CARBON FOOTPRINT OF AN ACADEMIC ORGANIZATION: A CASE STUDY OF THE DEPARTMENT OF ENVIRONMENTAL ENGINEERING, CHULALONGKORN UNIVERSITY

รอยพิมพ์คาร์บอนขององค์กรการศึกษา: กรณีศึกษา ภาควิชาวิศวกรรมสิ่งแวดล้อม จุฬาลงกรณ์มหาวิทยาลัย

Boonjira Janangkakan[1,4], Orathai Chavalparit[1,2*] and Premrudee Kanchanapiya[3]

[1] National Center of Excellence for Environmental and Hazardous Waste Management, Chulalongkorn University, Bangkok 10330, Thailand

[2] Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand

[3] Excellent Center for Eco Product (XCEP), National Metal and Materials Technology Center, Pathumthani 12120, Thailand

[4] Environmental Management (International Program), Chulalongkorn University, Bangkok 10330, Thailand

บุญจิรา จนางคะกาญจน์[1], อรทัย ชวาลภาฤทธิ์[2*] และ เปรมฤดี กาญจนปิยะ[3]

[1] ศูนย์ความเป็นเลิศด้านการจัดการสิ่งแวดล้อมและของเสียอันตราย จุฬาลงกรณ์มหาวิทยาลัย กรุงเทพมหานคร 10330 ประเทศไทย

[2] ภาควิชาวิศวกรรมสิ่งแวดล้อม คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กรุงเทพมหานคร 10330 ประเทศไทย

[3] ศูนย์เทคโนโลยีโลหะและวัสดุแห่งชาติ ปทุมธานี 12120 ประเทศไทย

[4] หลักสูตรการจัดการสิ่งแวดล้อม (นานาชาติ) จุฬาลงกรณ์มหาวิทยาลัย กรุงเทพมหานคร 10330 ประเทศไทย

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Abstract

This paper presented the carbon footprint evaluation of an academic institution, direct and indirect greenhouse gas (GHG) emissions were calculated. The major sources of GHG emissions were classified into four main categories, which were energy use, materials use, transportation, and waste (wastewater treatment and solid waste disposal). The aim of this research was to evaluate the GHG emissions of the Department of Environmental Engineering, Chulalongkorn University and to develop alternative options for reduction of the GHG emissions using the Life Cycle Assessment Methodology as a key factor. The result showed that the total carbon footprint of the department based on year 2009 was 138.6 tCO_2e/yr and the average carbon footprint per person was 1.08 ton carbon (tC) (permanent staff=35). From the calculation, energy consumption was

* corresponding author

E-mail : orathai.c@chula.ac.th

Phone : +66-2218-6670

considered as the biggest source of CO_2 emission that generated 85.2 tCO_2e annually. It accounted for 61.5% of the overall GHG emissions. The second source emissions produced from transportation, waste and materials use were 43.3, 9.5 and 0.6 tCO_2e annually or 31.3%, 6.8% and 0.4%, respectively. The implementation option for the reduction of carbon footprint was energy conservation within building. The strategies included use of appliance with high energy efficiency such as air conditioning and lighting as well as turning off air conditioning, lighting lamps and lab equipment when they were not in use. For the waste and materials use, 3R (reduce, reuse, and recycle) is considered to be the powerful strategy that should be promoted to decrease the GHG emissions. This implementation strategy should be carried out along with establishment of incentive system in the organization. A campaign to create and raise awareness on GHG emission problems among the staff members and students was also needed for the organization to achieve sustainable reduction of GHG emissions. The possible GHG reduction option recommended to the department was to replace lamps in the department; T-5 lamps to replace the T-8 lamps. This option's goals would save money and energy through efficient lighting strategies. The option would have money back in a short time.

Keywords: carbon footprint, organizational footprint, GHG emissions, academic organization

บทคัดย่อ

บทความนี้นำเสนอการประเมินรอยพิมพ์คาร์บอนของสถาบันการศึกษา โดยการคำนวณการปล่อยแก๊สเรือนกระจกทั้งทางตรงและทางอ้อม แหล่งกำเนิดแก๊สเรือนกระจกแบ่งออกเป็น 4 หมวดหลัก ได้แก่ การใช้ไฟฟ้า การใช้วัสดุ การใช้เชื้อเพลิงในการเดินทาง การใช้วัสดุและการกำจัดของเสีย (การบำบัดน้ำเสียและการกำจัดขยะ) วัตถุประสงค์ของการศึกษาเพื่อประเมินการปล่อยแก๊สเรือนกระจกของภาควิชาวิศวกรรมสิ่งแวดล้อม จุฬาลงกรณ์มหาวิทยาลัย และเสนอแนะทางเลือกในการลดการปล่อยแก๊สเรือนกระจก โดยใช้การประเมินตลอดวัฏจักรชีวิต ซึ่งผลการศึกษาพบว่าปริมาณรอยพิมพ์คาร์บอนทั้งหมดที่ถูกปลดปล่อยจากภาควิชาในปี 2009 เท่ากับ 138.6 ตันคาร์บอนไดออกไซด์เทียบเท่าต่อปี และค่าเฉลี่ยของปริมาณรอยพิมพ์คาร์บอนต่อคน เท่ากับ 1.08 ตันคาร์บอนไดออกไซด์เทียบเท่า (บุคคลากร 35 คน) ซึ่งพบว่าการใช้พลังงานเป็นแหล่งกำเนิดที่ใหญ่ที่สุดของการปลดปล่อยแก๊สเรือนกระจก โดยคิดเป็น 85.2 ตันคาร์บอนไดออกไซด์เทียบเท่าต่อปี หรือเท่ากับร้อยละ 61.5 ของแก๊สเรือนกระจกที่ปล่อยออกมาทั้งหมด รองลงมา คือการขนส่ง การจัดการของเสีย และการใช้วัสดุ คิดเป็น 43.3, 9.5 และ 0.6 ตันคาร์บอนไดออกไซด์เทียบเท่าต่อปี หรือเท่ากับร้อยละ 31.3, 6.8 และ 0.4 ตามลำดับ มาตรการที่ได้ผลดีและยั่งยืนในการลดการปล่อยแก๊สเรือนกระจก คือการใช้หลักการอนุรักษ์พลังงานภายในอาคาร ซึ่งนอกจากจะสามารถลดค่าไฟฟ้า ยังลดการปลดปล่อยเรือนกระจกได้อย่างมีประสิทธิภาพ ได้แก่ การใช้สินค้าอุปกรณ์ที่เป็นมิตรกับสิ่งแวดล้อม เช่น เครื่องปรับอากาศ หลอดไฟ และอุปกรณ์วิจัยประหยัดพลังงาน การลดการใช้ไฟฟ้าโดย ปิดเครื่องปรับอากาศ หลอดไฟ และเครื่องมือทดลองของห้องปฏิบัติการทุกครั้งเมื่อไม่ใช้งาน การสร้างจิตสำนึกเพื่อส่งเสริมให้ทุกคนในองค์กรรวมทั้งนิสิต นักศึกษาตระหนักถึงปัญหาด้านผลกระทบจากแก๊สเรือนกระจก และช่วยกันลดการใช้พลังงาน และ ใช้หลักการ 3Rs (การลดการก่อขยะ, การนำกลับมาใช้ใหม่ในสภาพเดิม, การนำกลับมาใช้ใหม่โดยผ่านการแปรสภาพ) ภายในองค์การมากขึ้น นอกจากนี้ยังพบว่ามาตรการลดแก๊สเรือนกระจกที่มีประสิทธิภาพเหมาะสมกับภาควิชา คือ การเปลี่ยนหลอดไฟภายในอาคาร จากชนิด T-8 มาเป็น T-5 ซึ่งเป้าหมายของมาตราการนี้ช่วยประหยัดเงินละพลังงานผ่านกลยุทธ การใช้ไฟฟ้าอย่างมีประสิทธิภาพและคืนทุนภายในระยะเวลาสั้น

คำสำคัญ: รอยพิมพ์คาร์บอน, รอยพิมพ์คาร์บอนขององค์กร, การปล่อยแก๊สเรือนกระจก, สถาบันการศึกษา

Introduction

Global warming is regarded as a severe environmental problem facing the world over the past decades. In recent years, public concern about climate change has grown significantly. The majority of GHG emission such as carbon dioxide, methane and nitrous oxide is caused by human activities. The Intergovernmental Panel on Climate Change (IPCC) have indicated that the risk of GHGs severe climate change impacts will increase markedly with a temperature increase of 2°C above preindustrial levels; the current rate of global temperature increase is between 0.2 and 0.3 °C/decade[1]. However, there is a high degree of certainty that the global temperature increase will be limited to 2°C, CO_2 equivalent (CO_2e) concentrations will have to be stabilized at levels of 400 to 450 ppm CO_2e[2].

Energy consumption is a major contributor to the rising concentrations of GHGs in the earth's atmosphere[3],[4]. According to the report issued by IPCC, the largest growth in global GHG emissions in 2004 has come from energy supply (25.5%), industry (19.4%) and transport (13.1%), while residential and commercial buildings (7.9%) have been growing at a lower rate[5]. Therefore, the need for reduction in carbon dioxide emission from fossil fuel combustion related to heating, electricity generation and transport has become a matter of urgency[6]. It was estimated that, in 2004, 27,044 million tons of carbon dioxide were added to the atmosphere as a result of combustion of fossil fuels. Cities are estimated to account for about 75% of the global total GHG emissions due to their high concentrations of both population and economic activities and they have become the hot spots for energy demand and GHG emissions[7]. Bangkok alone accounts for much of the country's emissions of carbon dioxide estimated to be 61.23 million tons in 2007. Technically, the residents of Bangkok were responsible for producing 7.1 tons of carbon dioxide per capita per year in 2005. In addition, Thailand accounted for only about 1.0 percent, which is less than global carbon dioxide emissions per capita per year to 1.23 tons in 2007[8]. However, emissions of carbon dioxide in Thailand have shown an increasing trend in recent decades, rising from 1.6 tons per capita per year in 1990 to 4.3 tons per capita per year in 2004[9]

A carbon footprint is a total GHG emissions caused by an organization, event, product or person. It is an impact of human activities on the environment in terms of the amount of GHGs produced, measured in the unit of carbon dioxide equivalent[10]. It is a representation of the effect of human activities on the environment, and in particular climate change in terms of the total amount of GHG emissions caused directly and indirectly[11]. Carbon footprint is often used as an environmental performance indicator for products or production activities. It has become popular for estimating contribution to climate change[12]. It is made up of the sum of two parts.

The direct or primary footprint is a measure of the direct emissions of CO_2e from the burning of fossil fuels including domestic energy consumption and transportation (e.g. car and plane). The indirect or secondary footprint is a measure of the indirect CO_2e emissions from the whole lifecycle of products and services we use, including those associated with their manufacture and eventual breakdown[2].

A carbon footprint for organizations is a method to represent the total GHG emissions generated from an organization. It is useful for organizations to conceptualize their contribution to global warming. Universities and academic institutions are also potential sources of GHG emissions since there are a large number of people spending a long portion of the day with many activities. Even if the potential is small, the carbon footprint should be properly addressed by the staff.

The World Resources Institute (WRI) in collaboration with the World Business Council for Sustainable Development (WBCSD) established a set of standards that enable organizations to define the operational boundaries for their GHG accounting and reporting endeavors. Identification of operational boundaries helps institutions to scope their sources of emissions providing accountability for the prevention of 'double counting'. The WRI/WBCSD GHG Protocol defined three scopes as follows:

Scope 1: Direct emissions: These are all direct GHG emissions produced by facilities owned and controlled by the organization.

Scope 2: Energy indirect emissions from purchased electricity and steam: all GHG emissions associated with purchased electricity, heat or steam.

Scope 3: Other indirect emissions: all emissions from outsourced activities. Such emissions may have resulted from activities of community members in the institution but occurred at sources owned and controlled by another organization.

Many universities in USA audit carbon footprint and most of the research studies are abided by "A Corporate Accounting and Reporting Standard", which is a document prepared by the WRI/WBCSD. It provides guidelines for organizations that wish to report their carbon emissions. In 2007, the University of Pennsylvania and Purdue University reported a carbon footprint of 1.9 and 2.1 tC per person[13],[14], respectively. The Department of Mechanical Engineering reported the total annual carbon footprint that was 557 ± 53 tonCO_2e and 2.73 tC per person[15], which appeared significantly higher because they were assessed for a single academic department, rather than the entire university. The aim of this study was to adopt the measured carbon footprint as a key factor to develop alternative options for reduction of GHG emissions from an academic institution using the Department of Environmental Engineering,

Chulalongkorn University, as a case study. It involved the calculation of GHG emissions generated by the staff members and students from all activities of the department. Importantly, this research was also aimed to create awareness of people in the institution about the GHG emissions.

Materials and Methods

Step 1: Definition of organizational boundary

The organization may comprise one or more facilities, so the researcher has to define boundaries in the organization what any units are within calculation limits of this project. The organizational boundary can be defined as control approach and equity share approach. In this study, the organizational boundary of the Department of Environmental Engineering, was set up based on control approach in order for the department being able to responsible for their emissions and control the secondary consists of 2 buildings; ENG 21 (1^{st} -5^{th} floor) and ENG 26 (4^{th} floor).

Step 2: Definition of operational boundary

In this study, the sources of GHG emissions from all activities in the department in 2009 were separated into 3 scopes according to the GHGs protocol[16], ISO 14064[17] and Thailand Greenhouse Gas Management Organization (TGO) guideline[18]. For scope 1, only GHG emissions from the wastewater treatment operation was considered in this study. The other sources of GHG emissions were neglected due to lack of data for the fire extinguisher, fugitive emissions, and no chemicals used in the laboratories in FY 2009. The department did not own vehicles so fuel consumption for vehicles was neglected. No chemical fertilizer was used for gardening. For scope 2, calculating only energy consumption attributed to the purchased electricity by the department. For scope 3, although these indirect emissions are an optional scope, they were included in this study for completeness of this carbon footprint assessment. It was divided into transportation, material use, and solid waste. For transportation, daily commuting and research staff travel were taken into account. For material use, only consumable materials, e.g. paper and water use, were included because they were the main material regularly used in the department. The last part was solid waste disposal. The other sources in scope 3 were not covered in this study such as chemicals for cleaning used by service contractor and electricity and LPG used in cafeteria and shop leased by the organization. Each scope was analyzed and determined as shown in Table 1.

Table 1 GHG emission sources classified by scope and emission category

Scope	Emission category	Data collection method	Emission source	
			Location	Inventory source
Scope 1	Wastewater treatment operation	Laboratory analysis data	ENG 21 building	Wastewater treatment operation
Scope 2	Energy Use (Purchased Electricity)	Electricity Bills and Calculation	Office (2 buildings) - 1 administrative room - 21 office rooms	Air-Conditioner; Lighting System, Office Equipment
			Laboratory (2 buildings) - 9 laboratories	Air-Conditioner; Lighting system, Lab equipment
			Others (ENG 21 building) - 2 student rooms - 2 meeting rooms - 1 library - 10 restrooms - Hallway	Air-Conditioner; Lighting system, Fan
Scope 3	Materials Use	Material purchasing records and Interview	Office - ENG 21 building	Paper Water
			Laboratory - ENG 21 building	Water
	Waste Disposal	Measurement and Calculation	2 buildings	Solid waste
	Transportation	Questionnaire and Interview	Daily Commute	
			Research Travel - Air - Ground	

Step 3: Calculation of GHG emissions

This step will create a GHG inventory of the department, which will help to identify source activities and to select an appropriate emission factor. Calculation of the GHG emissions for the department was separated into energy use, transportation, material use, and waste from the activities of the department. A number of activities and selected emission factor are needed for calculation of GHG emissions as shown in following equation: Activity data - a factor that quantifies an activity used to calculate the emissions generated.

GHG emissions = Activity data x Emission factor

Emission factor - a factor that allowing GHG emissions to be estimated from a unit of available activity data

Step 4: Evaluation of the important sources of GHG emissions

GHG emission sources obtained from the inventory will be comparatively assessed for degree of GHG contribution. They can be classified into scope 1, scope 2, and scope 3 emissions. This assists setting up proposed measures for reduction of the carbon footprint.

Step 5: Development of carbon footprint reduction strategies

The measured carbon footprint is used as a key factor to develop alternative options for minimization of the environmental impacts from GHG emissions.

Result and Discussion

The result from GHG evaluation in 2009 from all activities can be concluded that total annual carbon footprint, which was the sum of contributions from 3 scopes, was found to be 138.6 tCO_2e as shown in Table 2. The result demonstrated that energy consumption was considered as the biggest source of GHG emissions, accounting for 85.2 tCO_2e/yr (61.5%). Furthermore, transportation was also an important emission source producing 43.3 tCO_2e/yr. GHG emissions from wastewater treatment operation, solid waste disposal and materials use were 6.3, 3.2 and 0.6 tCO_2e/yr accounting for 4.5%, 2.3% and 0.4% of the overall GHG emissions, respectively (Table 2). The carbon footprint per staff of the department was 1.08 tC per person. Comparison with universities in USA shows that carbon footprint of the Department of Environmental Engineering was lower. This may be due to the fact that the department does not have fuel combustion, which generates high amount of GHGs. Since Thailand is in a tropical area and the climate is generally hot, therefore no heater use in any building. In addition, the

laboratories are energy-intensive when compared with other non-laboratory buildings. The area of the department's laboratories is approximately 50% of the total building area. It is estimated that laboratories consumed between four and five times the energy of a typical commercial space per ft^2 [18]. Comparison with the average emission per capita per year in Thailand shows that the carbon footprint per person of the department is less than the average GHG emissions of 4.3 tons per capita per year in 2004, and also less than Bangkok per capita per year GHG emissions of 7.1 tCO_2e in 2005. The principal sources of GHG emissions in Bangkok were transportation (37.68 %) and electricity generation (33.37 %) in 2007[8].

Table 2 Carbon Footprint of the Department of Environmental Engineering, Chulalongkorn University in 2009

Scope description	Emission source	Activity data	Emission factor ($kgCO_2$/unit)	GHG emissions (tCO_2e /yr)	% footprint
Scope 1: Direct emissions	Wastewater treatment operation	527 kgBOD	0.48 x 25 = 12[a]	6.3	4.5
Scope 2: Energy Indirect emissions	Purchased electricity	151,955 kWh	0.5610[b]	85.2	61.5
Scope 3: Indirect emissions	Total indirect emission			47.1	34.0
	Transportation			43.3	31.3
	- Staff daily commuting	8,321 L	2.1896/2.7080[c]	14.8	10.7
	- Staff travel by airplane and car	197,000 km and 1,351 L	0.126[d] and 2.1896/2.7080[c]	28.5	20.6
	Solid waste	3,216 kg	1.0025[e]	3.2	2.3
	Materials use			0.6	0.4
	- Paper use	375 kg	0.7350[f]	0.3	0.2
	- Water use	10,533 m^3	0.0264[g]	0.3	0.2
	Total			**138.6**	**100**

Remark: Emission factor reference from [a]IPCC, 2006 Vol.6 [b]TGO guideline, 2011 [c]IPCC, 2007
[d]GHG protocol – mobile guide, 2009 [e]IPCC 2006, Smith et al. 2001 and EPA 2008
[f]SimaPro [g]Metropolitan Waterworks Authority(Thailand)

Carbon footprint classified by the scope

The key factor determining energy use and GHG emissions in the department is the function of the location, whether it is an office or a laboratory. The energy consumption in an office is from various electric equipment such as air conditioners, lighting, computers, notebooks, and copy machines. Research laboratories are also host to high energy use equipment such as autoclaves, furnaces, fume hoods, hot air ovens, Total Kjeldahl Nitrogen (TKN) analyzers, and pumps. However, such apparatuses are used intermittently. For scope 1, wastewater treatment was the only source of emission from operation anaerobic process which generated 6.3 tCO_2e/yr, 4.5% of overall GHG emissions of the department. For scope 2, largest contributor of GHGs of the department was from energy consumption in laboratories, offices, and other space, 85.2 tCO_2e/yr. GHG calculations revealed that air conditioners were electrical equipment that generated the largest amount of GHGs as shown in Figure 1. For scope 3, transportation was the second main source of GHG emissions from the department, 43.3 tCO_2e/yr. It was accounted for 31.3% of the overall GHG emissions. Also, transportation was the largest contributor in scope 3 (Figure 4)

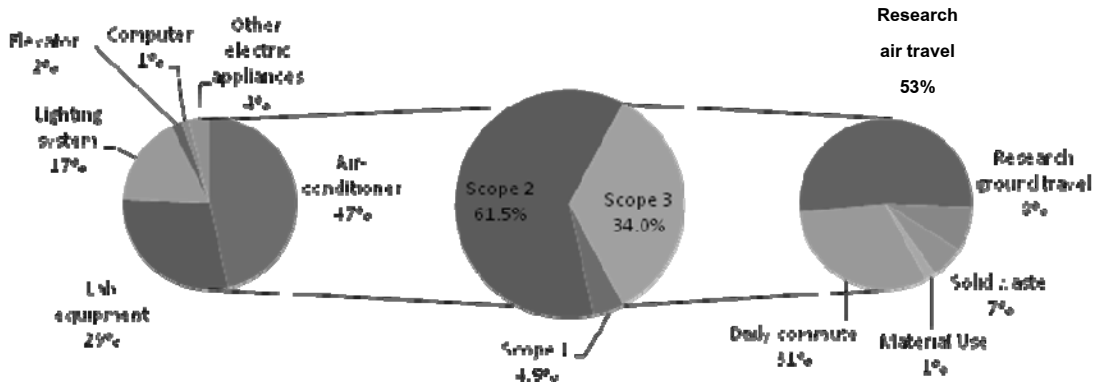

Figure 1 Proportion of the carbon footprint from each scope of the department

Carbon footprint reduction

It can be concluded that GHG emissions was mainly due to energy consumption of the department. As such, the proper and simple management strategy to reduce GHG emissions in the department should be energy conservation. The major electric energy consumption is air

conditioning system. In order to achieve a reduction in both energy consumption and GHG emissions, a comprehensive and integrated low carbon sustainability strategy is required. There are several measures that can help to achieve significant energy saving. The important strategy is to promote energy efficiency awareness among the staff members and students of the department.

Typically, energy conservation measures are quantified in terms of cost savings. However, it also reduces the amount of fossil fuels that are burned, resulting in a decrease in air pollutants that cause global warming[20].

The possible GHG reduction options, which will be recommended in this study are to replace lamps and air-conditioner of the Department of Environmental Engineering. Cost-effective of both options are as shown in Table 3.

Table 3 A summary of implementation of proposed GHG reduction options to the department

Option	Investment cost (baht)	Saving cost (baht/yr)	Payback period (yr)	Number of implementation units
- Replacement of T8 lamps with T5 lamps, 28 fluorescent lamps	117,530	39,292	3.0	511
- Replacement of the existing air-conditioner with Energy Label No.5	1,023,000	47,393	21.5	36

For transportation, air travel and daily commuting were regarded as the major carbon-intensive transportation mode. Therefore, reduction strategies are proposed in Table 4.

Finally, the measures to cope with a small proportion of GHG emissions from waste and materials use are 3R (reduce, reuse, and recycle) strategies. They should be implemented in all

activities to reduce GHG emissions. Energy conservation practices are proposed as listed in Table 4.

Table 4 Reduction strategy of carbon footprint in the major sources

Emission sources	Reduction strategies
Energy use	**Air-conditioner** - Set the temperature at 25°C and turn off when leaving the room. - Replace out of order air-conditioner with energy-efficient systems (e.g. label No.5), these measures can save up to 25% - 30% of electricity [21].
	Lighting system - Replace T8 fluorescent lamps with T5 fluorescent lamps and electronic ballasts. - Add reflective devices, de-lamping, and motion or daylight sensors.
Transportation	**Air travel** - Engage in proper trip planning and consider the length of the flight (because of a high percentage of fuel use and emission in take-off). - Reduce the organization's need for travel, or reduce the number of people joining each trip. - Engage in more virtual meetings (video teleconferences or the use of 3G technology).
	Daily commuting - Create incentives for employees to car pool or use other alternative methods for their commute, such as walking, cycling, and mass transit. - Allowing for lecturer to work at home 1 day per week

For the entire university, both short-and long-term carbon footprint reduction strategies should be set up. For the short-term, information campaigns and educational programs, which update and inform people on regular basis to encourage environmentally friendly habits. Seminars, posters, webpages, brochures, pamphlets and the like are helpful in raising awareness. For the long-term, such strategic plans include energy conservation within the buildings, sustainable construction of new buildings, use of renewable energy such as solar energy, biogas and adopting green purchase.

Conclusion

This study is to investigate the GHG emissions of an academic organization in Thailand. The Department of Environmental Engineering, Chulalongkorn University, was selected as a case study for evaluation and identification of major GHG emission sources.

The result showed that energy use contributes to the highest portion of GHGs accounted for 61.5% of the overall GHG emissions in the department, followed by transportation, waste, and materials use. The carbon footprint per capita of the department was

1.08 tC per person in 2009. Therefore, implementation of energy conservation measures is expected to cut down a substantial amount of energy consumption, which in turn mitigates the overall GHG emissions. Any incentive program to create and raise awareness of energy consumption among the people in the institution is also of importance. This study can be extended to conduct the carbon footprint for the entire university or other academic institutions. Carbon footprint database for an academic section will be informative for the government to develop a nationwide strategy for GHG emission reductions in long term.

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