ASSESSMENT OF CARBON FOOTPRINT IN THE ORTHOPAEDIC DEPARTMENT, QUEEN SIRIKIT NATIONAL INSTITUTE OF CHILD HEALTH

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ABSTRACT

The objective of this research was to assess the amount of Carbon Footprint, Greenhouse Gas (GHG) emissions and measurement of decreasing Carbon Footprint in the Orthopaedic Department, Queen Sirikit National Institute of Child Health. The research was conducted based on the direct and indirect activities that were divided into 3 areas, i.e., Area 1 (1.1) Fuel consumption per patient for meetings, trainings, business trip (1.2) Chemical usage in surgery operation (1.3) Water Supply Usage; Area 2 Electrical Usage and Area 3 (3.1) Fuel in daily transportation (3.2) Waste analysis: including general waste, hazardous waste, infectious waste and recyclable waste.

The results revealed in fiscal year 2013-2015, Orthopaedic Department released Carbon Footprint averagely per year as following details. Area 1, 2 and 3 emitted Carbon Footprint 11.98, 16.32 and 15.76 tonnes of carbon dioxide equivalent, respectively. The electric consumption in Area 2 has the highest Carbon Footprint emission 37.04 percent then followed by Area 3 and Area 1 35.77, 29.19 percents respectively. Therefore, Carbon Footprint can be reduced by all employees who already implemented continuously as Queen Sirikit National Institute of Child Health policies in order to reduce usage of energy and resources.

KEY WORDS: CARBON FOOTPRINT / ORTHOPAEDIC DEPARTMENT / QUEEN SIRIKIT NATIONAL INSTITUTE OF CHILD HEALTH / CARBON DIOXIDE EQUIVALENT

71 pages

การประเมินคาร์บอนฟุตพริ้นท์ในการให้บริการของกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

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บทคัดย่อ

การศึกษาวิจัยครั้งนี้มีวัตถุประสงค์ เพื่อคำนวณปริมาณคาร์บอนฟุตพริ้นท์ (Carbon Footprint) ประเมินปริมาณก๊าซเรือนกระจก และค้นหาวิธีลดปริมาณคาร์บอนฟุตพริ้นท์ของกระบวนการให้บริการกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี โดยดำเนินการเก็บรวบรวมข้อมูลกิจกรรมของกลุ่มงานศัลยกรรมกระดูกและข้อ ที่ทำให้เกิดการปล่อยคาร์บอนฟุตพริ้นท์ 3 ขอบเขต ทั้งทางตรงและทางอ้อม โดยขอบเขตที่ 1 คือ (1.1) สำรวจการใช้เชื้อเพลิงในการรับส่งต่อผู้ป่วย การประชุม อบรม ดูงาน (1.2) รวบรวมข้อมูลสารเคมีที่ใช้ในการผ่าตัดผู้ป่วยของกลุ่มงาน (1.3) เก็บข้อมูลจำนวนผู้ป่วย ญาติ และเจ้าหน้าที่ รวมทั้งข้อมูลการใช้น้ำประปาของสถาบันฯ เพื่อนำมาวิเคราะห์การใช้น้ำประปาของกลุ่มงาน ขอบเขตที่ 2 สำรวจข้อมูลการใช้ไฟฟ้าของหน่วยงาน และขอบเขตที่ 3 คือ (3.1) สำรวจการใช้เชื้อเพลิงในการเดินทางไปกลับเพื่อมาปฏิบัติงานของเจ้าหน้าที่ (3.2) รวบรวมปริมาณมูลฝอยทั่วไป อันตราย ติดเชื้อ รีไซเคิล

ผลการวิจัยพบว่า กิจกรรมการให้บริการของกลุ่มงานศัลยกรรมกระดูกและข้อในปีงบประมาณ 2556-2558 มีการปล่อยคาร์บอนฟุตพริ้นท์เฉลี่ยต่อปี ดังนี้ ขอบเขตที่ 1 มีปริมาณคาร์บอนฟุตพริ้นท์ จำนวน 11.98 ตันคาร์บอนไดออกไซด์เทียบเท่า ขอบเขตที่ 2 มีปริมาณคาร์บอนฟุตพริ้นท์ จำนวน 16.32 ตันคาร์บอนไดออกไซด์เทียบเท่า และขอบเขตที่ 3 มีปริมาณคาร์บอนฟุตพริ้นท์ จำนวน 15.76 ตันคาร์บอนไดออกไซด์เทียบเท่า การใช้ไฟฟ้าในขอบเขตที่ 2 มีปริมาณคาร์บอนฟุตพริ้นท์มากที่สุดถึงร้อยละ 37.04 รองลงมาเป็นขอบเขตที่ 3 และขอบเขตที่ 1 คิดเป็นร้อยละ 35.77 และร้อยละ 27.19 ตามลำดับ สำหรับแนวทางในการลดปริมาณคาร์บอนฟุตพริ้นท์ บุคลากรของกลุ่มงานได้ปฏิบัติกันมาอย่างต่อเนื่องตามที่สถาบันสุขภาพเด็กแห่งชาติมหาราชินี ได้กำหนดเป็นนโยบายเพื่อลดการใช้พลังงานและทรัพยากร

คำสำคัญ : คาร์บอนฟุตพริ้นท์ / กิจกรรมการให้บริการของกลุ่มงานศัลยกรรมกระดูกและข้อ / สถาบันสุขภาพเด็กแห่งชาติมหาราชินี / คาร์บอนไดออกไซด์

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CHAPTER I
INTRODUCTION

1.1. Background

The Carbon Footprint is a tool to calculate Greenhouse Gases emissions from products produced process. The life cycle of product, service and organization will show the results as quantitatively by calculated in carbon dioxide or equivalent. The Carbon Footprint can be classified into three types: human activities, products and organizations (Department of Health Ministry of Public Health, 2013). Greenhouse Gases emission from various activities will be causing climate change and global warming issue. Natural climate change will take long times to change but human activities have been contribute the affected and stimulated composition in the atmosphere. When global changed in climate, it will affect on natural resources and environment such as season changing, extinction, increasing desert areas and the melting of Arctic's ice. Flooding and drought issue were affected to biodiversity and food security. All nations were pay attention on global warming situation since 1979 and agreed to solve the problem together first time in the United Nations Conference on Environment and Development in 1992 at Rio de Janeiro, Brazil by signing the United Nations Framework Convention on Climate Change (UNFCCC) but it is only voluntarily and Greenhouse Gases emission still increasing. The 3rd of UNFCCC in 2000, all nation associates were endorsed Kyoto Protocol, which commits to reduction Greenhouse Gases efficiently by recognizing that developed countries need to reduce Greenhouse Gases 6 types such as CO_2, CH_4, N_2O, HFCs, PCFs and SF_6 for 5% of emission by 2010 under 3 conditions: Joint Implementation (JI), Emission Trading (ET) and Clean Development Mechanism (CDM) from 2008 to 2012 (Department of Environmental Quality Promotion, 2014, p.10-11).

Thailand has ratified to join the UNFCCC in 28 December 1994 and ratified in Kyoto Protocol in 28 August 2002. Thailand as a developing country under the protocol, then no obligation to reduce Greenhouse Gases but only provides

National Communication report that including Greenhouse Gas Inventory, track overall operation and voluntarily to reduce Greenhouse Gases propose to secretariat of the UNFCCC (Department of Environmental Quality Promotion, 2014, p.11).

The Carbon Footprint for organization in Thailand was established on 2011 by Thailand Greenhouse Gas Management Organization (Public Organization) that arranged the guidelines Carbon Footprint for organization. The aim of organization is to be an information and tools for assess Greenhouse Gases emission from varies activity and support government sector for Greenhouse Gases reporting (Pirat Ausuparat and Hanpol Pungrassami., 2014) . Furthermore, National Science and Technology Development Agency (NSTDA) Academy had seen the important of global warming issue and will like to support government sector and private body that interested in reduce the Greenhouse Gases emission then, they already developed Carbon Footprint assessment program for Carbon Footprint of Service (CFS). The assessment of Carbon Footprint will assess from Life Cycle Assessment (LCA) of products or processes to understand the Carbon Footprint emission of each step by support organization which properly step and process to assess the chance for improve environment for hospital. The hospital open 24 hrs. and has many patients came every day and used a lot of resources for treatment and service processes for each patient such as electricity, water usage, waste disposal and all of this can stimulating the global warming issue form both of direct and indirect Greenhouse Gases emission.

Queen Sirikit National Institute of Child Health is specialized medication for children and high quality of treatment, technology and medical devices. In everyday hospital has many patients visited hospital for treatment, and have class for medical students and a lot of department to supporting activiites related to energy and resources in order to satisfy government that able to efficient about energy management from 2010 till today. Queen Sirikit National Institute of Child Health got Thailand Energy Award in 2014 and 2015 that can reduced Carbon Footprint for organization. However, from the literature review found that the related reserch about Carbon Footprint assessment for service processess was only few reseach. Then, Orthopaedic surgery medical service process that open for patient from 8:00 am - 12:00 pm every Monday to Friday and approximately 9,000-10,000 patients visited hospital in the year. The assessment of Carbon Footprint can be the role model to another organization for assess Carbon Footprint of services from arrival to end service. It can be evaluated the Carbon Footprint from activities and also can be the databases for propose the plan to reduce Carbon Footprint emission of Orthopaedic surgery medical service process.

1.2 Research objectives

1.2.1 To calculate Carbon Footprint from Orthopaedic surgery medical service process of Queen Sirikit National Institute of Child Health.

1.2.2 To assess Greenhouse Gases from Orthopaedic surgery medical service process of Queen Sirikit National Institute of Child Health.

1.2.3 To propose measures of decreasing Carbon Footprint from Orthopaedic surgery medical service process of Queen Sirikit National Institute of Child Health.

1.3 Conceptual framework

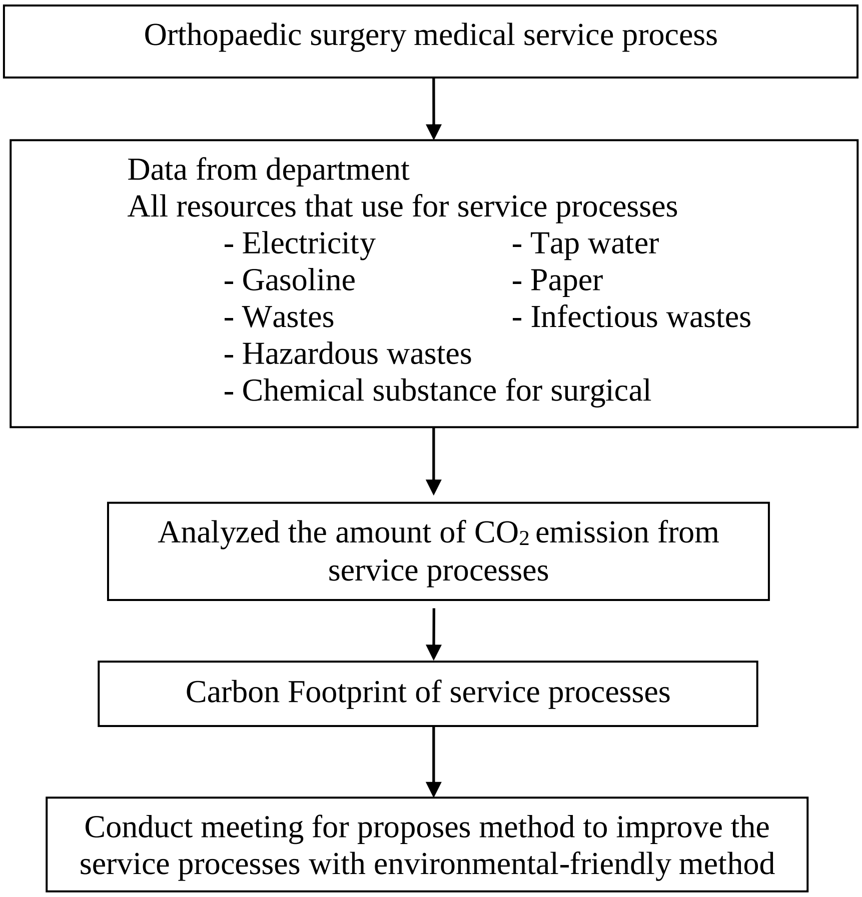

Figure 1.1 Conceptual framework

1.4 Scopes of the research

1.4.1 Study Area

Orthopaedic surgery medical service process of Queen Sirikit National Institute of Child Health Bangkok province, Thailand.

1.4.2 Content

This research was collected data from Orthopaedic surgery medical service process as below Figure 1.2

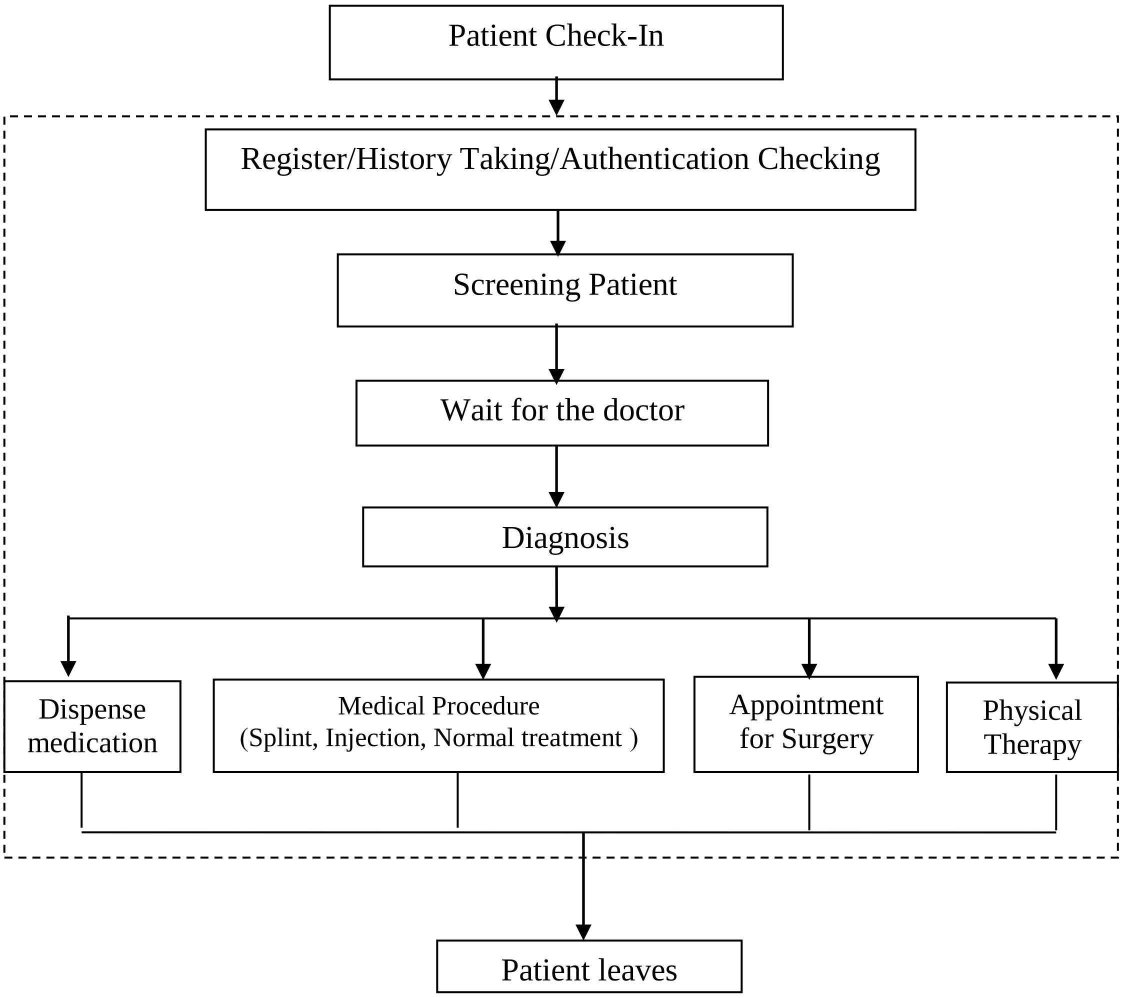

Figure 1.2 Orthopaedic surgery medical service

The data were collected from service processes and specified the Greenhouse Gases emission in three contents as follows;

(1) Direct GHG emissions from burning wastes disposal, landfill, transportation and waste water treatment.

(2) Energy indirect GHG emissions from electricity.

(3) Other indirect GHG emission from used another transportation and contracted service for refuse disposal (Department of Health, 2012, p.16).

1.4.3 Research period : 1 year

1.5 Expected outcomes

1.5.1 The Carbon Footprint of Orthopaedic surgery medical service process of Queen Sirikit National Institute of Child Health Bangkok province, Thailand.

1.5.2 The data and results in this reseach can be used to assess the Carbon Footprint of service processes to improve their process in order to reduce GHG.

1.5.3 The results can be used as data to determinate method for improve the service process which environmenatlly-friendly and more efficiency to reduce GHG.

1.6 Research definitions

Orthopaedic surgery medical service process means the process starts from patient check-in until patient leaves.

Carbon Footprint means the Carbon Footprint from Orthopaedic surgery medical service process.

Greenhouse Gases emission factor means the emission from each of service processes.

Coefficent of Greenhouse Gases emission (kg CO_2e/unit) means the total Greenhouse Gases emission from each activity.

CHAPTER II
LITERATURE REVIEW

This research assesses the Carbon Footprint of the Orthopaedic services at the Queen Sirikit National Institute of Child Health (QSNICH), utilizing concepts and literature surrounding the Carbon Footprints of the healthcare industry. These various concepts are summarized into four major concepts:

1. Global Warming
2. Greenhouse Effect
3. Effects of Global Warming
4. Carbon Footprint
5. Types of Carbon Footprint
6. Carbon Footprint Assessment
7. Carbon Footprint Calculation
8. General Information on Service Process at the Queen Sirikit National Institute of Child Health
9. Related Research

2.1 Global Warming

Global warming is an average rise in the Earth's surface temperature and seawater due to the increase in Greenhouse Gas emission from human activities, such as fuel combustion, industrial activities, and agriculture, especially in the latter half of 20th century. The 100-year forecast revealed 3-5 degrees Celsius rise in temperature, which would critically affect lives on earth unless the adverse effects were controlled and mitigated. Since 1958, the Keeling Curve, invented by an American scientist named Ralph Keeling, displayed a constant increase in carbon dioxide concentration in the Earth's atmosphere above Mount Moana Loa, Hawaii. Subsequently, the establishment of other forms of assessment or data synthesis such as the Intergovernmental

Panel on Climate Change (IPCC), which also forecasted climate change in Southeast Asia. Since 1961, the region was revealed several climate changes including temperature increase of 0.1-0.3 degrees Celsius per decade, reduced cumulative rainfall, 1-3 mm sea level rise per year, and a higher tendency for intensification of climate extremes (Department of Health, 2014, p.1-2).

2.2 Greenhouse Effect

Climate change refers to a change in climate due to both natural causes and human activities. Human activities that result in climate change are the sources of an increase in Greenhouse Gas in the atmosphere, which unnaturally intensifies the greenhouse effects and causes the temperature rise in the Earth's surface (Department of Health, 2014, p.3).

Greenhouse effect refers to the increase in the Earth's temperature. When carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other CFCs exist in the atmosphere, they continuously vibrate. This continuous vibration cycle causes human to feel more heat (Department of Health, 2014, p.3).

The most well-known Greenhouse Gas (GHG) is carbon dioxide (CO_2). Other greenhouses gases include methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbon (HFCs) , and perfluorocarbons (PFCs). The sources of each Greenhouse Gas and global warming potentials (Table 2.1).

Table 2.1 Sources of Greenhouse Gasses and global warming potentials of Greenhouse Gasses

Greenhouse Gases	Sources	Global Warming Potentials ($kgCO_2e/kg$ GHG)
Carbon Dioxide	Natural sources such as respiration and combustion of fossil fuels such as oil and coals	1
Methane	Breakdown of organic waste, animal farming, coal and natural gas production, and transportation.	25
Nitrous Oxide	Agriculture (nitrogen fertilizer), fossil fuel and organic matter combustion, industrial processes that utilize nitric acid, such as nylon production, chemical industry, and plastic manufacturing.	298
Sulfur Hexafluoride	Semiconductor production and magnesium industry	22,800
Hydrofluorocarbon	Refrigerants in air-conditioning units, foam production, solvent, fire suppressants, foam blowing agents, and propellants.	124 –14,800

Table 2.1 Sources of Greenhouse Gasses and global warming potentials of Greenhouse Gasses (cont.)

Greenhouse Gases	Sources	Global Warming Potentials ($kgCO_2e$/kg GHG)
Perfluorocarbons	Industries that use refrigerants and coolants, cooling systems of buildings and cars, cleaning process of electronics that results in aluminum tube byproducts, semiconductor production, and substitutes for ozone depleting substances.	7,390 –12,200

Source : “Carbon Footprint,” by Ponthip Wongsuchoto, 2012, *Environmental Journal* Chulalongkorn University, 16(3), p.41-42.

2.3 Effects of Global Warming

The true effect of global warming is a rise in the average Earth's temperature, which does not occur in all the Earth's area. Temperature rising causes melting glaciers, subsequently raising sea level. The ocean circulation of warm and cold currents is altered, inducing the change in both sea water and land surface temperature. The global warming phenomenon can manifest in climate change, making warm areas colder, cold areas warmer, or warm areas even warmer, which leads to the following tremendous consequences:

1) Climate variability – which is altered air mass and ocean circulation regarding directions and volume flow rate, causing the change in climate and seasons in various surface areas. This temperature rise results in higher concentration of water vapor rising into the atmosphere, which in turn induces more precipitation. Therefore, some surface areas face severe droughts, while others face severe floods.

2) Coastal erosion - which is caused by constant sea level rise due to melting glaciers. The glaciers retreat in both the northern and southern hemispheres causes coastal erosion and seawater surges in low-lying areas. There is evidence that sea water level continues to increase at an accelerating rate.

3) Famine - the changing climate, drought, flood, and coastal erosion all have adverse effects on agriculture and livestock, such as less crop yield and dying animals. Subsequently, these effects directly impact food production, causing famine in various areas.

4) Health Effects - There will be a higher risk of diseases and infection, such as malaria, dengue fever, cholera, and food poisoning. Certain infectious agents grow better in warmer temperature. Higher temperature and concentration of carbon dioxide in stagnant water accelerated the period that eggs develop into mosquitos from 7 to 5 days. Their feeding time also changes from strictly daytime to nighttime until 11 pm. However, the more dangerous effect is that dengue virus was also found in male Asian Tiger mosquitos, which was usually found only in female mosquitos. Male mosquitos could transmit the dengue virus to their offspring, making disease prevention more difficult. (Department of Health, 2014, p.5-6).

2.4 Carbon Footprint

Carbon Footprint refers to Greenhouse Gas emission from the entire life cycle of a product. The life cycle assessment accounts the whole lifespan of products, starting from raw material acquisition to transportation, product assembly, product use, and waste management after use. The Carbon Footprints are calculated in kilograms of CO_2 equivalent per product. One of the main sources of global warming is GHG emission from the manufacturing industry. There is a worldwide effort to include Carbon Footprint - or carbon label - on product labels to provide consumers with a choice to use various eco-friendly products. A carbon label displays the cumulative Carbon Footprint throughout the product's life cycle, detailing how much GHG is released. The effort could help build awareness and induce participation on reducing GHG emission to combat global warming (Department of Health, n.d.).

Assessing a Carbon Footprint through the life cycle assessment is a technique that evaluates climate change potential, which is a result CO_2 and other Greenhouse Gas emitted throughout the life cycle of a product or service. The climate change potential value is displayed quantitatively in kg CO_2 equivalent or ton CO_2 equivalent (Department of Health, 2014, p.18).

Displaying Carbon Footprints will increase consumer awareness, stimulate GHG reduction among manufacturers, and encourage environmentally responsible manufacturing. Eventually, it leads to a low-carbon society that many countries have integrated into their national development strategy and policy. In March of 2007, the Carbon Trust, a private organization established by the government, pioneered the effort to label Carbon Footprint. Now, carbon labels have been developed and used in many countries. In France, a policy legally mandates that details of Carbon Footprints be available on display for all product types by 2011. In Asia, Japan had announced a plan to become a low-carbon society. Carbon Footprints and carbon labels have been the driving force that has steered Japan towards the goal. In Thailand, Carbon Footprint labels have been collectively developed by Thailand Greenhouse Gas Management Organization and Thailand Environment Institute. Now, 151 products have officially registered the Carbon Footprints. Registered products included sugar, PVC powder, coconut milk, soy milk, Shera board products, cement, ceramic products, faucets, light bulbs, etc. (Department of Health, n.d.).

Carbon Footprints are quantitative data that indicate the green gas emission of products - such as a bottle of water, a T-shirt, a cellular phone, and a car - throughout their life cycle. The life cycle assessment accounts the entire life span of products, starting from raw material manufacturing to product manufacturing, selling process, product uses, and waste management. The Carbon Footprints are calculated in kilograms of CO_2 equivalent or gCO_2e. For example, a Carbon Footprint of a fruity drink includes green gas emissions from all activities involved throughout all stages of its life cycle: growing fruit trees, fertilizers manufacturing, water management, herbicides or insecticide manufacturing, various chemicals used in growing fruit trees, fruit collection and distribution, juice manufacturing process, juice packaging or filling, juice distribution, buyers traveling to stores, storing, consumption, and waste management after consumption (Porntip Wongsuchoto, 2012, p.40).

2.5 Types of Carbon Footprint

Carbon Footprints can be categorized into 3 types

(1) Carbon Footprints of humans refer to Carbon Footprints emitted from daily human activities such as transportation, staying at home, working, and eating meals. All activities resulted in GHG emission. The average GHG emission per capita in Thailand is 5.3 - 5.5 ton CO_2e per year.

(2) Carbon Footprints of products refer to an assessment of GHG emission of each product throughout its life cycle. The life cycle assessment accounts the entire lifespan of products, starting from raw material acquisition to transportation, product assembly, and waste management after use. The Carbon Footprints are calculated in kilograms of CO_2 equivalent.

(3) Carbon Footprints of an organization refer to GHG emission from activities of an organization or agency, such as hospitals and schools. Organizational footprint accounts both direct and indirect emissions such as electricity consumption and supply chain related activities. All GHG emissions are collectively calculated as a Carbon Footprint of an organization in kilograms of CO_2 equivalent (Department of Health, 2014, p.18-19).

The continuous emission of GHG from various human activities such as agriculture, development and growth of the manufacturing industry, transportation, deforestation, and destroying natural resources or environment in other methods are the cause of global warming. The adverse effects of global warming continue to intensify, prompting nations to become more proactive at reducing GHG emission. Carbon Footprint for Organization or Corporate Carbon Footprint (CCF) is another method to account quantities of GHG emission of an organization. It can guide policy makers to effectively reduce GHG emission across the production scales – as a single manufacturing company, industry, and nation. Currently, Thailand Greenhouse Gas Management Organization (Public Organization) is supporting a Carbon Footprint for corporate organization project, which is detailed below:

1. Carbon Footprint of the manufacturing industry

2. Carbon Footprint of organization governed by the regional government (Thailand Greenhouse Gas Management Organization (Public Organization), n.d.).

When assessing organizational Greenhouse Gasses, the crucial factor is to avoid accounting activities of third parties. The organization needs a clear boundary to understand which emission activities belong to which parties. Thus, emission boundary is explicated in details, according to sources of emission activities and the responsible parties. Most office type companies are responsible for indirect emission. By not being directly emitting GHG, the company contributes to Carbon Footprint reduction (Department of Health, 2014, p.24).

Advantages of Carbon Footprint assessment

(1) Benefits for Manufacturers

(1.1) Carbon Footprint assessment keeps the company informed of their GHG emission throughout the product's life cycle.

(1.2) Carbon Footprint assessment can identify critical areas, allowing companies to prioritize areas for improvement. GHG measurement can be adapted to develop low carbon product, especially in the product design stage that considers the entire product life cycle.

(1.3) Displaying carbon labels shows commitments to be environmentally and socially responsible while responding to consumers' need to mitigate global warming.

(2) Benefits for Health facilities

(2.1) Carbon Footprint assessment informs health facilities of their and emission level and activities that result in GHG emission.

(2.2) Carbon Footprint inventory can be incorporated into the decision-making process and management policy and is further used to increase efficiency in GHG reduction.

(2.3) Receiving carbon labels can positively influence the image of the health facilities, as they can be perceived as socially and environmentally responsible.

(2.4) Increase business opportunities for private hospitals.

(2.5) Providing consumers with a choice to help reduce global warming and climate change.

(3) Benefits for Consumers

(3.1) Be informed of GHG emission, which helps consumers to be more conscious of GHG emission from the daily human activity.

(3.2) Be informed of different product use and choosing to use products that have carbon labels to help reduce global warming.

Therefore, Carbon Footprint can be used as a tool to instigate global warming reduction mindset among manufacturers and consumers. Similarly, it provides an opportunity for consumers to help reduce GHG emission (Department of Health, 2014, p.26-27).

2.6 Carbon Footprint Assessment

The Carbon Footprint assessment process dictated by Thailand Greenhouse Gas Management Organization (Public Organization) consists of 5 stages:

1. Establish limitations on activities that can be performed or processed within an organizational boundary.

2. Establish an adequate level of education regarding Greenhouse Gas emission management to ensure effective Greenhouse Gas treatment across all levels of an organization. There are 3 scopes concerning Greenhouse Gas emission:

Scope1: Direct emission is defined as direct emissions of Greenhouse Gasses into the atmosphere. Examples include employee transportation using the organization's own fuel source, steam boiler combustion, and Greenhouse Gas emissions from chemical reactions.

Scope 2: Energy indirect emission is defined as indirect emissions of Greenhouse Gasses through purchased energy sources from other company, such as electricity.

Scope 3: Indirect emission is defined as indirect emissions of Greenhouse Gasses that are unspecified in previous scopes, such as landfills, other modes of transportation not provided by the organization, and paper usage. However, ISO 14064 specifies that Scope 3 is optional.

Clearly state sources of Greenhouse Gas and calculation of the emission, which is assessed directly from the sources through Greenhouse Gas measurement, GHG emission factors (Table 2.2) and Carbon Footprint calculation.

Reports should be comprised of 4 main sections:

4.1 General information of an organization such as area, demographics, annual budget, organization chart, and function.

4.2 Greenhouse Gas emission management

1) Objectives and criteria for Greenhouse Gas reports

2) Organizational boundary

2.1 Establish the boundary and control approach (operational or financial) of Greenhouse Gas emissions and removals.

2.2 Facilities or departments within the boundary are accounted for Greenhouse Gas inventory and calculations of Greenhouse Gas emissions and removals. Comprehensive physical boundaries such as areas and numbers of organizational facilities, communities, geologically-defined population, and employees should also be accounted in the report.

2.3 Facilities or departments out of the emission boundary and inventory process need to be identified and provided reasons for the exemption.

3) Organization chart including organizational structure, management positions, and departments - especially the one responsible for Greenhouse Gas emission management.

4) Base year and period of assessment should be identified, together with the rationale behind choosing the specific year, for comparisons of the changes in emission levels in the following period. The context for significant changes in emission levels should also be provided, which is not included in the previous report.

5) Validation and verification bodies provide accreditation requirements and other relevant materials for the application.

4.3 Greenhouse Gas inventory in this section exhibits the cumulative Greenhouse Gas emission. Details include the period of assessment, reporting year, organizational boundary, activities relevant to Greenhouse Gas emission in all 3 scopes, and any limitations to obtaining relevant emission data. Inventory reports should include the following:

1) Sources or sites of Greenhouse Gas emission that are categorized into various types of activities that result in Greenhouse Gas emissions and removals.

2) Summarization of net Greenhouse Gas emissions and removals expressed in metric tons (kilograms) of CO_2 equivalent, and each Greenhouse Gas per activity type.

3) Data collection method

3.1 Relevant details of the data collection process, such as sources used to calculate inventory of each Greenhouse Gas per activity type and how the sources are obtained.

3.2 Details of the calculation process, assumptions, the calculation itself, and emission factors used in the calculation of GHG emissions and removals.

3.3 Details and explanations of changes related to the data collection method, the calculation process, and assumptions that are previously excluded in the inventory report.

4) References of all documentations used in the calculation of Greenhouse Gas emissions and removals that can be traced back to original sources to ensure the reliability of reports.

4.4 Other information that a local administration can further contribute to the assessment of Greenhouse Gas emissions and removals report. Examples are listed below:

1) Indirect Greenhouse Gas emissions and removals from activities in scope 3

2) Greenhouse Gas emissions per public utility within the boundary

3) Applications of Greenhouse Gas inventory report, such as further use in an analysis that displays cost reduction, exhibiting the effectiveness of management.

4) Guidelines or management policies to reduce Greenhouse Gas emission from organization activities.

5. Uncertainty analysis of Greenhouse Gas inventory reflects the quality of the GHG emission data. A data quality scorecard (Table 2.3) and data uncertainty scorecard (Table 2.4). (Thailand Greenhouse Gas Management Organization (Public Organization), n.d.).

2.7 Carbon Footprint Calculation

The equation for calculating emissions uses activity data from the organization and Greenhouse Gas emission factor to calculate emissions, which is expressed in metric tonsCO_2 equivalent. The equation is shown below:

$$CO_2 = \text{Activity data x GHG Emission factor}$$

Where:

CO_2 = Emissions of a GHG from an activity (kgCO_2e)

Activity Data = Activity rate in activity units

GHG Emission factor = Coefficients for the amount of gasses emitted from an activity, relative to activity units (kgCO_2e/activity unit) (Department of Health, 2012, p.17).

Table 2.2 Greenhouse Gas emission factors

Technology	Activity Unit	GHG emission factor (KgCO_2e/activity unit)
Nitrous Oxide	kg	0.296 MT CO_2e/kg
Isoflurane	kg	0.350 MT CO_2e/kg
Sevoflurane	kg	1.526 MT CO_2e/kg
Rubbing alcohol	kg	1.2600 kgCO_2e/kg
Gasoline (Benzine)	L	2.6 kgCO_2e/L
Diesel fuel	L	3.0 kgCO_2e/L

Table 2.2 Greenhouse Gas emission factors (cont.)

Technology	Activity Unit	GHG emission factor ($KgCO_2e$/activity unit)
Natural gas (NGV)	kg	0.24 $kgCO_2e$/kg
Electricity	kWh	0.5610$kgCO_2e$/kWh
Water utility	m^3	0.0264 $kgCO_2e$/ m^3
Human waste management	kg BOD	0.42 kg CH_4/kg BOD
Wastewater treatment byproducts from a - centralized system or an aerobic treatment plant	kg BOD	0.18 $kgCH_4$/kg BOD
- Septic system	kg BOD	0.30 kg CH_4/kg BOD
Centralized system *For off-site system, GHG emissions include emission from waste transportation	ton-km	0.0494 kg CO_2e/ton-km

Source: Department of Health, 2012, p.61-62.

Table 2.3 Calculation data quality level

Description	Data Quality Scorecard			
Data collection method	X = 6 points	Y = 3 points		Z = 1 points
	Continuous data monitoring from an automatic measuring system	Meter and utility bills		Estimation
GHG Emission Factor	A = 4 points	B = 3 points	C= 2 points	D = 1 point
	Actual measurement	From manufacturers	From national data	From global standardized data

Source: "The Carbon Footprint assessment for organization, Thammasat University Rangsit," by Pirat AuSuparat and Hanpol Pungrassami, 2014, *Science and Technology Journal*, 22 (1).

Table 2.4 Level of data uncertainty and data quality

Rank	Net Uncertainty Score	Descriptions
1	1-6	High uncertainty. Poor data quality.
2	7.12	Moderate uncertainty. Moderate data quality.
3	13-18	Low uncertainty. Good data quality.
4	19-24	Very low uncertainty. High data quality

Source: "The Carbon Footprint assessment for organization, Thammasat University Rangsit," by Pirat AuSuparat and Hanpol Pungrassami, 2014, *Science and Technology Journal*, 22 (1).

2.8 General Information on Services at the Queen Sirikit National Institute of Child Health

The Queen Sirikit National Institute of Child Health (QSNICH), Department of Medical Services, Ministry of Public Health or Children Hospital was established in 1954 on Ratchawithi Road. Occupying an area of 18,717.6 m^2 with a total of 7 buildings, QSNICH approximately utilizes electricity consumption of 7-8 million kWh annually. QSNICH provides tertiary care to pediatric patients with complex cases, starting from newborns to 15-year-old teens. QSNICH employs 1,486 workers (4 November 2015) and has the capacity of 426 beds and 22 wards - approximately capable of and handling 381,669 outpatient visits and admitting 15,000 inpatients, of which 5,167 are surgical cases. There are 4 Centers of Excellence at QSNICH:

1. Neonatal Center is a tertiary care center that provides medical services and has an average referral of 1,200 patients per year from both hospitals in Bangkok or provincial hospitals. This center treats the highest number of premature neonates (<1,500g) in the country, with a mortality rate of 94% and the lowest disability rate.

2. Pediatric Cardiac Center provides full-service cardiac disorder treatments. Services include echocardiography, cardiac catheterization in neonates, and open heart surgeries. The pediatric cardiac center is the most medically advanced in the country, with referrals of over 1,500 cases per year, or 90% of all patients.

3. The Dengue Hemorrhagic Fever Center is the leading research institute involving in a collaborative project with WHO to provide treatment worldwide. Countries that are affected by Dengue Fever, such as Bangladesh, Bhutan, Brazil, Cambodia, Cape Verde, Indonesia, Laos, Malaysia, Maldives, Pakistan, Sri Lanka, Sudan, Timor-Leste, Venezuela, and Vietnam have shown a reduction in the fatality rate.

4. The Neonatal Surgery Center has been operational since 2000 as the first referral center providing neonatal surgery services. The center handles an average of 400-500 surgical cases yearly.

Center of Special Expertise and Clinic (COSE): 10 centers

1. Mobility-Impaired Children
2. Developmental and Behavioral Pediatrics
3. Breastfeeding Sick Babies
4. Birth Defects Information
5. New emerging diseases (HIV/Inf.)
6. Children's Eye (ROP)
7. Pediatric Ear Nose and Throat
8. Pediatric Cancer
9. Pediatric Neurology and Neurosurgery
10. Pediatric Imaging

Clinical Departments: 35 clinics

1. Internal medicine: 22 clinics
2. Psychiatry: 3 clinics
3. Otolaryngology: 1 clinic
4. Ophthalmology: 1 clinic
5. Surgery: 5 clinics
6. Orthopaedic: 1 clinic
7. Physical therapy: 1 clinic
8. Dentistry: 1 clinic

The Orthopaedic clinical department specializes in treating children, and has sufficient ready-to-use medical equipment. The clinic is opened on weekdays from 8.00 a.m. - 12.00 p.m., with a yearly average of 9,000 - 10,000 patients. It employs five doctors, two nurses, a general administration officer, and a patient assistant. Number of patients in Orthopaedic clinical department (Table 2.5-2.6).

Table 2.5 Numbers of patients in Orthopaedic clinical department between the fiscal years of 2013 - 2015

Month	2013	2014	2015
October	1,003	996	857
November	837	832	782
December	665	705	760
January	855	616	776
February	770	697	757
March	883	945	831
April	897	877	828
May	833	873	802
June	697	826	783
July	772	727	714
August	762	791	764
September	806	884	771
Net Patients	9,780	9,769	9,425

Source: Queen Sirikit National Institute of Child Health, 2015.

Table 2.6 Type of patients between the fiscal year of 2013 - 2015

Type of Patient	2013	2014	2015
Outpatients	9,780	9,769	9,425
Inpatients	781	738	717
Surgical patients	727	668	604

Source: Queen Sirikit National Institute of Child Health, 2015.

Hospitals management requires significant amount of resources, demanding the performance of different types of activities. These various activities, directly and indirectly, result in Greenhouse Gas emissions. The assessment of Carbon Footprint falls within the three Scopes (Table 2.7).

Table 2.7 Scope of boundary for Carbon Footprint assessment

Scope of Boundary	Activities
1.Direct emission	- Waste incineration/landfills - Hospital's transportation fuels -Wastewater Treatment -Waste disposals
2.Energy indirect emission	Purchased electricity
3.Indirect emission	-Transportation fuels not owned by the hospital -Waste management such as incineration or landfills by a subcontractor - Subcontractors' activities

Source: Department of Health, 2012, p.16.

2.9 Related Research

Pirat AuSuparat and Hanpol Pungrassami (2014) were studied Carbon Footprints of Thammasat University at Rangsit in 2010 to provide data for further studies on resource management and adverse environmental impacts. Data application includes future Greenhouse Gas reduction management. Results revealed a net Greenhouse Gas emission of 34,355 metric tons CO_2e per year. Scope 1 emitted 1,693 metric tons of CO_2e. Scope 2 emitted 31,271 tonnes of CO_2e, with 91% of the emission resulted from electricity. Scope 3 emitted 1, 391 metric tons of CO_2e. Concerning emissions per capita, one student emitted 1.62 metric tons CO_2e each year.

Thanut Plupratin et. al. (2011) had assessed CO_2 equivalent of Greenhouse Gas emissions from the chemical engineering department of Kasetsart University. All activities and Greenhouse Gas calculation of the department fell under the standard of

ISO14064-1 and ISO/WD TR14069. Activities were categorized into 3 Scopes: Scope 1 was defined as emissions from refrigerant leakage of and the departmental fuel consumption, Scope 2 was defined as electricity consumption, and Scope 3 was defined as transportation, undergraduate meals, water utility, and other resources such as liquid nitrogen used in a laboratory, 80g A4 paper, toilet paper in the administration office. Results revealed that in 2010, the chemical engineering department emitted 1, 036.43 metric tons of CO_2e per year. Respectively, major contributors of Greenhouse Gas emission were electricity consumption (52.9%), transportation (24.7%), and undergraduate meals (21.5%). Other activities only resulted in 0.81% of the total emission. The data found were later used to design Greenhouse Gas reduction guideline and improvement protocol for GHG emission data management for the following academic year.

Nareth Yaiwong (2011) assessed a Carbon Footprint of canned sweet corn by parameter screening method. This research examined a 12-ounce canned sweet corn to evaluate its Carbon Footprint throughout the product’s life cycle, starting from plantation to growing corn, transportation, production process, canning process, and cargo transport to harbor. Results revealed that one can of sweet corn produced 246 g of CO_2e. The raw material acquisition process was shown to emit the highest level of Greenhouse Gasses (94%). The following main contributor was the actual sweet corn production process. Regarding Greenhouse Gas value, Carbon Footprint assessment of canned sweetcorn by parameter screening method displayed a Greenhouse Gas value (RGHG) of 23.04. The production process emitted the highest level of Greenhouse Gas value (RGHG = 26%). The following respective emission levels were from packaging process, plantation, transportation to the production site, and transportation to a harbor. Therefore, a GHG emission reduction protocol should focus on increasing the effectiveness of raw material management and energy.

Nuchanart Wararakprapak (2014) had assessed CO_2 equivalent of Greenhouse Gas emissions from an alcohol manufacturing site in Khonkaen using a Carbon Footprint assessment method. The research focused on the effectiveness of the environmental management system regarding Greenhouse Gas emission of this manufacturer. The research adopted Carbon Footprint assessment protocol from the Thailand Greenhouse Gas Management Organization (Public Organization) or TGO, which categorized activities into two Scopes. Scope 1 refers to direct Greenhouse Gas emission. Scope 2 refers to Greenhouse Gas emission from energy consumption. The organizational boundary was based on an operational control approach, with the base year being 2013 (Jan 1 - Dec 31). Results revealed that the alcohol manufacturing site released 24,859.68 metric tons of CO_2e. The highest level of direct emission was biogenic carbon (20,991.48 tCO_2eq or 84.44%). The following respective sources of GHG emissions were fossil fuels (2,010.79 tCO_2eq or 8.09%) and indirect electricity consumption (1,857.41 tCO_2eq or 7.47%). The major activities that contributed to GHG emissions were yeast fermentation (62.53%), biogas fired steam boiler (21.91%), electricity consumption (7.47%), oil fired steam boiler (3.96%), and transportation fuels (2.26%). Greenhouse Gas reduction should start from the easiest and most economical method that could involve changing materials, equipment, and technologies to conserve energy. Furthermore, an organization should seek new protocols and studies geared towards enhancing resource utilization, concurrent with consideration for feasibility, practicality, and value.

Rungtiwa Pongakrasila et. al. (2015) had assessed the Carbon Footprint of Her Majesty Cardiac Center in the fiscal year 2014. Research procedure was adopted from the Carbon Footprint assessment protocol by TGO and The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition. Operational boundary categorized activities into 3 Scopes: chemical usage in medical procedures, electricity consumption, human transportation, water utility, A4 paper usage, and waste. Results revealed a net Greenhouse Gas emission of 537 tCO_2e: Scope 1 emitted 33 tCO_2e, Scope 2 emitted 395 tCO_2e, and Scope 3 emitted 109 tCO_2e. Electricity consumption under Scope 2 released the highest level of emission (74%). Subsequently, Scope 3 emissions released 20% of GHG and Scope 1 emissions released 6% of GHG.

Sriarun Sukjaroen et. al. (n.d.) analyzed cost structure, management perspectives, and competencies of onsite treatment of infectious waste by autoclave technology at Hat Yai Hospital, which manages 300 kg of infectious waste daily. Hatyai Hospital utilizes autoclave technology for sterilization - 100kg of infectious waste are subjected to a steam pressure of 30 lbs. per square in at 134 °C for 45 minutes. Results revealed that within a 10-year lifespan, the cost of waste processing from a rental autoclave amounts to 10.92 Baht/kg, but a purchased autoclave only amounts to 8.39 Baht/kg of waste. In comparison to offsite waste incineration, which amounts to 26 Baht/kg, onsite treatment of infectious waste by autoclave technology can significantly lower cost by 58%. Inspections showed that this infectious waste treatment method is in compliance with the biosafety standard of 94% sterilization efficacy. Furthermore, this approach reduces 52% of Greenhouse Gas emission due to waste transportation in the case of offsite incineration. The consensus from management, scholars, and hospital workers after observing the autoclave is that the technology can reduce risks of exposure to contaminants and has lower waste management cost than offsite incineration. There were no discrepancies of consensus before and after the observation of the autoclave, as it performed as expected. Furthermore, this method of infectious waste treatment does not contribute to dioxin/furan and other toxic gas emissions. The hospital aimed to implement onsite treatment of infectious waste by autoclave technology, as well as, offered a suggestion to grind treated infectious waste before collection and transportation to municipal solid waste landfills. To increase the sterilization efficacy to 100%, the Department of Health suggests that infectious waste should be subjected to a steam pressure of 30 lbs. per square inch at 134 ° C for 60 minutes.

Somchai Chamchuklin et. al. (n.d.) had assessed a Carbon Footprint of a community health center in Nakhon Ratchasima province in 2009-2011 to evaluate emission levels from various activities and draw GHG reduction guideline for management. The research adopted Carbon Footprint assessment protocol from the GHG Protocol developed by World Resource Institute (WRI) and World Business Council for Sustainable Development (WBCSD), in which the Thai Department of Health, Ministry of Public Health, has also adopted as a guideline. Results revealed that respectively between 2009-2011, the community health center released a Carbon Footprint of 503,193 $kgCO_2e$, 446,747 $kgCO_2e$, and 428,829 $kgCO_2e$. By 2011, the community health center was able to reduce their Carbon Footprint by 14.78%. The highest emission induced activities were electricity and fuel consumptions (88.43% - 89.52%). GHG emission per capita were 12.05 $kgCO_2e$ in 2009, 12.06 $kgCO_2e$ in 2010, and 11.68 $kgCO_2e$ in 2011. By 2011, the community health center was able to reduce GHG emission per capita to 0.37 $kgCO_2e$. The successful reduction in the comprehensive Carbon Footprint was due to the implementation of a project, specifically through curbing fuel consumption. However, annual electricity consumption continued to rise each year. Therefore, Carbon Footprint reduction protocol of the following year should specifically address the rising trend of electricity consumption.

Ueno et. al. (1999) conducted a life cycle analysis of an appliances containing multiple electronic components. The process requires a life cycle inventory database of each component to completely account all energy inputs and pollution released. Financial calculations can be assessed by multiplying a unit cost by raw material production and manufacturing process figures from
the database. The research found that raw material production of electric components generates only a few environmental impacts. Afterward, the life cycle analysis is more commonly assessed per type of appliances.

Laurent et. al. (2010) previous research on "Carbon Footprint as environmental performance indicator for the manufacturing industry," especially addressing the Kyoto protocol mandate of 6 Greenhouse Gas : carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFCs) , perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) – congruent with human toxic impacts. Results revealed a weak relationship between the GHG emissions and human toxic impacts. Therefore, the outcome elicits two distinct applications: (1) human toxic impacts, especially from raw materials, as an indicator for sustainable production and (2) Carbon Footprint as environmental sustainability indicator for product design and manufacturing. Thus, Carbon Footprint acts as various indicators of a product.

Jone et. al. (2011) developed a Carbon Footprint management, tracking GHG emission by individual behaviors, households, and communities. The research aimed to analyze impacts of a Carbon Footprint on climates and financial resources, as well as, advantages of effective carbon reduction protocol, using the life-cycle theory of consumption. Data were taken from U.S. households across 28 cities and categorized into six city type by population density and 12 income levels. Carbon inventory also included indirect emissions from transportation, energy consumption, water utility, food, waste, purchased products, and services.

Results revealed a positive correlation between reduction in GHG emissions and decreased spending in all households, leading to a conclusion that the size of organizations and Carbon Footprints are directly related to geographic locations and general demographics unique to that region. Reduction in Carbon Footprint management spending further supports the notion. However, different protocols in carbon reduction are needed for the different population group. Findings of this research further resulted in a cooperative effort to design online GHG management tools to encourage behavior change at the household level and provide personal feedbacks.

CHAPTER III
METHODOLOGY

This research aimed to assess the Carbon Footprint of the Orthopaedic services at the Queen Sirikit National Institute of Child Health (QSNICH) by assess from start services until end services of the Orthopaedic services and used data from the process to calculate the Carbon Footprint as follow below details.

3.1 Data collection

3.1.1 Secondary data collection

The secondary data was collected from hospital's transportation (pick-up, drop-off and employees seminar), chemical substance usage in medical procedure, wastewater treatment data from related departments 3 years ago (2013-2015)

3.1.2 Primary data collection

The primary data was collected as following below;

1) The data of electricity consumption from the Orthopaedic services by calculated electrical appliances (Appendix A).

2) The data of employee transportation using fuel from the Orthopaedic services 9 peoples (Appendix B).

3) The data of total municipal solid waste such as infectious and hazardous waste by weighed all municipal solid waste (Appendix C).

4) In-depth interview with 2-nurse officer that one of them has been working for 5 years and has known thoroughly department processes by used structured interview or formal interview. This in-depth interview is open end question and focus interview in order to collected data of the Orthopaedic services process by

coordinate with department and issued formal letter from Faculty of Environment and Resources studies, Mahidol University.

Table 3.1 The data collection from Greenhouse Gases of the Orthopaedic services

Activity	GHG emission activity	Data	Source	Unit
1	1.1 The hospital's transportation (pick-up, drop-off and employees seminar)	secondary	- Ambulance service - Human resources	Liter (L)
	1.2 Chemical substance usage in medical procedure	secondary	Nurse Anesthetists	Kilogram (kg)
	1.3 Wastewater treatment	secondary	Maintenance	Kg BOD
2	2.1 Electricity consumption	secondary	calculated electrical appliances	Kilowatt (kWh)
3	3.1 Used fuel of employee transportation	primary	Questionnaire	Liter (L)
	3.2 Municipal solid waste disposal	primary	Collection data	Kilogram (kg)

This study was collected secondary and primary data (Table 3.1) by issued formal letter from Faculty of Environment and Resources studies, Mahidol University and then, coordinated with representative from department for in-depth interview and used questionnaires.

3.2 Scope of research

Calculation the Carbon Footprint of the Orthopaedic services processes that included start of services until the end of services by collected data 3 years from fiscal year 2013 – 2015. The scope of research was divided into 3 scopes as below :

Scope 1: Direct GHG emission activities

1) The hospital's transportation
2) Chemical substance usage in medical procedure
3) Wastewater treatment

Scope 2: Indirect GHG emission activities

Electricity consumption of the Orthopaedic services

Scope 3: Other indirect GHG emission activities

1) Employees transportation for going to work
2) Municipal solid waste such as infectious waste and hazardous waste

3.3 Method

3.3.1 Electrical consumption collection by Electrical consumption Form (Appendix A).

3.3.2 Fuel usage collection by used fuel of employee transportation questionnaire (Appendix B).

3.3.3 Municipal solid waste disposal collection by Total municipal solid waste Form and included infectious waste and hazardous waste (Appendix C).

3.3.4 In-depth interview (Appendix D).

3.4 Carbon Footprint calculation

For assessment of Carbon Footprint, the calculation used activity data from the organization multiply with Greenhouse Gas emission factor: EF and results will expressed in metric ton (kilogram) of CO_2 equivalent. The equation is shown below;

$$CO_2 = \text{Activity data x GHG Emission factor}$$

Where

CO_2 = Emissions of a GHG from an activity ($kgCO_2e$)

Activity Data = Activity rate in activity units

GHG Emission factor = Coefficients for the amount of gasses emitted from an activity, relative to activity units ($kgCO_2e$/activity unit) (Department of Health, 2012, p.17).

The calculation of GHG emission factor of the Orthopaedic services as shown in Table 3.2.

Table 3.2 Greenhouse Gas emission factors

Activity	GHG emission activity	Unit	GHG emission factor ($KgCO_2e$/activity unit)
1	1.1 The hospital's transportation (pick-up, drop-off and employees seminar)	Liter (L)	- Gasoline (Benzine) 2.6 $kgCO_2e/L$ - Diesel fuel 3.0 $kgCO_2e/L$
		kilogram (kg)	- Natural gas (NGV) 0.24 $kgCO_2e/kg$
	1.2 Chemical substance usage in medical procedure	kilogram (kg)	- Isoflurane 0.350 MT CO_2e/kg - Sevoflurane 1.526 MT CO_2e/kg
	1.3 Wastewater treatment	kg BOD	0.18 $kgCH_4$/kg BOD
2	2.1 Electricity consumption	kWh	0.5610 $kgCO_2e/kWh$

Table 3.2 Greenhouse Gas emission factors (cont.)

Activity	GHG emission activity	Unit	GHG emission factor ($KgCO_2e$/activity unit)
3	3.1 Used fuel of employee transportation	Liter (L)	- Gasoline (Benzine) 2.6 $kgCO_2e/L$ - Diesel fuel 3.0 $kgCO_2e/L$
		kilogram (kg)	- Natural gas (NGV) 0.24 $kgCO_2e/kg$
	3.2 Municipal solid waste disposal Municipal solid waste Infectious waste and hazardous waste	kilogram (kg)	0.0494 kg CO2e/ton-km 0.8421 kg CO_2e/kg 6 $kgCH_4/Gg$ 41 gN_2O/ton

Note: If used outsource for disposal the municipal solid waste disposal, infectious waste and hazardous waste, it need to assess GHG emission for transportation as well.
Source: Department of Health, 2012, p.61-62.

Table 3.3 The Carbon Footprint calculation

Activity	GHG emission activity	Calculation
1	1.1 The hospital's transportation (pick-up, drop-off and employees seminar)	Used fuel × EF ($kgCO_2e/l$)
	1.2 Chemical substance usage in medical procedure	Used chemical (kg)× EF (MT CO_2e/kg)
	1.3 Wastewater treatment	Average wastewater in system × BOD (mg/l BOD)

Table 3.3 The Carbon Footprint calculation (cont.)

Activity	GHG emission activity	Calculation
2	2.1 Electricity consumption	Electricity consumption (kWh) × EF (kgCO_2/kWh)
3	3.1 Used fuel of employee transportation	Used fuel (1) × EF (kgCO_2e/l)
	3.2 Municipal solid waste disposal	Municipal solid waste (kg) × round trip (km) × EF (kgCO_2e/ton-km of each municipal solid waste type) + (municipal solid waste (kg)) × EF of municipal solid waste disposal

Source: Department of Health, 2012, p.61-62.

3.5 Uncertainly Data analysis

The uncertainly data assessment are important process that shown the level of data quality included data collected from activities and coefficient of Greenhouse Gases emission. The results from uncertainly data assessment able to manage the quality of data for access Carbon Footprint in the further study (Pirat AuSuparat and Hanpol Pungrassami, 2014).

Table 3.4 Calculation data quality level

List	Data quality level			
Data collection	X = 6 score	Y = 3 score		Z = 1 score
	Automatic system	Meter and Bill		Estimated value
Emission Factors	A = 4 score	B = 3 score	C = 2 score	D = 1 score
	Quality measures	Producer	National level	International level

From Table 3.4 shown that the level of data quality collected from different sources and it made the level of data quality were not equal. To consider the uncertainly data was considered from point of data reliability rating by divided into three level and level of data quality of emission factor four level. When considered the level of data quality from all activities, it can be concluded that the level of data quality were four level (Table 3.5).

Table 3.5 Level of data uncertainty and data quality

Level	Level of data score	Explanation
1	1 – 6	uncertainty : high quality : bad
2	7 – 12	uncertainty : medium quality : medium
3	13 – 18	uncertainty : low quality : good
4	19 – 24	uncertainty : low quality : excellent

Source: “The Carbon Footprint assessment for organization, Thammasat University Rangsit,” by Pirat AuSuparat and Hanpol Pungrassami, 2014, *Science and Technology Journal*, 22 (1).

3.6 Data analysis

3.5.1 Analyzed primary data and secondary data from calculation of Carbon Footprint emission.

3.5.2 Analyzed in-depth interview from nurse of the Orthopaedic services 1 person to present Carbon Footprint emission of the Orthopaedic services and then used data from each process in order to calculated carbon dioxide (CO_2) emission or equal.

3.5.3 Considered the data of carbon dioxide (CO_2) emission or equal look for reduce and propose options that it will not impact to the service process. To arrange meeting in department for reduce GHG emission as follow below details.

1) Arrange the meeting period for brainstorm approximate 3 hrs.

2) To clarify the results of GHG emission of service process that can realized activity or scope of work emission. It take time approximate 30 minutes.

3) To brainstorm and open change for all members to recommend or suggestions any methods to reduce GHG emission. It take time approximate 2 hrs and conclude the method that will used together and take time approximate 30 minutes.

CHAPTER IV
RESULTS AND DISCUSSION

This research assessed the Carbon Footprint of the Orthopaedic services at the Queen Sirikit National Institute of Child Health (QSNICH). A secondary data collection method was used to gather information on hospital's fuel use, chemicals used in surgical procedures, and wastewater treatment. A primary data collection method was used to gather information on electricity consumption, employee commute, and waste disposal through in-depth interviews. Both data collection methods aimed to fulfill the following research objectives:

4.1 To calculate the Carbon Footprint of the Orthopaedic services at the QSNICH. Both primary and secondary data collection methods were utilized to gather information on all 3 Scopes of activities. Each specific activity data is used to calculate its Carbon Footprint.

4.2 To evaluate Carbon Footprint inventory of the Orthopaedic services at the QSNICH. The emission level of each activity is subsequently ranked in order.

4.3 To identify effective Carbon Footprint reduction protocol of the Orthopaedic services at the QSNICH. Previous Carbon Footprint inventory and interview data are further presented in an Orthopaedic center's meeting to explore Carbon Footprint reduction methods in a collaborative effort.

Result and Discussion

4.1 Carbon Footprint of the Orthopaedic services at the QSNICH were collected comprehensively using both primary and secondary data collection methods. Data were collected between the fiscal years 2013-2015, taking account the entire medical care process from start to finish. The activities were classified into 3 Scopes:

Scope 1 emission is defined as direct Greenhouse Gas emission from the following activities:

1. Transportation using the hospital's fuels such as employee travels, ambulances, and transports to medical conferences. The following data was taken from secondary sources.

Table 4.1 Fuel use by hospital's vehicles in fiscal years 2013 - 2015

Month	Fuel type	2013	2014	2015	Net Fuel use
October	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
November	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
December	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
January	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
February	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
March	Gasoline	0	0	0	0
	Diesel	571.42	571.42	571.42	1,714.26
	CNG	0	0	0	0
April	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0

Table 4.1 Fuel use by hospital's vehicles in fiscal years 2013-2015 (cont.)

Month	Fuel type	2013	2014	2015	Net Fuel use
May	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
June	Gasoline	0	0	0	0
	Diesel	1.2	1.2	1.2	3.6
	CNG	0	0	0	0
July	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
August	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0
September	Gasoline	0	0	0	0
	Diesel	0	0	0	0
	CNG	0	0	0	0

Note: Fuel use is only relevant to hospital transports, medical conferences/workshops, or academic activities in the field of Orthopaedics. Patient transport is negligible due to low occurrences.

Table 4.2 Carbon Footprint from car fuel between the fiscal years 2013-2015

Fuel Type	Fuel Amount (L) (1)	Emission factor (2)	Carbon Footprint (1 x 2)
Diesel	572.62	3.0 $kgCO_2e/L$	1,717.86 $kgCO_2e$ or 1.72 $tonCO_2e$

The diesel gasoline is the main fuel type consumed by the transportation department and the main use of car fuel in the Orthopaedic center at the QSNICH is to attend the biannual medical conference at the Healthcare Accreditation Institute (Public Organization) in March and June. By the way, QSNICH have staffs only 9 peoples and not able to attended the conference, so the fuel data from 2013-2015 was calculated from normal time and excluded special event that the results of distances and fuel might be changed. The data that used for calculate the Carbon Footprint start from 2013-2015 was 1.72 tonCO_2e per year (Table 4.2). To study and do the research is the main mission of QSNICH then, they needed to add skills in professional field and necessary to travel by using hospital's car to attend conference every year. However, the transportation department was developed Carpool project in order to save energy and resources with another hospital in same area from 2003 till recently and developed campaign for using public transportation accordingly. The finding is consistent with research from Thammasat University at Rangsit, which stated that fuel consumption within Scope 1 is the direct source of significant GHG emissions. Machines such as lawn mowers, electrical generators, and steam boiler are operated on fuel types. There are five major types of fuels: gasohol 91, gasohol 95, diesel, gasoline, biodiesel, and NGV. The comprehensive Carbon Footprint inventory of fuels in 2010 was 537,866 kgCO_2e. Diesel accounted for 69% of total emission (Pirat Ausuparat et. al. 2014).

2. Chemicals used in Orthopaedic surgical procedures during 2013 – 2015 are displayed in Table 4.3. The following data was taken from secondary sources.

Table 4.3 Amounts of chemical used in Orthopaedic surgical procedures during the fiscal years 2013-2015

Month	Chemicals	2013	2014	2015	Net Chemical use
October	Isoflurane	0.98	1.56	0.2	2.74
	Sevoflurane	0.2	0.24	0.16	0.6
November	Isoflurane	0.4	1.6	1.22	3.22
	Sevoflurane	0.17	0.29	0.15	0.61
December	Isoflurane	0.3	0.8	1.54	2.64
	Sevoflurane	0.42	0.35	0.23	1
January	Isoflurane	2.2	1.6	0.8	4.6
	Sevoflurane	0.38	0.28	0.21	0.87
February	Isoflurane	1.1	0.6	1.2	2.9
	Sevoflurane	0.25	0.32	0.2	0.77
March	Isoflurane	1	2.6	1.8	5.4
	Sevoflurane	0.44	0.29	0.23	0.96
April	Isoflurane	0.86	0.23	0.5	1.59
	Sevoflurane	0.42	0.37	0.18	0.97
May	Isoflurane	0.95	1.3	1.2	3.45
	Sevoflurane	0.41	0.25	0.12	0.78
June	Isoflurane	0.82	0.75	1.2	2.77
	Sevoflurane	0.4	0.31	0.14	0.85
July	Isoflurane	0.28	0.6	0.24	1.12
	Sevoflurane	0.42	0.24	0.18	0.84
August	Isoflurane	0.94	0.5	0.75	2.19
	Sevoflurane	0.43	0.36	0.21	1
September	Isoflurane	1.9	1.96	0.35	4.21
	Sevoflurane	0.41	0.22	0.23	0.86
Total	**Isoflurane**	**11.73**	**14.1**	**11**	**36.83**
	Sevoflurane	**4.35**	**3.52**	**2.24**	**10.11**

Table 4.4 Carbon Footprint of chemicals used in surgical procedures during the fiscal years 2013-2015

Fiscal Year	Chemicals	Amounts of Chemicals (kg) (1)	Emission factor ($MTCO_2e$/kg) (2)	Carbon Footprint ($tonCO_2e$) (1 x 2)
2013	Isoflurane	11.73	0.350	4.11
	Sevoflurane	4.35	1.526	6.63
			Total	10.74
2014	Isoflurane	14.10	0.350	4.94
	Sevoflurane	3.52	1.526	5.37
			Total	10.31
2015	Isoflurane	11.00	0.350	3.85
	Sevoflurane	2.24	1.526	3.42
			Total	**7.27**
			Average per year	**9.44**

The most three common chemicals used in Orthopaedic surgical procedures were nitrous oxide, isoflurane, and sevoflurane. However, the utilization of a piping system rendered the precise amounts unquantifiable by anesthesiologists. From the three chemical, isoflurane and sevoflurane are the chemicals with the highest global warming potentials 36.83 kg and 10.11 kg respectively (Department of Health, 2014). The Carbon Footprints of isoflurane and sevoflurane was 10.74 $tonCO_2e$, 10.31 $tonCO_2e$ and 7.27 $tonCO_2e$ from 2013-2015 respectively or average 9.44 $tonCO_2e$ per year (Table 4.4). The chemical used in Orthopaedic surgical procedures is unavoidable tasks then, QSNICH was attended energy saving activity from Ministry of Energy that developed method to saving resources and energy by each of department. The anesthesiology department was developed method to reduced Inhaled Anesthesia and met the need of patients by meeting with all professional field and experiment method to reduced Inhaled Anesthesia flow. The total Carbon Footprint can reduced was 8.24 $tonCO_2e$ or equal and reduced QSNICH expenses was 114,344 baht per year. The results are in alignment with the Carbon Footprint assessment from Her Majesty

Cardiac Center at Siriraj Hospital, stating that Nitrous oxide, isoflurane, and sevoflurane have a total Carbon Footprint of 33 tCO_2e per year (Rungtiwa Pongakrasila, 2015).

3. Wastewater treatment - water usage per capita displayed in Table 4.5 was assessed based on numbers of outpatients, inpatients, at least two visitors (parents), and medical staff. All data was taken from secondary sources.

Table 4.5 Water usage (cubic meter/m^3) in the fiscal years 2013-2015

Month	2013	2014	2015
October	135.81	134.87	116.06
November	113.40	112.73	105.93
December	90.18	95.58	102.96
January	115.83	83.57	105.12
February	104.36	94.50	102.56
March	119.61	127.98	112.55
April	121.50	118.80	112.14
May	112.86	118.26	108.63
June	94.50	111.92	106.07
July	104.63	98.55	96.75
August	103.28	107.19	103.50
September	109.22	119.75	104.45
Total	**1,325.16**	**1,323.68**	**1,276.70**

Note: Water use per person is 45 L/person/day (Assoc. Prof. Dr. Thongchai Panswad, System design for Wastewater and Stormwater Management)

Table 4.6 Carbon Footprint from wastewater treatment during the fiscal year 2013-2015

Fiscal Year	Water Amount (m^3) (1)	BOD Before Entering the System	Emission factor (2)	Carbon Footprint (1 x 2)
2013	1,325.16	161	0.18 $kgCH_4$/kg BOD	960.08 $kgCO_2e$ or 0.96 $tonCO_2e$
2014	1,323.68	151	0.18 $kgCH_4$/kg BOD	899.50 $kgCO_2e$ or 0.90 $tonCO_2e$
2015	1,276.70	107	0.18 $kgCH_4$/kg BOD	614.75 $kgCO_2e$ or 0.61 tonCO2e
			Average per year	**0.82 tonCO2e**

Note: Methane has a global warming potential of 25 $kgCO_2e$ ($kgCO_2e$/kg GHG)

The combination of water use from staff and patients between the fiscal years 2013-2015 were 1,325.16 m^3, 1,323.68 m^3, and 1 ,2 7 6 . 7 0 m^3 respectively. It resulted in 0.96 $tonCO_2e$, 0.90 $tonCO_2e$ and 0.61 $tonCO_2e$ of Carbon Footprints respectively (Table 4.6) . Normally, the children patient will come to QSNICH accompany with parent then, used a lot of water. However, QSNICH was developed policy and campaign to saving energy by installed saving water posture at information counter and every restroom, reduced water flow from tap equipment. The findings are consistent with the Carbon Footprint assessment from Her Majesty Cardiac Center at Siriraj Hospital, stating that water use resulted in Carbon Footprint of 7 tCO_2e per year (Rungtiwa Pongakrasila, 2015). The findings also are consistent with research from Thammasat University at Rangsit, stating that water use in Scope 3 emission resulted in a Carbon Footprint of 41.387 tCO_2e (Pirat AuSuparat et. al., 2014). Consistent with Carbon Footprint from Regional Health Promotion Center 9 Nakhon Ratchasima, wastewater treatment system was the source of 1.68% of Carbon Footprint in 2009, and 2.65% in 2011 (Somchai Chamchuklin et. al., n.d.).

Scope 2 emission boundary is defined as activities that cause indirect GHG emission

1. Electricity consumption by electrical equipment of the Orthopaedic Center was assessed by an electrical energy calculation, using the following formula:

$$\text{Energy consumption (kWh)} = \frac{\text{Power (W) x hours of work (h)}}{1{,}000}$$

Table 4.7 Electricity consumption of the Orthopaedic Department

Rank	Electrical Equipment	Electrical Energy (W)	Working Hours (h)	Electricity Consumption (kWh)
1	Office desktop computer #1	60	4	0.24
2	Office desktop computer #2	60	4	0.24
3	Office desktop computer #3	60	4	0.24
4	Diagnosis room 1 desktop computer for information input and X-ray viewing	60	4	0.24
5	Diagnosis room 2 desktop computer for data input and X-ray viewing	60	4	0.24
6	Desktop computer at the nurse station	60	4	0.24
7	Office printer	41	2	0.08

Table 4.7 Electricity consumption of the Orthopaedic Department (cont.)

Rank	Electrical Equipment	Electrical Energy (W)	Working Hours (h)	Electricity Consumption (kWh)
8	Printer at the nurse station - Prescription printing - Label printing	41	4	0.16
9	X-ray viewer in Diagnosis room 1			
10	X-ray viewer in Diagnosis room 2	84	4	0.34
11	X-ray viewer in Diagnosis room 3	-	-	-
12	X-ray viewer in Diagnosis room 4	-	-	-
13	Cast Cutter (3 minutes/patient with an average of 20 patients)	16.5	1	0.02
14	Boiler for making cast	1,200	4	4.8
15	Water boiler (30 minutes)	2,000	0.5	1
16	Electric Thermos (15 minutes)	670	0.25	0.17
17	Refrigerator	103	24	2.47
18	Laptop	65	3	0.19
19	Projector	814	3	2.44
20	Air conditioner	12,290	8	98.32
21	Light bulb	21	8	0.16

Table 4.7 Electricity consumption of the Orthopaedic Department (cont.)

Rank	Electrical Equipment	Electrical Energy (W)	Working Hours (h)	Electricity Consumption (kWh)
22	fluorescent tube light bulb	39	8	0.31
23	10 Wall-mounted fans (48Watts/fan)	480	4	1.92
24	5 fans (46Watts/fan)	230	4	0.92
25	fan	225	4	0.90
26	Television	50	4	0.20
27	Microwave	600	0.08	0.04
28	Electric frying pan	1,050	0.5	0.53
	Total			**116.34**

Table 4.8 Carbon Footprint of electricity consumption in the fiscal years 2013-2015

Electric Energy (kWh) (1)	Emission factor (2)	Carbon Footprint per Day (1 x 2)	Carbon Footprint per Year
116.34	0.5610 $kgCO_2e/kWh$	65.27 $kgCO_2e/kWh$	16,316.69 kgCO2e or 16.32 $tonCO_2e$

Note: 250 working days/year

Electricity consumption was calculated from total electricity consumption, as the Hospital did not install separate meters for each center. The researcher used a formula to calculate electric energy that the statistic of customers visited department on Monday to Friday was not regularly and effected to electricity consumption which including season changed also. It found that daily electricity consumption was 116.34 kWh (Table 4.7). Resulted in a daily Carbon Footprint of 65.27 $kgCO_2e/kWh$ and the researcher estimated Carbon Footprint of 16.32 tonCO_2 per year from 2013-2015 respectively (Table 4.8) . The department has been developed procedure to saving energy was closed every electrical equipment after used such as computer, printing, medicine on-line service, ex-ray by PAC system by setting energy save mode. By the way, another two equipment that used high electrical is air conditioner and light bulb were set by used fan to help air conditioner speed cooler and for light bulb was changed to T5 type instead after that electrical inspection teams will check all equipment after working time as well. The emission was consistent with the Carbon Footprint of Her Majesty Cardiac Center at Siriraj Hospital. Scope 2 emission emitted 74% (395 tCO_2e) of total emission per year, which was the highest level of GHG emission (Rungtiwa Pongakrasila, 2015). Furthermore, the emission level was also consistent with research from Thammasat University at Rangsit, stating that the electricity consumption resulted in the highest level of GHG emission. Despite being an indirect source of emission, electricity consumption released the highest amount of Carbon Footprint due to fuel consumption in the electricity production process. Therefore, the Carbon Footprint of electricity consumption was classified into six different categories: buildings, cafeterias, housings, sports stadiums, and hospitals. The comprehensive Carbon Footprint of Scope 2 emission was 31,271 kgCO_2e (Pirat Ausuparat et. al. 2014). Similarly, the high emission level is also consistent with Regional Health Promotion Center 9 Nakhonratchasima Carbon Footprint assessment. The activity that resulted in the highest emission in 2009 and 2011 was electricity consumption respectively 53.21% and 68.52% (Somchai Chamchuklin et. al., n.d.).

Scope 3 emission boundary is defined as activities that cause other indirect GHG emission. Activities included:

1. Fuel consumption from daily commute of 9 employees (Table 4.9).

Table 4.9 Employee fuel consumption (month)

Employee	Mode of Transportation	Fuel	
		Type	Liter
1	Personal transport	Gasoline	160
2	Public transport (bus)	NGV	NA
3	Public transport (BTS)	NGV	NA
4	Walking	-	0
5	Personal transport	Gasoline	120
6	Public transport (Bus)	NGV	NA
7	Public transport (motorcycle)	Gasoline	NA
8	Public transport	NGV	NA
9	Personal transport	Gasoline	40
	Total		**320**

Table 4.10 Carbon Footprint resulting from employee fuel consumption in the fiscal year 2013-2015

Fuel Amount (L) (1)	Emission factor (2)	Carbon Footprint per Month (1 x 2)	Carbon Footprint per Year
320	2.6 $kgCO_2e/L$	832 $kgCO_2e/L$	9,984 $kgCO_2e$ or 9.98 $tonCO_2e$

The amount of fuel needed for employee transportation, which was calculated by travel distance and fuel use per day and month. Total employee fuel consumption (benzine) amounted to 320 L. Most of the information was provided by the three employees with personal transports. The employee that walk did not contribute to carbon emission. The other five employees that utilized public transports were incapable of providing the amount of fuel use. Thus, total Carbon Footprint from fuel consumption between the fiscal years 2013-2015 amounted to 9.98 $tonCO_2e$ per year (Table 4.10). Limited of this activity was researcher only interviewed 1 day and calculated from normal working day in 1 year not included different season. The results were consistent with the Carbon Footprint assessment at Her Majesty Cardiac Center at **S**iriraj Hospital, stating that Scope 3 emission by fuel use, from 80% response rate, released the total Carbon Footprint of 98 tCO_2e. Furthermore, varying modes of transportation such as carpools, walking, biking, or even transportation to public transports should be taken into consideration. These modes of transportation could either reduce the company's Carbon Footprint to the bare minimum or eliminate carbon emission. Research found that 75% of employees at Her Majesty Cardiac Center at Siriraj Hospital used transports that resulted in minimum or no carbon emission, such as public buses, boats, motorcycle, walking, or car pool (Rungtiwa Pongakrasila, 2015).

2. Waste disposal (general, infectious, hazardous, and paper waste) was assessed from waste weights in the fiscal years 2013-2015, as displayed in Table 4.11.

Table 4.11 Amounts of waste in kilograms in the fiscal years 2013-2015

Waste	2013	2014	2015	Total
General waste	1,820	1,680	1,500	5,000
Infectious waste	235	220	185	640
Hazardous waste	155	140	125	420
Paper waste	54.6	7.8	28.6	91

Note: 1 ream of paper weighs 2.6 kg

Table 4.12 Carbon Footprint of waste in the fiscal years 2013-2015

Fiscal years	Waste type	Total (kg) (1)	Emission factor (2)	Carbon Footprint ($tonCO_2e$) (1 x 2)
2013	Normal	1,820	0.8421 $kgCO_2/kg$	1.53
	Infectious	235	6 $kgCH_4/Gg$ 41 gN_2O/ton	2.91
	Hazardous	155	6 $kgCH_4/Gg$ 41 gN_2O/ton	1.92
			Total	**6.36**
2014	Normal	1,680	0.8421 $kgCO_2/kg$	1.41
	Infectious	220	6 $kgCH_4/Gg$ 41 gN_2O/ton	2.72
	Hazardous	140	6 $kgCH_4/Gg$ 41 gN_2O/ton	1.73
			Total	**5.86**
2014	Normal	1,500	0.8421 $kgCO_2/kg$	1.27
	Infectious	185	6 $kgCH_4/Gg$ 41 gN_2O/ton	2.29
	Hazardous	125	6 $kgCH_4/Gg$ 41 gN_2O/ton	1.55
			Total	**5.11**
			Average per year	**5.78**

Note: Methane has potential to global warming ($kgCO_2e/kg$ GHG) was 25 $kgCO_2e$ and Nitrous oxide has potential to global warming ($kgCO_2e/kg$ GHG) was 298 kg CO_2e.

The four types of waste generated from the hospital services: general, infectious, hazardous, and paper waste. Respectively, the total waste from 2013 to 2015 amounted to 5,000 kg, 640 kg, 420 kg, and 91 kg respectively (Table 4.11).

Waste disposal protocol stipulated the Hospital to employ a commercial disposal company to dispose of waste by garbage truck every day and also collected waste from other department so, we cannot calculated Carbon Footprint from distance of transportation but general waste was transported to landfills, infectious waste was incinerated. The Carbon Footprint was 6.36 tonCO_2e, 5.86 tonCO_2e and 5.11 tonCO_2e respectively from 2013-2015 or average was 5.78 tonCO_2e per year (Table 4.12) in regards to paper, which is one of the main resources in the hospital service, if an appropriate recycling protocol was implemented, papers can be reused. The Carbon Footprint can be reduced by 0.13 tCO_2e. Following the hospital policy that promotes resource efficiency, the implementation of waste sorting system in the Center was used to lower costs. The 5Rs (Reuse, Reduce, Recycle, Reject, and Replace) was introduced to establish the practice of reusing papers, which ultimately reduces paper use. Furthermore, The Center staff aimed to use the entire page before printing and relay information electronically via E-mail. The practice was consistent with onsite infectious waste treatment by autoclave technology research at Chiangmai Ram Hospital. The Carbon Footprint emitted in 2011 from 58,000 kg of infectious waste subjected to treatment by autoclave technology or steam sterilization was 14.19 kgCO_2e per year. If the waste were incinerated off site, the GHG emission would become 50 times higher or 703.63 kgCO_2e yearly. In 2012, 64,646 kg of infectious waste was treated by the autoclave technology, generating GHG emission of 15.71 kgCO_2e. If the amount were incinerated off site at Nakhon Sawan Province, the process would have released 1,504.17 kgCO_2e of GHG emission, which was 145 times higher than the autoclave technology. In regards to Hatyai Hospital, 90,072 kg of infectious waste was generated in 2011. The subsequent treatment by the autoclave technology resulted in 21.89 kgCO_2e of GHG emission. If the waste were incinerated off site, the process would have generated 1,138.61 kgCO_2e of GHG emission, which was 52 times higher. In 2012, the Hatyai Hospital generated 117,890 kg of infectious waste. Treatment by the autoclave technology resulted in 28.65 kgCO_2e of GHG emission. If the amount were incinerated off site at Nakhon Sawan Province, the process would have released 1,590.27 kgCO_2e of GHG emission, which was 52 times higher than the autoclave technology (Sriarun Sukjaroen et. al., n.d.). Consistent with findings from Carbon Footprint assessment at Her Majesty Cardiac Center at Siriraj

Hospital, Scope 3 emission activities released a Carbon Footprint of 0.8 tCO_2e per year. The small emission amount was the outcome of the project Following the King's footstep in being green. The 7Rs efforts (Reduce, Reuse, Recycle, Repair, Reject, Return, and Rethink) were implemented to tackle a substantial amount of A4 paper use in the office and research center. Documents were mainly printed on reuse papers sent electronically via E-mails in substitution of paper if a printout was not necessary. In consideration of waste, since hospitals typically generate more waste, waste separation and recycling facilitated waste reduction (Rungtiwa Pongakrasila, 2015).

4.2 Greenhouse Gas emission assessment of the Orthopaedic services at the Queen Sirikit National Institute of Child Health (QSNICH) revealed that between the fiscal years 2013-2015, the Center released a total Carbon Footprint averaging 44.06 $tonCO_2e$ per year. The highest amount of emission resulted from Scope 2 emission activities, or electricity consumption, releasing 16.32 $tonCO_2e$ or 37.04% of Carbon Footprint. Scope 3 emission activities employee commute and waste disposals (general, infection, and hazardous waste) released 15.76 $tonCO_2e$ or 35.77% of Carbon Footprint. Scope 1 emission activities employee transportation, chemical use during surgical procedures and wastewater treatment emitted the lowest amount of GHG, releasing 11.98 $tonCO_2e$ or 27.19% of total Carbon Footprint (Table 4.13).

Table 4.13 Carbon Footprint of the Orthopaedic services per year

Scope	Activities	Carbon Footprint of Each Activity (tCo_2e)	Total Carbon Footprint	Percentage of Carbon Footprint
Scope 1	1.1 Hospital transports	1.72	11.98	27.19
	1.2 Chemicals used during surgical procedures	9.44		
	1.3 Wastewater treatment	0.82		
Scope 2	Electricity consumption	16.32	16.32	37.04
Scope 3	3.1 Employee commute	9.98	15.76	35.77
	3.2 General, infectious, and hazardous waste disposal	5.78		
Total			**44.06**	**100**

From data of the Orthopaedic services can assessed uncertainly of data found that uncertainly level and quality of data was 25 points that specify as low uncertainly and excellent quality of data as Table 4.14.

Table 4.14 Data quality level for GHG emissions calculation of Orthopaedic Department

List	Emission Factor (EF) ($kgCO_2e$/unit)	Reference sources of Emission Factor	Score level for Data collection	Score level for Emission Factors
Diesel	3.0 $kgCO_2e$/L	Department of Health	Record Form Y = 3 score	National level C = 2 score
			Score level = 1	
- Isoflurane -Sevoflurane	0.350 $MTCO_2e$/kg 1.526 $MTCO_2e$/kg	Department of Health	Record Form Y = 3 score	National level C = 2 score
			Score level = 6	
Wastewater treatment	0.18 kgCH4/kg BOD	Department of Health	Estimated value Z = 1 score	National level C = 2 score
			Score level = 2	
Electricity consumption	0.5610 $kgCO_2e$/kWh	Department of Health	Estimated value Z = 1 score	National level C = 2 score
			Score level = 2	
Gasoline	2.6 $kgCO_2e$/L	Department of Health	Estimated value Z = 1 score	National level C = 2 score
			Score level = 2	

Table 4.14 Data quality level for GHG emissions calculation of Orthopaedic Department (cont.)

List	Emission Factor (EF) ($kgCO_2e$/unit)	Reference sources of Emission Factor	Score level for Data collection	Score level for Emission Factors
General waste	0.8421 kgCO2/kg	Department of Health	Record Form Y = 3 score	National level C = 2 score
			Score level = 6	
Infectious waste and hazardous waste	6 $kgCH_4$/Gg 41 gN_2O/ton	Department of Health	Record Form Y = 3 score	National level C = 2 score
			Score level = 6	

4.3 The proposal of Carbon Footprint reduction guideline at the Orthopaedic services is designed based on previous GHG emission assessment. Scope 2 emission activity (electricity consumption) released the highest amount of Carbon Footprint. Respectively, Scope 3 and Scope 1 emission activities released lower amounts of Carbon Footprint. The emission assessment and insights from the in-depth interviews with nurses revealed the following service process:

1. The process of services provided to patients and resources and energy required in each stage.

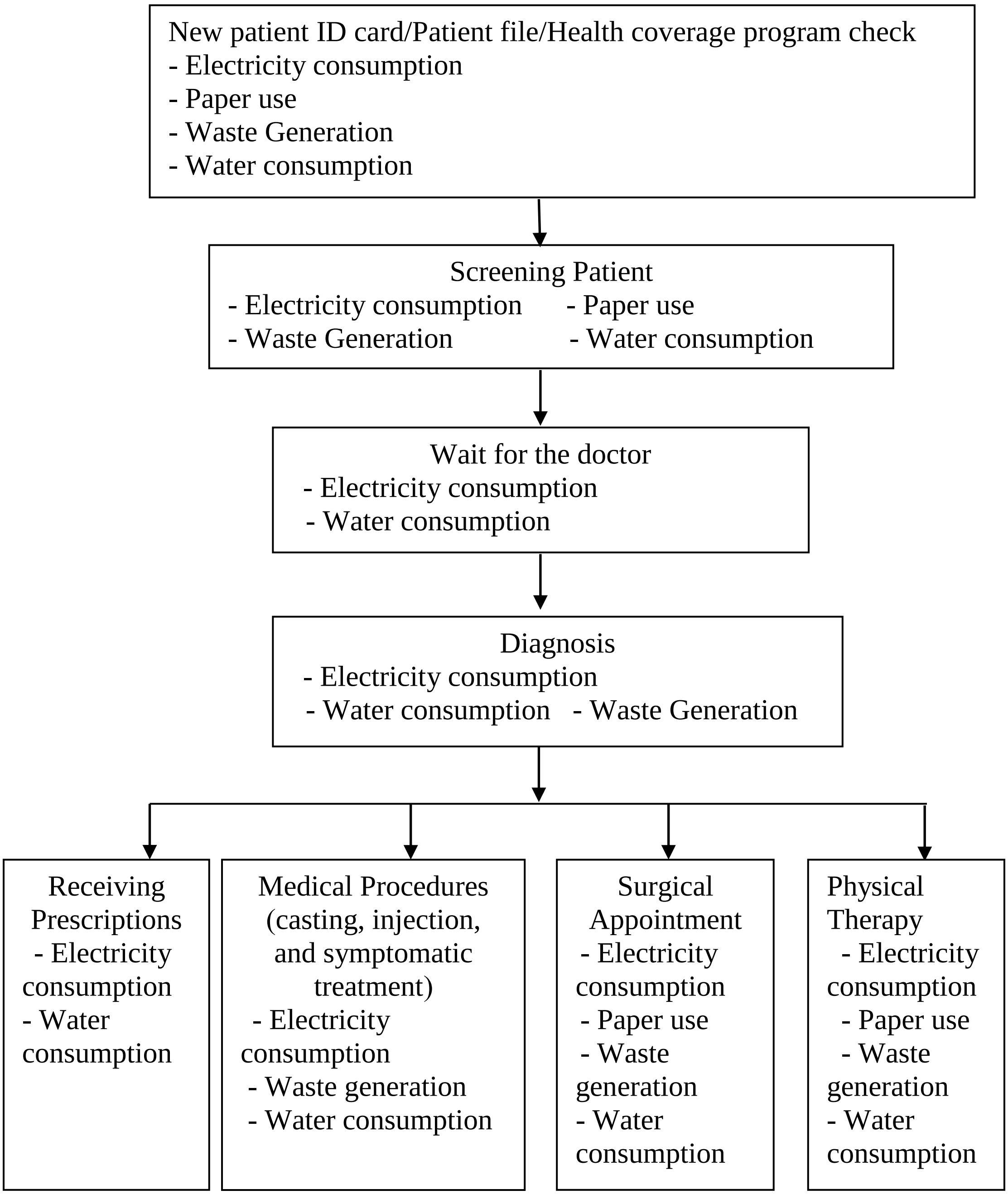

Figure 4.1 Service process of Orthopaedic

2. The processes that required the most resources/energy were the processes powered by electricity, which was all the processes. Electricity consumption was an important factor in providing medical care.

3. A process innovation that helps reduce resources or energy consumption in the service process was implemented at the QSNICH. This process

aimed to decrease paper use in all medical services by installing an online system to prescribe medicine and relay information electronically via E-mail. This protocol was implemented at the operational level, making it effective for paper use reduction in all the medical centers. The QSNICH received a Thailand Energy Reward for the protocol, which has the following guideline:

(1) Set a screensaver on all computers

(2) Control the temperature at a constant 25°C

(3) Change light bulbs to energy saving T5 or LED bulbs

(4) Unplug all electrical appliances when not in use

(5) Turn off lights and air conditioning during an hour lunch break

(6) Encourage staff to turn off air conditioning 30 minutes prior to the end of their shifts.

After brainstorming for GHG protocol, the attendees determined that the established protocol cultivated a suitable practice that employees are willing to adopt.

CHAPTER V
CONCLUSION, LIMITATION AND RECOMMENDATION

The conclusions and recommendations of the Carbon Footprint assessment at the Orthopaedic services at the Queen Sirikit National Institute of Child Health (QSNICH) between the fiscal years 2013-2015 are as followed:

5.1 Conclusion

5.1.1 The Carbon Footprint sources of the Orthopaedic services were categorized into 3 Scopes of activities that resulted in direct and indirect emissions. Scope 1 emission released a total Carbon Footprint of 11.98 tCO_2e. Fuel consumption from transporting patients, attending medical conferences, seminars, and workshops emitted 1.72 tCO_2e. Chemicals used in surgical procedures emitted 9.44 tCO_2e. Wastewater treatment, calculated from the water utility, emitted 0.82 tCO_2e. Scope 2 emission released a total Carbon Footprint of 16.32 tCO_2e from electricity consumption. Scope 3 emission released a total Carbon Footprint of 15.76 tCO_2e. Fuel consumption from employee commute emitted 9.98 tCO_2e. General, infectious, and hazardous waste disposal emitted 5.78 tCO_2e. The results revealed that activities that caused GHG emission in the Orthopaedic service processes emitted Carbon Footprints. The activities ranged from employee transportation to filing patient record, Screening Patient, Wait for the doctor, Diagnosis, and receiving prescriptions. All the resources or energy utilized in each activity emitted Carbon Footprints.

5.1.2 Carbon Footprint assessment of Orthopaedic services revealed that Scope 2 activity emitted the highest amount of Greenhouse Gasses 37.04%. Scope 3 activities emitted 35.77% of Greenhouse Gasses. Scope 1 activities emitted the least amount of Greenhouse Gasses 27.19 %.

5.1.3 Recommendation to reduce Carbon Footprint contains the following steps:

(1) Set a screensaver on all computers

(2) Control the temperature at a constant 25°C

(3) Replace light bulbs with energy saving T5 or LED bulbs

(4) Unplug all electrical appliances when not in use

(5) Turn off lights and air conditioning during an hour lunch break

(6) Encourage staff to turn off air conditioning 30 minutes prior to the end of their shifts

The Carbon Footprint protocol was fully instated and practiced at QSNICH to continuously minimize resources and energy use. The Center identified key personnel responsible for enforcing the policy to ensure proper maintenance of electrical equipment, as the maintenance assures its continued satisfactory performance and reduce energy use.

5.2 Limitations and Recommendations

The researcher had collected each activity data by averaging resource use in the Orthopaedic services, which caused imprecision in the assessment. A more detailed and comprehensive data collection method or innovative data filing technology can enhance the reliability of the assessment. Brainstorming for approaches to minimize Carbon Footprints yielded the following recommendation for subsequent studies:

1. A comprehensive template for filing specific data for each GHG emitting activity is recommended

2. Summaries of the Carbon Footprint of each carbon emitting activity in the Orthopaedic service processes should be included in annual reports.

3. A Carbon Footprint assessment should also be performed at other similar medical care providers to compare performances and further identify Carbon Footprint reduction protocol.

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APPENDICES

APPENDIX A
ELECTRIC CONSUMPTION RECORD FROM

แบบบันทึกการใช้พลังงานไฟฟ้าของหน่วยงานต่อวัน

ลำดับที่	อุปกรณ์เครื่องใช้ไฟฟ้าในหน่วยงาน	กำลังไฟฟ้า (W)	ชั่วโมงการทำงาน (h)	ปริมาณการใช้ไฟฟ้าต่อวัน (kWh/day)

APPENDIXB

FUEL OILS RECORD FROM

แบบสำรวจการใช้น้ำมันเชื้อเพลิงในการเดินทางมาทำงานของพนักงาน

การเดินทางไป-กลับ ของบุคลากรกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

Emission factor	2.60	ต่อลิตร	3.00	ต่อลิตร	0.24	ต่อลิตร	1.80	ต่อลิตร	2.60	ต่อลิตร	0.0631867	0.0631867	0.04675	0	0	เดินทางปกติ	กรณีพิเศษ	ทำงานปีละ
Employee	รถยนต์ (เบนซิน)		รถยนต์ (ดีเซล)		รถยนต์ (ก๊าซ NGV)		รถยนต์ (ก๊าซ LPG)		จักรยานยนต์		รถโดยสาร	รถไฟ	รถไฟฟ้า	เดิน	จักรยาน			
	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม.	กม.	กม.	กม.	วัน	วัน	250 วัน
1 (ไป)																		
1 (กลับ)																		
1 (กรณีพิเศษ)																		
2 (ไป)																		
2 (กลับ)																		
2 (กรณีพิเศษ)																		
3 (ไป)																		
3 (กลับ)																		
3 (กรณีพิเศษ)																		

แบบสำรวจการใช้น้ำมันเชื้อเพลิงในการเดินทางมาทำงานของพนักงาน (ต่อ)

การเดินทางไป-กลับ ของบุคลากรกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

Emission factor	2.60	ต่อลิตร	3.00	ต่อลิตร	0.24	ต่อลิตร	1.80	ต่อลิตร	2.60	ต่อ ลิตร	0.0631867	0.0631867	0.04675	0	0	เดินทาง ปกติ	กรณี พิเศษ	ทำงานปี ละ
Employee	รถยนต์ (เบนซิน)		รถยนต์ (ดีเซล)		รถยนต์ (ก๊าซ NGV)		รถยนต์ (ก๊าซ LPG)		จักรยานยนต์		รถโดยสาร	รถไฟ	รถไฟฟ้า	เดิน	จักรยาน			
	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม.	กม.	กม.	กม.	วัน	วัน	250 วัน
4 (ไป)																		
4 (กลับ)																		
4 (กรณีพิเศษ)																		
5 (ไป)																		
5 (กลับ)																		
5 (กรณีพิเศษ)																		
6 (ไป)																		
6 (กลับ)																		
6 (กรณีพิเศษ)																		
7 (ไป)																		
7 (กลับ)																		
7 (กรณีพิเศษ)																		

แบบสำรวจการใช้น้ำมันเชื้อเพลิงในการเดินทางมาทำงานของพนักงาน (ต่อ)

การเดินทางไป-กลับ ของบุคลากรกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

Emission factor	2.60	ต่อลิตร	3.00	ต่อลิตร	0.24	ต่อลิตร	1.80	ต่อลิตร	2.60	ต่อลิตร	0.0631867	0.0631867	0.04675	0	0	เดินทาง ปกติ	กรณี พิเศษ	ทำงาน ปีละ
Employee	รถยนต์ (เบนซิน)		รถยนต์ (ดีเซล)		รถยนต์ (ก๊าซ NGV)		รถยนต์ (ก๊าซ LPG)		จักรยานยนต์		รถโดยสาร	รถไฟ	รถไฟฟ้า	เดิน	จักรยาน			
	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม./ลิตร	กม.	กม.	กม.	กม.	กม.	วัน	วัน	250 วัน
8 (ไป)																		
8 (กลับ)																		
8 (กรณีพิเศษ)																		
9 (ไป)																		
9 (กลับ)																		
9 (กรณีพิเศษ)																		

หมายเหตุ : กรณีพิเศษ หมายถึง การเดินทางมาปฏิบัติในวันหยุด และวันหยุดราชการ

APPENDIX C
WASTE RECORD FORM

แบบบันทึกปริมาณมูลฝอยรวม (ทั่วไป ติดเชื้อ อันตราย) ต่อเดือน

ประเภท และปริมาณมูลฝอย

มูลฝอยทั่วไป…………………กิโลกรัม

การกำจัด ☐ เผา ☐ ฝังกลบ ☐ ทำปุ๋ย

มูลฝอยติดเชื้อ…………………กิโลกรัม

การกำจัด ☐เผา ☐ฝังกลบ ☐ทำปุ๋ย

มูลฝอยอันตราย…………………กิโลกรัม

การกำจัด ☐เผา ☐ฝังกลบ ☐ทำปุ๋ย

APPENDIX D
IN-DEPTH INTERVIEW FOR ASSESSMENT OF CARBON FOOTPRINT IN THE ORTHOPAEDIC DEPARTMENT, QUEEN SIRIKIT NATIONAL INSTITUTE OF CHILD HEALTH

สาขาเทคโนโลยีการจัดการสิ่งแวดล้อม (ภาคพิเศษ)
คณะสิ่งแวดล้อมและทรัพยากรศาสตร์มหาวิทยาลัยมหิดล

แบบสัมภาษณ์เชิงลึกเรื่อง การประเมินคาร์บอนฟุตพริ้นท์ในการให้บริการของกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

ขอทราบขั้นตอนและกระบวนการให้บริการของกลุ่มงานศัลยกรรมกระดูกและข้อ สถาบันสุขภาพเด็กแห่งชาติมหาราชินี

- ขั้นตอนการให้บริการผู้ป่วยที่เข้ามารับบริการของกลุ่มงาน

- ทรัพยากร/พลังงานที่ใช้ในแต่ละกระบวนการ

- กระบวนการที่ใช้ทรัพยากร/พลังงานสูงที่สุด

- ผลงาน/นวัตกรรมที่ช่วยลดการใช้ทรัพยากรหรือพลังงานในกระบวนการให้บริการ

BIOGRAPHY

NAME	Tunyaporn Sated
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