. The strategies could be practically implied by establishment of special committee responsible for carbon footprint evaluation or sustainable organization development.

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APPENDIX A

GLOSSARY

GLOSSARY

Activity data:	Quantitative measure an activity that results in a GHG emission or removal. Examples of GHG activity data include the amount of energy, fuels or electricity consumed, materials produced, services provided or area of land affected.
Base year:	Historical period specified for the purpose of comparing GHG emissions or removals or other GHG-related information over time.
Boundary:	GHG accounting and reporting boundaries can have several dimensions, eg., organizational, operational, and geographic. These boundaries determine which emissions are accounted for and reported by the organization.
Carbon dioxide equivalent (CO_2 eq):	Unit for comparing the radiative forcing of a GHG to carbon dioxide. The carbon dioxide equivalent is calculated using the mass of a given GHG multiplied by its global warming potential.
Carbon footprint for organization:	The measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of the organization
Direct GHG emissions:	GHG from GHG source owned or controlled by the organization.
Emission factor:	Factor relating activity data GHG emissions or removals.
Emission year:	The calendar year or fiscal year in which the emission occurred.
Greenhouse gas (GHG):	Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth’s surface, the atmosphere, and clouds. GHG

including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbon (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

Inventory: An organization’s GHG sources, GHG sinks, GHG emissions and revivals.

Offsets: Represent the reduction or avoidance of GHG emissions from a specific project that is used to compensate for (i.e., offset) GHG emissions occurring elsewhere.

Operational boundaries: The boundaries that determine the direct and indirect emissions associated with operations within an organization’s organizational boundary.

Operation control: Full authority to introduce and implement operating policies at an operation. Operational control is one of two ways to define control.

Other indirect emissions: GHG emission, other than energy an indirect GHG emission, which is a consequence of an organization’s activities, but arises from GHG sources that are owned or controlled by other organization.

APPENDIX B

DATA VERIFICATION SHEETS

Table B1 Carbon Footprint Verification Sheet for 2015

บัญชีรายการก๊าซเรือนกระจก				**TCFO_R_01** Version 01 : 31/8/2013
ชื่อฟอร์ม	บัญชีรายการก๊าซเรือนกระจก	**องค์กร**	อาคารสำนักงานอธิการบดี ม.สงขลานครินทร์	**หน้าที่** 4
รหัสฟอร์ม	Fr-04 Year 2015	**ผู้จัดทำ**	คณะการจัดการสิ่งแวดล้อม	**วันที่**

ขอบเขต	รายการ	ค่า LCI			ค่า EF ($kgCO_2$ eq./หน่วย)	ที่มา 1st		2nd						แหล่งอ้างอิง	ผลคูณ	สัดส่วน (%)	คำอธิบายเพิ่มเติม
		หน่วย	ปริมาณ	ชนิดก๊าซ		Self collet	Supplier	PCR Gen.	TH LCI D	Thai Res.	Int. DB	Other	Subsitute				
ประเภท 1	การใช้น้ำมันเบนซินในเครื่องตัดหญ้า			CO_2	2.1816									IPCC Vol.2 table 2.3, DEDE			
				CH_4	0.0024									IPCC Vol.2 table 2.3, DEDE			
				N_2O	0.0056									IPCC Vol.2 table 2.3, DEDE			
		ลิตร	2,020	GHG	2.1896				●					IPCC Vol.2 table 2.3, DEDE	4,423	0.8	
	การใช้น้ำมันดีเซลในเครื่องพ่นยุง			CO_2	2.6987									IPCC Vol.2 table 2.3, DEDE			
				CH_4	0.0027									IPCC Vol.2 table 2.3 DEDE			
				N_2O	0.0065									IPCC Vol.2 table 2.3 DEDE			
		ลิตร	222	GHG	2.7079				●					IPCC Vol.2 table 2.3 DEDE	601	0.1	
	การใช้น้ำมันเบนซินในยานพาหนะองค์กร			CO_2	2.1816									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				CH_4	0.0260									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				N_2O	0.0300									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
		ลิตร	12,226	GHG	2.2376				●					IPCC Vol.2 table 3.2.1, 3.2.2, DEDE	27,356	5.0	
	การใช้น้ำมันดีเซลในยานพาหนะองค์กร			CO_2	2.6987									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				CH_4	0.0036									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				N_2O	0.0423									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
		ลิตร	37,772	GHG	2.7446				●					IPCC Vol.2 table 3.2.1, 3.2.2, DEDE	103,667	19.1	
	การปล่อยก๊าซมีเทนในระบบ Septic tanks	กิโลกรัม CH_4	1,830	CH_4	25						●			IPCC Fourth Assessment Report, 2007	45,738	25.2	
		รวม													**181,785**	50.3	
ประเภท 2	ปริมาณการใช้ไฟฟ้า	กิโลวัตต์-ชั่วโมง	574,560	GHG	0.5821				●					Thailand Grid Mix Electricity LCI Database 25	334,451	61.7	
		รวม													**334,451**	61.7	
ประเภท 3	ปริมาณการใช้กระดาษ A4 ในสำนักงาน	กิโลกรัม	3,380	GHG	1.1800						●			Ecoinvent 2.2, IPCC 2007 GWP 100a :Paper, woodfree, coated, at regional storage/CH U	3,989	0.7	
	ปริมาณการใช้น้ำประปา	ลบ.ม.	5,209	GHG	0.7043						●			IPCC Vol.5 table 6.2, 6.8	3,669	0.7	
	การปล่อยก๊าซมีเทนในระบบบำบัดน้ำเสีย	ลบ.ม.	0	CH_4	25						●			IPCC Vol.5 table 6.2, 6.8	0	0.0	
	การจัดการขยะโดยการส่งไปกำจัดยังเตาเผาเทศบาล	กิโลกรัม	91,476	CO_2	1				●					Thai National Database	17,414	3.2	
				CH_4	25				●					Thai National Database	0	0.0	
				N_2O	298				●					Thai National Database	3	0.0	
		กิโลกรัม CO_2		GHG					●					Thai National Database	18,205	3.4	
															25,863	4.6	
														Total	**542,099**		$kgCO_2$ eq.

Table B2 Carbon Footprint Verification Sheet for 2016

บัญชีรายการก๊าซเรือนกระจก			**TCFO_R_01** Version 01 : 31/8/2013
ชื่อฟอร์ม บัญชีรายการก๊าซเรือนกระจก	**องค์กร**	อาคารสำนักงานอธิการบดี ม.สงขลานครินทร์	**หน้าที่** 4
รหัสฟอร์ม Fr-04 Year 2016	**ผู้จัดทำ**	คณะการจัดการสิ่งแวดล้อม	**วันที่**

ขอบเขต	รายการ	ค่า LCI			ค่า EF (kgCO$_2$ eq./หน่วย)	ที่มา								แหล่งอ้างอิง	ผลคูณ	สัดส่วน (%)	คำอธิบายเพิ่มเติม
		หน่วย	ปริมาณ	ชนิดก๊าซ		1st		2nd				Other	Subsitute				
						Self collet	Supplier	PCR Gen.	TH LCI DB	Thai Res.	Int. DB						
ประเภท 1	การใช้น้ำมันเบนซินในเครื่องตัดหญ้า			CO$_2$	2.1816									IPCC Vol.2 table 2.3, DEDE			
				CH$_4$	0.0024									IPCC Vol.2 table 2.3, DEDE			
				N$_2$O	0.0056									IPCC Vol.2 table 2.3, DEDE			
		ลิตร	2,400	GHG	2.1896				●					IPCC Vol.2 table 2.3, DEDE	5,255	1.0	
	การใช้น้ำมันดีเซลในเครื่องพ่นยุง			CO$_2$	2.6987									IPCC Vol.2 table 2.3, DEDE			
				CH$_4$	0.0027									IPCC Vol.2 table 2.3 DEDE			
				N$_2$O	0.0065									IPCC Vol.2 table 2.3 DEDE			
		ลิตร	1,100	GHG	2.7079				●					IPCC Vol.2 table 2.3 DEDE	2,979	0.5	
	การใช้น้ำมันเบนซินในยานพาหนะองค์กร			CO$_2$	2.1816									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				CH$_4$	0.0260									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				N$_2$O	0.0300									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
		ลิตร	11,278	GHG	2.2376				●					IPCC Vol.2 table 3.2.1, 3.2.2, DEDE	25,236	4.6	
	การใช้น้ำมันดีเซลในยานพาหนะองค์กร			CO$_2$	2.6987									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				CH$_4$	0.0036									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
				N$_2$O	0.0423									IPCC Vol.2 table 3.2.1, 3.2.2, DEDE			
		ลิตร	30,580	GHG	2.7446				●					IPCC Vol.2 table 3.2.1, 3.2.2, DEDE	83,928	15.2	
	การปล่อยก๊าซมีเทนในระบบ Septic tanks	กิโลกรัม CH$_4$	2,111	CH$_4$	25						●			IPCC Fourth Assessment Report, 2007	52,779	9.5	
		รวม													**170,177**	30.8	
ประเภท 2	ปริมาณการใช้ไฟฟ้า	กิโลวัตต์-ชั่วโมง	615,592	GHG	0.5821				●					Thailand Grid Mix Electricity LCI Database 2	358,336	64.8	
		รวม													**358,336**	64.8	
ประเภท 3	ปริมาณการใช้กระดาษ A4 ในสำนักงาน	กิโลกรัม	3,044	GHG	1.1800						●			Ecoinvent 2.2, IPCC 2007 GWP 100a :Paper, woodfree, coated, at regional storage/CH U	3,592	0.6	
	ปริมาณการใช้น้ำประปา	ลบ.ม.	692	GHG	0.7043						●			IPCC Vol.5 table 6.2, 6.8	487	0.1	
	การปล่อยก๊าซมีเทนในระบบบำบัดน้ำเสีย	ลบ.ม.	0	CH$_4$	25						●			IPCC Vol.5 table 6.2, 6.8	0	0.0	
	การจัดการขยะโดยการส่งไปกำจัดยังเตาเผาเทศบาล	กิโลกรัม	102,232	CO$_2$	1				●					Thai National Database	19,462	3.5	
				CH$_4$	25				●					Thai National Database	0	0.0	
				N$_2$O	298				●					Thai National Database	3	0.0	
		กิโลกรัม CO$_2$		GHG					●					Thai National Database	20,346	3.7	
															24,425	4.3	
														Total	**552,937**		**kgCO$_2$ eq.**

APPENDIX C

COLLECTING DATA AND CALCULATION OF CARBON FOOTPRINT OF PRESIDENT'S OFFICE

COLLECTING DATA AND CALCULATION OF CARBON FOOTPRINT OF PRESIDENT'S OFFICE

Scope 1 Direct emission

Emission from stationary combustion

Table C1 Fuel Consumption from Stationary Combustion by Type of Fuel

Month	Gasoline (L)		Diesel (L)	
	2015	2016	2015	2016
October	200	400	0	0
November	0	200	0	1,050
December	200	200	0	50
January	0	200	0	0
February	200	200	0	0
March	200	200	0	0
April	800	200	0	0
May	20	200	0	0
June	0	200	0	0
July	200	200	0	0
August	200	0	0	0
September	0	200	222	0
Total	**2,020**	**2,400**	**222**	**1,100**

$$GHG\ Emission_{fuel,\ stationary} = Fuel\ consumption_{fuel} \bullet EF_{fuel} \qquad \text{(Eq. C1)}$$

Calculation example

In 2015, fuel consumption of gasoline = 2,020 L/yr,

EF_{fuel} = 2.1896 for gasoline in stationary fuel combustion (IPCC Vol.2 table 2.3, DEDE)

Therefore, $GHG\ Emission_{gasoline,\ stationary}$ = 2,020 L/yr • 2.1896 kg CO_2 eq/L

= 4,423 kg CO_2 eq/yr

Emission from mobile combustion

Table C2 Fuel Consumption from Mobile Combustion by Type of Fuel

Month	Gasoline (L)		Diesel (L)	
	2015	2016	2015	2016
October	860.99	1,073.25	2,794.61	3,484.04
November	362.84	1,465.97	1,967.87	3,700.49
December	1,154.34	1,527.88	3,304.56	3,360.48
January	1,119.73	1,185.74	2,803.44	3,340.60
February	1,014.13	1,246.66	3,585.99	3,931.70
March	1,227.26	1,241.76	3,373.60	3,077.12
April	927.94	208.49	2,816.64	522.28
May	899.54	180.34	1,901.22	125.55
June	870.41	221.02	3,092.09	248.94
July	1,140.49	195.12	3,625.58	327.05
August	1,414.42	1,559.69	4,194.35	4,466.11
September	1,233.93	1,172.43	4,311.59	3,995.28
Total	**12,226.02**	**11,278.35**	**37,771.54**	**30,579.64**

$$GHG\ Emission_{fuel,\ stationary} = Fuel\ consumption_{fuel} \bullet EF_{fuel} \qquad \text{(Eq. C2)}$$

Calculation example

In 2015, fuel consumption of diesel = 37,771.54 L/yr,

EF_{fuel} = 2.7446 for diesel in mobile fuel combustion (IPCC Vol.2 table 3.2.1, 3.2.2, DEDE)

Therefore, $GHG\ Emission_{diesel,\ mobile} = 37{,}771.54\ \mathrm{L/yr} \bullet 2.7446\ \mathrm{kg\ CO_2\ eq/L}$

$= 103{,}667\ \mathrm{kg\ CO_2\ eq/yr}$

CH_4 emission from septic tank

$$CH_4\ Emission_{\mathrm{septic\ tank}}\ (\mathrm{kg\ CH_4/yr}) = [U \bullet T \bullet EF_{\mathrm{s}}] \bullet (TOW\text{-}S)\text{-}R \qquad \text{(Eq. C3)}$$

Defining S = 0 according to without sludge removal,

R = 0 according to without methane recovery,

U = 1 based on population database from Chiangrai municipality,

T = 1 based on urban-high income, IPCC Vol. 5, table 6.5 (applied from Indonesia reference as same region and same BOD value per person)

$$EF_{\mathrm{s}} = B_0 \bullet MCF \qquad \text{(Eq. C4)}$$

EF_{s} = Emission Factor from septic tank (kg CH_4/kg BOD),

B_0 = Maximum CH_4 producing capacity (kg CH_4/kg BOD) from IPCC Vol. 5 table 6.2,

MCF = Methane correction factor (fraction) from IPCC Vol. 5 table 6.3

Whereas, B_0 = 0.6 for default maximum CH_4 producing capacity,

MCF = 0.5 with regards to septic system treatment.

Therefore, $EF_{\mathrm{s}} = 0.6 \bullet 0.5 = 0.3$ kg CH_4/kg BOD

Total organically degradable carbon in wastewater (TOW) could be calculated from below equation

$$TOW \text{ (kg BOD)} = P \cdot BOD \cdot 0.001 \cdot I \cdot N \qquad \text{(Eq. C5)}$$

P = Population (For PO operation; P = 630 in 2015, P = 707 in 2016)

BOD = 40 g/person/day

I = 1 (Default value for Asia)

N = Number of days by inventory year (Working days in 2015 = 242 days, Working days in 2016 = 241 days)

Calculation example

In 2015, P = 630, N = 242

$$TOW = 630 \cdot 40 \cdot 0.001 \cdot 1 \cdot 242$$

$$= 6{,}098 \text{ kg BOD}$$

$$CH_4\ Emission_{\text{septic tank}} = [U \cdot T \cdot EF_S] \cdot (TOW\text{-}S)\text{-}R \qquad \text{(Eq. C6)}$$

$$= 1 \cdot 1 \cdot 0.3 \cdot (6{,}098.4 - 0) - 0$$

$$= 1{,}830 \text{ kg } CH_4\text{/yr}$$

$$= 1{,}829.52 \cdot 25 \text{ (GWP of } CH_4\text{)}$$

$$= 45{,}738 \text{ kg } CO_2 \text{ eq/yr}$$

Scope 2 Carbon Emission from Electricity Consumption

Table C3 Electricity Consumption of PO in 2015 and 2016

Month	2015 (kWh)	2016 (kWh)
October	42,120	54,144
November	41,472	49,860
December	41,364	44,856
January	43,020	49,752
February	48,492	41,112
March	61,236	61,380
April	47,124	57,384
May	51,948	55,152
June	56,196	55,332
July	45,036	25,840
August	55,152	57,960
September	41,400	62,820
Total	**574,560**	**615,592**

$GHG\ emissions_{\text{electricity}}\ (\text{kg CO}_2\ \text{eq/yr}) = E \bullet EF_e$ (Eq. C7)

E = Electricity consumption (kWh/yr)

EF_e = 0.5821 kWh (Thailand Grid Mix Electricity LCI Database 2557 (2014)_Update 1 Jan 2017)

Calculation example

In 2015, electricity consumption = 574,560 kWh, $EF_e = 0.5821$

$$GHG\ emissions_{\text{electricity}} = 574{,}560 \bullet 0.5821 = 334{,}451.38\ (\text{kg CO}_2\ \text{eq/yr})$$

Scope 3 Other indirect emission

Paper (A4) use

Table C4 The Paper Used in PO Buildings in 2015 and 2016

Month	2015 (reams)		2016 (reams)	
	80 gram	120 gram	80 gram	120 gram
October			20	-
November		18	32	-
December			34	-
January			40	-
February		48	137	-
March			133	-
April	420		113	-
May			25	-
June		24	44	-
July			69	-
August	800		70	-
September			273	-
Total	**1,220**	**90**	**1,220**	**0**

$$GHG\ emissions_{\text{paper}}\ (\text{kg CO}_2\ \text{eq/yr}) = A4 \cdot EF_{\text{A4}} \qquad \text{(Eq. C8)}$$

$A4$ = Total use of Paper A4 (kg/yr)

$A4 = A \cdot G \cdot R \cdot 500 \cdot 10^{-4} \cdot 10^{-3}$

A = Area of A4 paper = 623.7 cm^2

G = Weight of A4 paper (g/piece)

R = No. of paper in an inventory year (ream)

500 = No. of paper in a ream (paper 1 ream = 500 pieces)

10^{-4} = Conversion factor from cm^2 to m^2 ($1\ cm^2 = 10^{-4}\ m^2$)

10^{-3} = Conversion factor from g to kg ($1\ g = 10^{-3}\ kg$)

A4 80 gram 1 ream = 2,494.8 g, A4 120 gram 1 ream = 3,742.20 g

Calculation example

In 2016, A4 80 gram of about 1,220 reams was used

$$A4_{2016} = 623.7 \cdot 80 \cdot 1{,}220 \cdot 500 \cdot 10^{-4} \cdot 10^{-3}$$

$$= 3{,}043.66\ \text{kg}$$

EF_{A4} = 1.18 kg (Ecoinvent 2.2, IPCC 2007 GWP 100a :Paper, woodfree, coated, at regional storage/CH U)

Therefore, $GHG\ emissions_{\text{paper}} = 3{,}043.66 \cdot 1.18$

$$= 3{,}591.51\ \text{kg}\ CO_2\ \text{eq/yr}$$

Water consumption

Table C5 Water Consumption in 2015 and 2016

Month	2015 (m^3)	2016 (m^3)*
October	36	11
November	512	4
December	596	55
January	597	68
February	774	60
March	759	81
April	897	37
May	634	91
June	0	74
July	307	63
August	89	62
September	8	86
Total	**5,209**	**692**

* Water gauge has error on center axis

$GHG\ emissions_{\text{water consumption}}$ (kg CO_2 eq/yr) = $W \bullet EF_w$ (Eq. C9)

W = Water consumption (m^3/yr)

EF_w = 0.7043 m^3 (Thailand National Database)

Calculation example

In 2015, water consumption = 5,209 m^3, EF_w = 0.7043

$$GHG\ emissions_{\text{water consumption}} = 5{,}209 \bullet 0.7043$$

$$= 3{,}668.7 \text{ kg } CO_2 \text{ eq/yr}$$

CH_4 from wastewater treatment

Table C6 Wastewater Volume of President's Office Buildings

Month	2015 (m^3)	2016 (m^3)*
October	36	11
November	512	4
December	596	55
January	597	68
February	774	60
March	759	81
April	897	37
May	634	91
June	0	74
July	307	63
August	89	62
September	8	86
Total	**5,209**	**692**

* Water gauge has error on center axis

$CH_4\ emissions = ([TOW - S] \cdot EF_w) - R$ (Eq. C10)

$TOW = \Sigma(W \cdot BOD_i)$ (Eq. C11)

$EF_w = B_0 \cdot MCF$ (Eq. C12)

Where;

W = the volume of waste water (m^3) = 90% of water supply (Table C5)

BOD_i = 200 mg/L (From Average BOD of Thailand domestic wastewater)

S = 0 (No sludge removal)

B_0 = 0.25 kg CH_4/kg BOD

$MCF = 0$ (According to IPCC Vol. 5, Table 6.8, Wastewater treated by Aerobic treatment plant, well-managed)

Calculation example

Emission Factor = 0, therefore, wastewater treatment has no CH_4 emissions **Waste management by incinerator**

To achieve GHG emissions from waste incinerator, total amount of municipal waste generation (MSW_i) could be considered

Example of estimating MSW_i

$$MSW_i = P \cdot P_{frac} \cdot MSW_P \cdot B_{frac} \cdot N \cdot 10^{-6} \qquad \text{(Eq. C13)}$$

MSW_i = Total amount of municipal solid waste as wet weight incinerated, Gg/yr

P = Population (capita) (For PO operation; $P = 630$ in 2015, $P = 707$ in 2016)

P_{frac} = Fraction of population burning waste, (fraction)

In a developing country, mainly in urban areas, P_{frac} can be roughly estimated as being the sum of population whose waste is not collected by collection structures and population whose waste is collected and disposed in open dumps that are burned. In general, it is preferable to apply country- and regional specific data on waste handling practices and waste streams. In this case, P_{frac} could be considered equal 1 with regard to waste collected from all population is collected prior to incinerate

MSW_P = Waste generation per capita, kg waste/capita/day (MSW generation rate in Prince of Songkla University = 0.60 kg/capita/day – Master Thesis of PSU Waste Management)

B_{frac} = fraction of the waste amount that is burned relative to the total amount of waste treated, (fraction)

B_{frac} means the fraction of waste for which carbon content is converted to CO_2 and other gases. When all the amount of waste is burned B_{frac} could be considered equal 1 (an oxidation factor related to the combustion efficiency is applied later to estimate emissions using Equation 5.1 or 5.2) (IPCC, 2006)

N = Number of days by inventory year (Working days in 2015 = 242 days, Working days in 2016 = 241 days)

10^{-6} = Conversion factor from kilogram to gigagram

Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include CO_2, CH_4 and N_2O. Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions. (IPCC, 2006)

Total emission (ton CO_2 eq/yr) = (CO_2 + CH_4 + N_2O emissions) (kg/yr) • 10^{-3}

10^{-3} = Conversion factor from kilogram to ton (1 kg = 10^{-3} ton)

Calculation example

CO_2 emissions

$$CO_2\ emissions = MSW \bullet \Sigma_j\ (WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j) \bullet 44/12 \qquad \text{(Eq. C14)}$$

CO_2 emissions = CO_2 emissions in inventory year, kg/yr

MSW_i = Total amount of solid waste (wet weight) incinerated or open-burned, kg/yr

WF_j = Fraction of waste type/material of component j in the MSW (as wet weight incinerated or open- 41 burned)

dm_j = Dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CF_j = Fraction of carbon in the dry matter (i.e., carbon content) of component j

FCF_j = Fraction of fossil carbon in the total carbon of component j

OF_i = Oxidation factor, (fraction)

44/12 = Conversion factor from C to CO_2

With $\Sigma_j\ WF_j = 1$

j = component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, 6 wood, garden/yard and park waste, disposable nappies, rubber and leather, plastics, metal, glass, 7 other inert waste.

Where MSW_p = 1.15 kg/capita/day for urban area,

dm_i = 0.603, CF_i = 0.42, FCF_i = 0.205 (Default value for MSW)

OF_i = 1 (Default value for incinerator)

CH_4 emissions

$$CH_4\ emissions = \sum_i ((IW_i \bullet EF_i) \bullet 10^{-6} \qquad \text{(Eq. C15)}$$

Where, CH_4 emissions = CH_4 emissions in inventory year, kg/yr

IWi = Amount of solid waste of type i incinerated or open-burned, kg/yr

EF_i = Aggregate CH_4 emission factor, kg CH_4/Gg of waste

10^{-6} = Conversion factor from kilogram to gigagram (1 kg = 10^{-6} Gg)

i = Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

EFi for continuous incineration stoker type (Table 5.3) = 0.2 (kg/Gg waste incinerated on a wet weight basis))

N_2O emissions

$$N_2O\ emissions = \sum_i ((IW_i \bullet EF_i) \bullet 10^{-6} \qquad \text{(Eq. C16)}$$

Where, CH_4 emissions = CH_4 emissions in inventory year, kg/yr

IWi = Amount of solid waste of type i incinerated or open-burned, kg/yr

EF_i = Aggregate N_2O emission factor, kg N_2O/Gg of waste

10^{-6} = Conversion factor from kilogram to gigagram (1 kg = 10^{-6} Gg)

i = Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

EF_i = 29 (kg/Gg waste incinerated on a wet weight basis))

Table C7 Summary of GHGs Emissions from Waste Incineration

Parameter	Unit	Value	
		2015	2016
		CO_2 emission calculation	
P	capita	630	707
N	days	242	241
MSW_p	kg/capita/day	1.15	1.15
MSW_i	kg/yr	175,329	195,945
SW_i	kg/yr	175,329	195,945
CO_2 *emission*	kg/yr	33,376.87	37301.49
		CH_4 emission calculation	
IW_i	kg/yr	175,329	195,945
EF_i	kg CH_4/t waste	0.2	0.2
CH_4 *emission*	kg/yr	0.040	0.039
		N_2O emission calculation	
IW_i	kg/yr	175,329	195,945
EF_i	kg N_2O/t waste	29	29
N_2O *emission*	kg/yr	5.085	5.682
		Total emission	
GHG emissions	**ton CO_2 eq/yr**	**34.9**	**39.0**

APPENDIX D

LIST OF EMISSION FACTORS

LIST OF EMISSION FACTORS

Description	Unit	Unit for Carbon Emission	Emission Factor	References
Scope 1	Emission Factor for Stationary Combustion			
Gasoline	litre	kg CO_{eq}/unit	2.1896	IPCC Vol. 2, Table 2.3, DEDE, TGO
Diesel	litre	kg CO_{eq}/unit	2.7079	IPCC Vol. 2, Table 2.3, DEDE, TGO
Scope 1	Emission Factor for Mobile Combustion			
Gasoline	litre	kg CO_{eq}/unit	2.2376	IPCC Vol. 2, Table 3.2.1, 3.2.2, DEDE, TGO
Diesel	litre	kg CO_{eq}/unit	2.7446	IPCC Vol. 2, Table 3.2.1, 3.2.2, DEDE, TGO
Scope 1	Methane Emission from Septic tank			
CH_4 Emission from Septic tank	kg CH_4 / unit	kg CH_4/unit	0.3	Calculation based on default MCF from IPCC Vol. 5 table 6.3
Scope 2	Indirect Emission from Purchased Electricity			
Thailand Grid Mix Electricity	kWh	kg CO_{eq}/unit	0.5821	Thailand Grid Mix Electricity LCI Database 2557 (2014)

Description	Unit	Unit for Carbon Emission	Emission Factor	References
Scope 3				Other Indirect Emission
Paper	kg	kg CO_{eq}/unit		Ecoinvent 2.2, IPCC 2007 GWP 100a :Paper, woodfree, coated, at regional storage/CH U
Water	m^3	kg CO_{eq}/unit	0.7043	IPCC Vol. 5, Table 6.2, 6.8
Wastewater	m^3			
Methane Conversion Factor (Wastewater Treatment – Aerated pond)	kg CH4/kg COD	kg CH_4/unit	0	IPCC Vol.5, Table 6.3, TGO
Waste Management (continuous incineration stoker type)	ton of waste			
- CH_4 Emission		kg CH_4/unit	0.2	IPCC Vol.5 Table 5.3, TGO
- N_2O Emission		kg N_2O/unit	29	IPCC Vol.5 Table 5.4, 5.5, 5.6, TGO

TGO = Thailand Greenhouse Gas Management Organization (Public Organization)

APPENDIX E

SURVEILLANCE EVALUATION FORM FOR ELECTRICITY APPLIANCE

SURVEILLANCE EVALUATION FORM FOR ELECTRICITY APPLIANCE

Table E1 Electricity Appliance Survey

Section …………...……………… Room no…………………Date ………………

Electricity Appliance	Capacity (w)	No.	Remark
Computer - Desktop			
Computer - Laptop			
Scanner			
Printer			
Photocopier			
Projector			
Fax machine			
Telephone			
Microwave oven			
Refrigerator			
Pot			
Fan			
Television			
Blower			
Rice cooker			

Table E2 Lighting Survey

อาคาร/ ชนิดโคม	หลอด Ft 36 W	หลอด Ft 18 W	หลอด ตะเกียบ 9 W	หลอดประหยัด 18 W	หลอดดวงเดือน 32 W
สำนักงานอธิการบดี (ทุกตึก)					
หลอด Ft 1 x 28 W	100 หลอด				
หลอด Ft 3 x 28 W	453 โคม				
หลอด Ft 1 x 14 W		43 หลอด			
หลอดตะเกียบ 9 W			111 หลอด		
หลอด Ft 2 x 28 W	221 โคม				
หลอด Ft 3 x 14 W		21 โคม			
หลอด Ft 2 x 28 W	221 โคม				
หลอด Ft 2 x 14 W		4 โคม			
โคมไฟ 2 x 18 W รอบอาคาร		8 โคม			
หลอดประหยัด 12 W				29 หลอด	
หลอด Ft 2 x 18 W		4 โคม			
หลอดดวงเดือน 32 W					2 โคม

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APPENDIX F

ELECTRICITY CONSUMPTION AND COST CALCULATION

ELECTRICITY CONSUMPTION AND COST CALCULATION

F1 Electricity Consumption

Energy Consumption (kW/yr) = Power consumption (watt) x 10^{-3} (kW) x no. of appliance x Hour of use per day x the amount of working days per year (Eq. F1)

A. Energy consumption from air conditioning

Power consumption (kW/yr) = AC size (BTU/hr) / EER x 10^{-3} (kW) x no. of appliance x operating time (hr/d) x working days per year (d/yr) (Eq. F2)

EER (Energy Efficiency Ratio)

A room air conditioner's efficiency is measured by the energy efficiency ratio (EER). The EER is the ratio of the cooling capacity (in British thermal units [Btu] per hour) to the power input (in watts). The higher the EER rating, the more efficient the air conditioner. EER was tested by 30 AC from TRANE© company.

Table F1 EER for Air Conditioners in President's office

AC no.	EER	AC no.	EER
1	11.78	16	11.95
2	11.67	17	11.8
3	11.66	18	11.33
4	12.27	19	11.42
5	11.82	20	11.32
6	11.68	21	11.15
7	11.85	22	11.1
8	11.72	23	11.52
9	12.13	24	11.18
10	11.94	25	11.03
11	11.97	26	11.58
12	11.74	27	11.66
13	12.24	28	11.47
14	11.9	29	11.71
15	11.75	30	11.88
Average			**11.65**

AC Operating time (hr/d) = Working time (hr/d) x working ratio of air compressor

Table F2 Working Time of AC in President's Office Buildings

Facility type	Working time* (hr)
Administration	7
Meeting	6
Executive	2

* working time was estimated from staff interview

Working ratio of air compressor = 0.55

Calculation example

1 AC size 12,000 BTU , EER = 11.65, Working ratio of air compressor = 0.55, Working hour = 7 h/d, Working days per year = 242 (d/yr)

Power consumption (kW/yr) = $\frac{12,000}{11.65}$ x 10^{-3} x 1 x 7 x 0.55 x 242

= 959.69 kW/yr

B. Lighting system

Energy Consumption (kW/yr) = Power consumption (watt) x 10^{-3} (kW) x no. of appliance x Hour of use per day (h) x the amount of working days per year (d/yr)

100 T5 fluorescent lamps 28 watt 3 arrays in administrative section which operating for 8 h/d in 242 working days/yr.

Energy consumption (kW/yr) = 28 x 10^{-3} x 3 x 100 x 8 x 242

= 16262.40 kW/yr

C. IT device

43 Desktops with capacity 200 watt in personnel division which operating for 8 h/d in 242 working days/yr.

Energy consumption (kW/yr) = 200 x 10^{-3} x 43 x 8 x 242

= 16,649.60 kW/yr

D. Auxiliary appliance

6 microwaves with capacity 800 watt in administrative division which operating for 0.5 h/d in 242 working days/yr.

Energy consumption (kW/yr) = 800 x 10^{-3} x 6 x 0.5 x 242

= 580.80 kW/yr

Energy cost (Bht/yr) = Energy consumption (W/yr) x Cost of electricity (Bht/W)

Cost of electricity in President's office in 2016 equaled to 3.962 THB/W. The electricity cost was derived from building and ground service statistic sheet for electricity cost of Prince of Songkla University.

Table F3 Type of Data

Description	Unit	Type of Data
Power consumption	W	Measurement and Calculation
No. of appliance	-	Measurement
Working operation	hour	Estimation from interview
Working day	day	Measurement
Cost	THB	Evidence

Table F4 Electricity Appliances in Administrative Division of President’s Office

Appliance / Division	General	Personnel	Planning 2nd Fl	Planning 3rd Fl	Finance - Material	Finance	Education service		International Affairs	Building and ground service	Student affairs	Total	Capacity (Watt)
Room No.							112	118		Building 2 (2)	Building 2(3)		
IT device													
Desktop	37	43	17	10	12	50	11	6	12	21	16	235	200
Laptop	5	6	5	0	0	1	1	1	1	3	1	24	65
Scanner			3	1			2	1	0	1	2	10	20
Printer	8	8	3	2	6	15	6	6	4	9	5	72	40
Electricity Appliance													
Photocopier	1	1	1	0	0	0	0	0	0	0	0	3	1100
Projector	0	1	1	0	0	0	0	0	0	2	1		210
Fax machine	1	1	1	1	1	1	1	0	1	1	1	10	10
Telephone	10	18	9	4	1	15	7	4	7	15	14	104	10
Microwave oven	1	1	0	1	0	1	1	0	1	0	0	6	800
Refrigerator	1	2	1	1	1	1	1	1	1	1	1	12	125
Pot	1	1	1	1	1	2	0	1	1	1	2	12	700
Fan	2	0	0	0	2	18	5	3	0	3	6	39	75

Appliance	Division	General	Personnel	Planning 2nd Fl	Planning 3rd Fl	Finance - Material	Finance	Education service		International Affairs	Building and ground service	Student affairs	Total	Capacity (Watt)
	Room No.							112	118		Building 2 (2)	Building 2(3)		
Television		2	1	1	1	1	1	0	1	1	1	0	10	90
Blower		5	7	4	3	1	4	2	2	2	3	5	38	30
Rice cooker											1		1	600

F2 Scenario Evaluation

Table F5 Electricity Consumption Allocation in 2015 by Energy System

	Electricity Consumption (kWh/yr)	Ratio (%)	Electricity from Allocation (kWh)
AC	323,705	56.59	325,159.43
Lighting	119,859	20.95	120,397.54
IT Device	87,712	15.33	88,106.10
Auxiliary Appliance	40,714	7.12	40,896.93
Total	571,990	100	
Baseline (2015)			574,560

Example of Allocation

Total electricity consumption from calculation = 571,990 kWh

Electricity consumption ratio of AC = $\frac{323,705}{571,990}$ x 100 = 56.59 %

Baseline (Total Electricity Consumption in 2015) = 574,560 kWh

Therefore, in total electricity consumption 574,560 kWh ;

Electricity consumption of AC = $\frac{56.59}{100}$ x 574,560 = 325,159.43 kWh/yr

Table F6 Energy Consumption Scenario Calculation in 2015

Scenario	Baseline	I	II	III	IV	V	VI	VII	VIII
Option		X	A	B	C	X + A	A + B + C	X + A + C	X1+ A + C
AC	325,159.43	325,159.43	259,678.04	325,159.43	325,159.43	259,678.04	259,678.04	259,678.04	259,678.04
Lighting	120,397.54	78,723.14	120,397.54	119,858.60	120,397.54	78,723.14	119,858.60	78,723.14	68,882.74
IT Device	88,106.10	88,106.10	88,106.10	88,106.10	87,325.76	88,106.10	87,325.76	87,325.76	87,325.76
Auxiliary Appliance	40,896.93	40,896.93	40,896.93	40,896.93	40,896.93	40,896.93	40,896.93	40,896.93	40,896.93
Total (kWh)	574,560	532,885.60	509,078.61	574,021.06	573,779.66	467,404.21	507,759.33	466,623.87	456,783.47

Table F7 Summary of Electricity Consumption and GHGs Emisssion Scenario in 2015

	Electricity Consumption (kWh/yr)	GHGs Emission (ton CO_2 eq)*
Baseline	574,560	334
I	532,885.60	310
II	509,078.61	296
III	574,021.06	334
IV	573,779.66	333
V	467,404.21	272
VI	507,759.33	295
VII	466,623.87	271
VIII	456,783.47	266

* Emission Factor of Electricity = 0.5821

Remark:

Table F8 Scenario Description

Option	Description
A	AC - Operation time reduction: Turn on from 9-11.30am and 1.30 – 4.00pm (5 hrs operation)
B	Lighting – Turn off during lunch time (Reduce 1 hr operation)
C	IT devices – Switch off during lunch time (Reduce 1 hr operation)
X	LED installation instead of fluorescent at normal operation (8 hrs)
X1	LED installation instead of fluorescent at 7 hrs operation

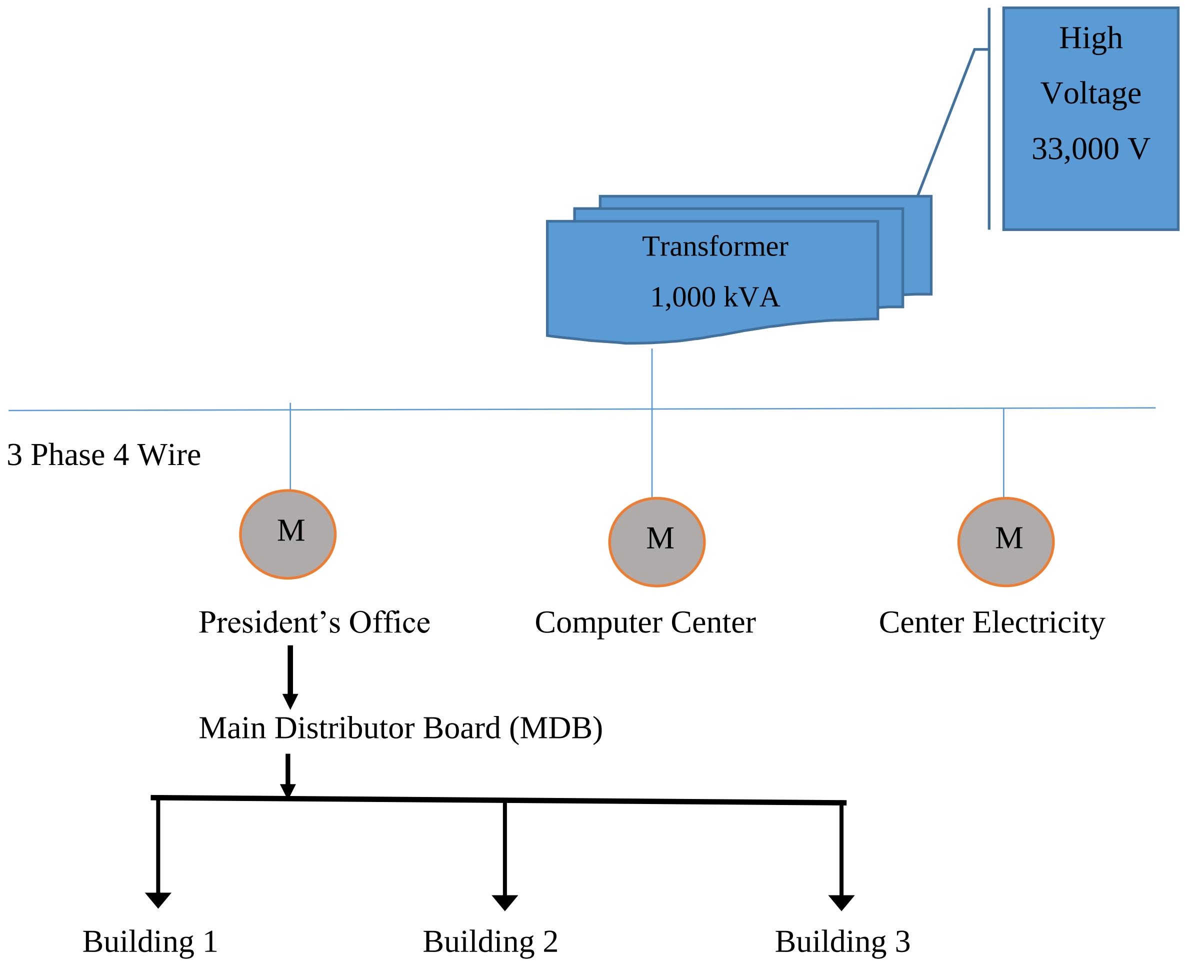
Table F9 Scenario Option

Scenario	Option
Baseline	Control condition at normal operation
I	X
II	A
III	B
IV	C
V	X + A
VI	A + B + C
VII	X + A + C
VIII	X1 + A + C

APPENDIX G

ELECTRICITY CONSUMPTION AND COST CALCULATION

ELECTRICITY PATTERN OF PRESIDENT'S OFFICE BUILDINGS



APPENDIX H

GREEN UNIVERSITY RELATIVE INTERVIEWS

GREEN UNIVERSITY RELATIVE INTERVIEWS

บทสัมภาษณ์ความคิดเห็นจากอาจารย์กร ศรเลิศล้ำวนิชย์ ในฐานะตัวแทนผู้บริหารมหาวิทยาลัยสงขลานครินทร์

1. มหาวิทยาลัยอยู่ในระดับใด ในการเข้าสู่ มหาวิทยาลัยสีเขียว

GU เริ่มเข้ามาช่วงปี 2008 – 2009 เริ่มใช้คำว่า Green University (GU) ก่อนจะมี UI criteria (UI เริ่ม effective 2011) สำหรับมุมมองของผู้บริหารมหาวิทยาลัยแต่ละวิทยาเขตนั้น มองเรื่องการเข้าสู่ GU ตาม UI matrix แตกต่างกันไป

2. วางแผนตั้ง schedule ในการเข้าสู่ Green Univ. ในปีไหน

เดิมทีนั้น ได้มองอย่าง optimistic มีปัจจัยภายนอกสนับสนุนรอบด้าน เช่น งบจากรัฐบาล เอกชน ชุมชน ปัจจัยภายใน ผู้บริหาร มี 5 stakeholders ที่พอจะเห็นความเป็นไปได้

แต่เมื่อเริ่มดำเนินการ จึงได้รู้ว่า ความยากอยู่ที่การจัดการภายใน แต่ข้อดีคือ ดึง effort จากภายนอกไม่ยาก ทำให้รู้ว่าการขับเคลื่อน GU นั้นไม่ง่าย เมื่อได้ไปดูงานที่ CU ผู้บริหาร CU แนะนำว่า ต้องใจเย็น ใช้เวลานาน ขนาด CU ที่มีความพร้อมสูง ใช้เวลาไม่ต่ำกว่า 10 ปี เพราะเป็นเรื่องของการเปลี่ยนแปลง โดยเฉพาะภายใน เป็นการดึงคนจากภายในมาช่วยกันทำ เป็น the must หากเป็นภายนอก ยังสามารถเลือกได้ ยังปฏิเสธได้ แต่คนภายใน / คนในพื้นที่ เลือกไม่ได้

Milestone ในการขับเคลื่อน GU

1. ปลูกต้นไม้ - ในปี 2011 GU เริ่มจาก top-down policy โดยอธิการบดี ด้วยการปลูกต้นไม้ ทำอย่างชัดเจนใน Theme วันแม่ ครบรอบ 80 พรรษามหาราชินี วางโครงการปลูกต้นไม้ไว้ที่ 1,000 ต้น คาดการณ์คนเข้าร่วมงาน 300 คน วันงานมาจริงๆ เป็นหมื่นคน โดยมีภาพความร่วมแรงร่วมใจมากัน เช่น พาครอบครัวมาร่วมกันปลูกต้นไม้ แสดงให้เห็นถึงความพร้อมในการมีส่วนร่วมของประชาชนที่มีจิตสำนึก คนมี willingness จะทำอยู่แล้ว นี่เป็นปรากฏการณ์แรก
2. รถไฟฟ้า – ช่วงปี 2011 – 2012 พัฒนาระบบขนส่งมวลชน จากเดิมที่เคยมีโครงการนี้ใน 2001 – 2002 (แต่ไม่สามารถดำเนินโครงการให้สำเร็จได้) จึงได้นำเข้าที่ประชุมวิทยาเขต ด้วยทุนเริ่มต้น 5-6 ล้านบาท มีการไปดูงานที่มหาวิทยาลัย 3 แห่ง คือ จุฬา (CU), ธรรมศาสตร์ (TU), มหาวิทยาลัยเชียงใหม่ (CMU) ทั้ง 3 แห่งมีรูปแบบที่แตกต่างกัน ดังนี้ CMU เป็นรถไฟฟ้าแบบรถกอล์ฟ นั่งได้ 12 ที่นั่ง สัมปทานเอกชน มีต้นทุนค่าใช้จ่าย 10 ล้านบาท/ปี, CU เป็น hybrid มีแอร์ ในขณะที่ TU เป็นรถใช้ก๊าซธรรมชาติ

หลังจากไปดูงานทั้ง 3 แห่ง จึงมีความคิดว่า มอ. ต้องเป็นรถไฟฟ้าล้วนเท่านั้น เพื่อ support GU ได้อย่างแท้จริง ต่อมา ได้พบกับศิษย์เก่า มอ. ที่มีอู่รถและดัดแปลงเครื่องยนต์ได้ จึงให้โจทย์เป็นรถไฟฟ้า 40 ที่นั่ง ได้ต้นแบบมา เป็นรถไฟฟ้าสีขาว นั่งได้ 2 ชม. ที่ความเร็วสูงสุด 20 กม./ชม. คิดราคาคันละ 1.2 ล้านบาท จึงสามารถซื้อได้ 5 คัน เป็นชุดแรก ซึ่งปัจจุบันมีกว่า 10 คัน โดยเคยของบสนับสนุนจากโลตัสในการรับ-ส่งคนจากอาคารเย็นศิระ เข้าโลตัส และไปโรงพยาบาล แต่ผู้บริหาร

ของโลตัสไม่สนับสนุน โดยมีความคิดแบบเสือนอนกิน ว่า สามารถทำรายได้สูงอยู่แล้ว แม้จะไม่มีรถเวียนผ่านโลตัสก็ตาม จึงได้ไปคุยกับนายกเทศมนตรีเทศบาลนครหาดใหญ่ ได้รับอนุมัติรถไฟฟ้ามา 3 คัน สำหรับการใช้น้ำมัน Biodiesel เติมในรถขนส่งในมหาวิทยาลัยนั้น เคยได้มีการหารือกันมาบ้างแล้ว แต่ทราบว่า ราคาแพง และ supply ไม่สม่ำเสมอ มี affordable ต่ำ จึงไม่เหมาะสมในการใช้กับการขนส่งมวลชนที่ต้องใช้เป็นประจำ

3. การสร้างลานจอดรถ บริเวณสนามบน “ทุ่งตำเสา” มีความจำเป็นต้องตัดต้น ทุ่งตำเสา ออกจำนวนหลายสิบต้น จัดเป็นประเด็นแหลมคม ที่ทำให้มีผู้มองจาก 2 ฝ่าย คือ ฝ่ายที่ห่วงใยในทัศนียภาพ และฝ่ายที่มองการใช้ประโยชน์ มีการเชิญวิทยากรด้านการดูแลต้นไม้ จึงเป็นอีกวาระที่ได้มีการพูดถึง Green Univ. ผลสุดท้ายสามารถรักษาต้นไม้ที่มีอายุเก่าแก่ไว้ได้ 2 ต้น จากจำนวนหลายสิบต้นที่ถูกตัดไป

4. อดีตอธิการบดี ได้เคยกล่าวถึงนิยาม GU ไว้ 5 ด้าน ได้แก่ การสัญจร วิถีชีวิต (รายละเอียด อ.กร จะส่งให้ อ.พนาลีภายหลัง)

5. นโยบาย GU เริ่มนับจริงจังตั้งแต่ มค. 59 โดยสภาฯ ให้นโยบายไว้ 4 ด้าน ได้แก่
    1. ข้อมูลการใช้พื้นที่
    2. พลังงาน
    3. การสัญจร
    4. การปรับจิตสำนึก และการมีส่วนร่วมของนักศึกษา และบุคลากร

โดยสามารถแปลงสู่การปฏิบัติ โดย แต่งตั้งกรรมการเชิงนโยบาย เพื่อจัดทำแผนยุทธศาสตร์ และแต่งตั้งคณะทำงาน เพื่อประยุกต์แผนสู่การปฏิบัติจริง

2 กุมภาพันธ์ 2560 เวลา 11.30 น.

..

บทสัมภาษณ์ วิศวกรไฟฟ้า กองอาคารสถานที่ มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่

คำถาม: มาตรการประหยัดพลังงานที่เคยทำในสำนักงานอธิการบดี มีอะไรบ้าง และได้ผล หรือไม่ อย่างไร ?

เนื่องจากมหาวิทยาลัย ต้องการลดค่าใช้จ่ายไฟฟ้า ปีละกว่า 20 ล้านบาท จึงมีการรณรงค์กิจกรรมเพื่อประหยัดพลังงานอย่างต่อเนื่อง ผู้บริหารให้ความสำคัญกับการประหยัดพลังงานทุกยุคทุกสมัย สำหรับสำนักงานอธิการบดีนั้น ที่ผ่านมามีการประยุกต์นโยบายต่างๆ มาใช้ ได้แก่

1. มาตรการการปรับเปลี่ยนเวลาการเปิดเครื่องปรับอากาศ จาก 8.30 – 16.30 น. เป็น 9-11.30 น. และ 13.30 – 16.00 น. แต่ทำได้ไม่นาน เนื่องจากบุคลากร คนทำงาน ร้อน อยู่ไม่ไหว ต้องเปิดแอร์ แต่บางส่วนงานก็ทำได้ เช่น ห้องที่มีคนน้อยๆ พื้นที่ไม่มาก ก็อาจจะเปิดหน้าต่างนั่งทำงานจนถึง 9 โมงเช้าได้ แต่พออากาศร้อนจริงๆ ก็ไม่ไหว คนทำงานก็ได้รับผลกระทบ ทำให้ทำงานไม่ได้เต็มประสิทธิภาพก็มี และเนื่องจากตัวอาคารหันตามทิศทางของพระอาทิตย์ เวลาแสงแดดส่องก็ทำให้ร้อนมาก และไม่มีร่มไม้มาบังตัวตึกเลย
2. เคยขอความร่วมมือ ยกระดับอุณหภูมิเครื่องปรับอากาศ จาก 25 ซ เป็น 26 ซ ช่วงประมาณ ปี 2550 – 2551 แต่ก็ทำไม่ได้ น่าจะเกรงผลกระทบต่องาน
3. ขอความร่วมมือ ไม่ให้ทำโอที แต่ก็ไม่ประสบผลสำเร็จ เนื่องจากบางส่วนงานก็มีความจำเป็นในการทำงานแต่ละหน้าที่ เช่น งานเร่ง และต้องส่งในกำหนดเวลากระชั้น

อย่างไรก็ดี ที่ผ่านมา มาตรการต่างๆ ที่นำมาใช้ เป็นการขอความร่วมมือ และเป็นกิจกรรมที่ทำโดยความสมัครใจทั้งสิ้น ไม่ได้มีมาตรการบังคับ หากมีการบังคับ เช่น เป็นนักศึกษา อาจจะตัดคะแนนได้ แต่บุคลากร ทำไม่ได้ หากขับเคลื่อนด้วยแรงจูงใจทางเศรษฐศาสตร์ เอาตัวเงินมาสร้างความต้องการให้บุคลากรประหยัดพลังงานได้ และได้คืนเป็นเงิน หรือผลตอบแทนให้องค์กร ก็คงพอจะช่วยให้การประหยัดพลังงานในส่วนงานมีความเป็นไปได้ และเห็นผลสัมฤทธิ์มากขึ้น ตลอดจนการรณรงค์ประชาสัมพันธ์และจัดกิจกรรมอย่างต่อเนื่อง

คุณชัยยศ ชิตวัฒน์ – วิศวกรไฟฟ้า มหาวิทยาลัย

8 พฤษภาคม 2560 เวลา 11.10 น.

APPENDIX I

PRESIDENT’S OFFICE LAYOUTS

VITAE

Name Mr. Samnang TIM

Student ID 5710920020

Educational Attainment

Degree	Name of Institution	Year of Graduation
Bachelor's of Science (Environmental Science)	Royal University of Phnom Penh (Cambodia)	2013

Scholarship Awards during Enrolment

Matching fund of Her Royal Highness Princess Maha Chakri Sirindhorn with Faculty of Environmental Management, Prince of Songkla University for Excellent Students from Cambodia. Awarded on August 2014.

List of Publication and Proceeding

Samnang Tim, Warangkana Jutidamrongphan. 2018. Life Cycle Cost Analysis and Energy Performance of President's Office, Prince of Songkla University, Thailand. Songklanakarin Journal of Science and Technology. 40(4). (In press)

Samnang Tim, Warangkana Jutidamrongphan. 2016. Energy efficiency and green building: A case of Prince of Songkla University, Thailand. Proceedings of the 53rd International conference on Civil and Architectural Engineering, Phnom Penh, Cambodia, July 13th, 2016, pp. 1-6.