CHAPTER IV
RESULTS AND DISCUSSION

4.1 Organizational Boundary

In this study, the Petroleum and Petrochemical College (PPC) and Office of the President, Chulalongkorn University (CU) were selected as a case study to evaluate the carbon footprint of organization and retated GHG measures to mitigate the impact were developed. All activities of the PPC were particularly focused in this research since the College offers mainly teaching and researching activities, e.g., lecturing and laboratory study. While the office of the president was selected due to the fact that the Office offers administration activities, e.g., office for work and meeting. The organization boundary of this study was set based on a control approach. In addition, the emissions from Scope 1 to 3 were discussed with alternative solution to reduce the CO_2 as function of each buildings.

4.1.1 The Petroleum and Petrochemical College

The PPC has 8 floors, which is located on the same building of Metallurgy and Materials Science Research Institute. The location of PPC's building is shown in Figure 4.1. The PPC academic program offers International Master's Degree Programs divided into three majors; Petroleum Technology, Petrochemical Technology and Polymer Science, and offers two degree program i.e., master's and doctoral. The PPC provides comprehensive educational and research opportunities in science and engineering, the principal focusing areas include transport phenomena, advanced chemical engineering calculations, advanced chemical engineering thermodynamics, chemical reaction engineering, natural gas processing, advanced fluid mechanics, petroleum refining technology, polymer synthesis, physical chemistry of polymer, polymer physics and polymer processing. All course instruction is in the English language jointly taught by professors from collaborating institutions and College faculty. In addition, a number of visiting professors from overseas and local industries are invited each year to teach elective courses.

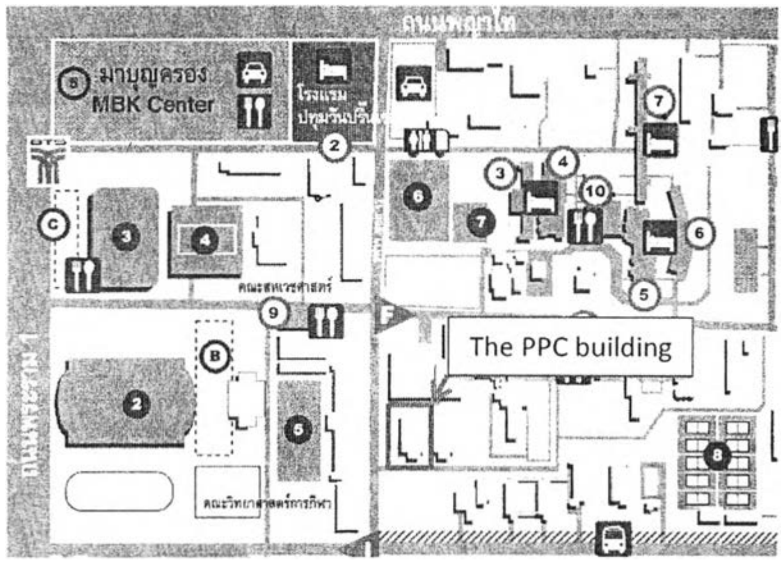

Figure 4.1 The Map presenting location of the PPC building.

The PPC built with a number of laboratories containing various bench-scale experimental systems and analytical instrument for educational and research purpose.

In 2014 the master's degrees student numbers were 179, 25 students studing for doctoral degrees and 65 members working as faculty and staff members (Table 4.1).

Table 4.1 The Petroleum and Petrochemical College' demographic in 2011-2014

Sector	**2011**	**2012**	**2013**	**2014**
Faculty	20	20	23	23
Staff	42	42	42	42
Students	104	106	102	84
Master' degree	89	100	99	80
Doctoral degree	15	6	3	4
Total	**166**	**168**	**167**	**149**

4.1.2 The Office of the President, Chulalongkorn University

Office of the President was selected as an administration function. It has one building with 7 floors, located near the main CU library building as shown in Figure 4.2.

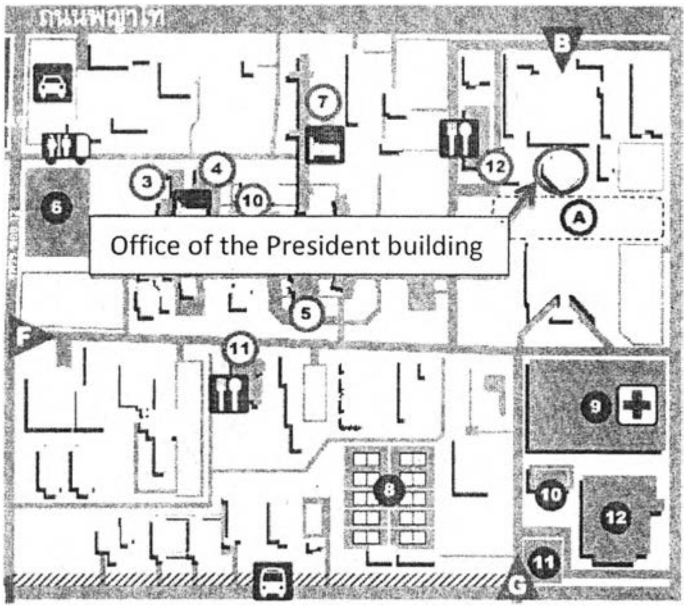

Figure 4.2 The Map presenting location of the Office of the President building.

The Office of the President consists of a variety of meeting rooms, with various scales for meeting and serving members and visitors. Moreover, the building has administrative offices supporting room for various administrative purposes. The Faculty and staff numbers were 42 in 2011-2014 as shown in Table 4.2.

Table 4.2 The Office of the President' demographic for 2011-2014

Sector	2011	2012	2013	2014
Staff	42	42	42	42
Total	**42**	**42**	**42**	**42**

4.2 Operational Boundary

4.2.1 The Operational Boundary of the PPC

The operational boundary of the PPC building was allocated to cover all activities that generated GHGs. The boundary is illustrated in Figure 4.3. All direct and indirect emissions from various activities are listed as shown in Figure 4.3 and were classified into three scopes based on the greenhouse gas protocol, ISO14069 and 14064 parts 1 and TGO guideline as shown in Table 4.3.

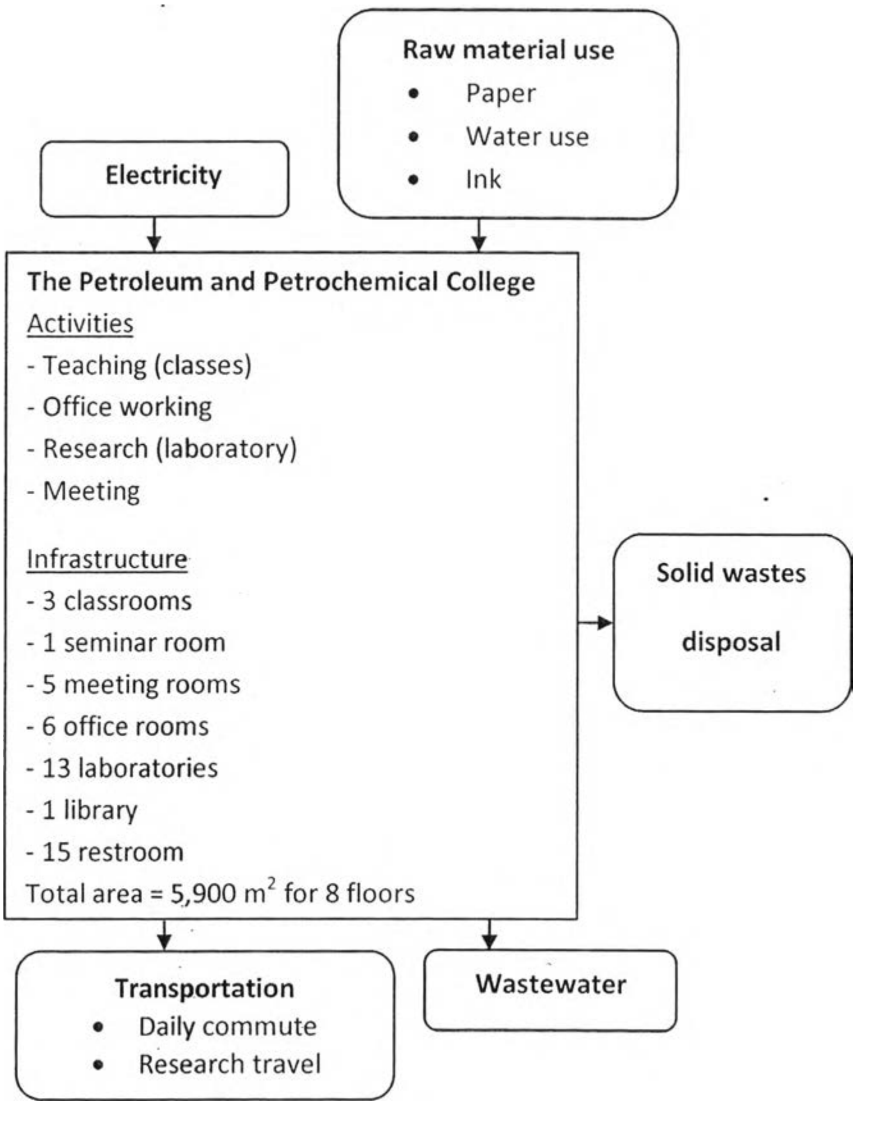

Figure 4.3 System boundary of the PPC.

Table 4.3 The PPC scope emission boundaries and source of data

Scope description	**GHG Protocol's Standard Boundaries (TGO, 2013)**	**Type of Data**	**Source**
Scope 1: Direct emissions	• Consumption of fuels from vehicles fleet • GHG's from wastewater operation	Primary data Secondary data	The mileage used record Estimated from tap water use
Scope 2: Energy indirect emissions	Purchased electricity	Primary data	collected from the CU website
Scope 3: Indirect emissions	• Staff commuting • Travel between the internal organization by owned vehicles • Use of chemical to clean • Use of tap water • Use of office equipment and consumable material • Waste disposal	Primary data Primary data Primary data Primary data Primary data Primary data	by questionnaire and recorded from the mileage Collected from service company Collected from the CU website Asking and recorded by my hand Count it by myself

For Scope 1, the GHG emissions from the own vehicles and the wastewater treatment were accounted in this study. The other sources of GHG emissions were neglect, i.e. the fire extinguisher emissions due to lack of data, while the chemicals used for research study in the laboratories, were neglect because it is not routine activity and the use of chemicals depending on individual research study. No chemical fertilizer was used for gardening due to a little area of garden.

For Scope 2, the GHG emission from consumption gathered from the purchased electricity by the College were accounted as indirect emission..

For Scope 3, even though the indirect emissions are an optional scope, they were considered in this work for fullness of this carbon footprint calculation. The sources of emission were divided into transportation, material use, and landfill waste. For the transportation, the daily commuting vehicles, and the staff and student travel for academic purpose, were taken into the account. For the materials use, only consumable materials, i.e., paper, ink and water use were accounted due to the fact that they are the main type of materials used regularly in the College.

4.2.2 Operational Boundary of the Office of the President

The operational boundary conditions of the Office of the President were covered all activities that generate GHGs. The system boundary is illustrated in Figure 4.4. Similar with the PPC activity, direct and indirect emissions were classified into three scopes based on the greenhouse gas protocol, ISO14064 parts 1 and 14069 and TGO guideline. The fact that Office of the President is the office for administration activity, therefore there is no emission related to student and research activities. The emissions are listed as shown in Table 4.4.

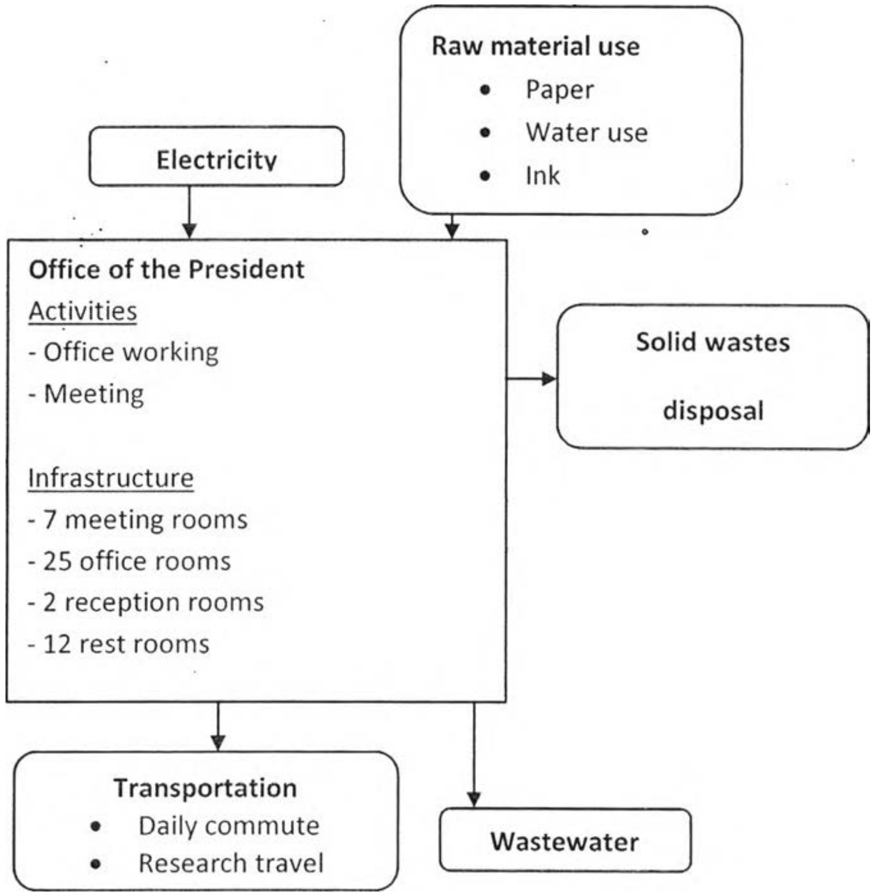

Figure 4.4 System boundary of the Office of the President.

Table 4.4 The Office of the President scope emission boundaries and source of data

Scope Description	GHG Protocol's Standard Boundaries (TGO, 2013)	Type of Data	Source
Scope 1: Direct emissions	• Consumption of fuels from vehicles fleet • GHG's from wastewater operation	Primary data Secondary data	The mileage used record Estimated from tap water use
Scope 2: Energy indirect emissions	Purchased electricity	Primary data	Collected from the CU website
Scope 3: Indirect emissions	• Staff commuting • Travel between the internal organization by owned vehicles • Use of chemical to clean • Use of tap water • Use of office equipment and consumable material • Waste disposal	Primary data Primary data Primary data Primary data Primary data Primary data	by questionnaire and recorded from the mileage Collected from service company Collected from the CU website Asking and recorded by myself It will be estimated by a No. of populations

For scope 1, the GHG emissions from the own vehicles and the wastewater treatment were considered in this study. The other sources of GHG emissions were neglect i.e. the fire extinguisher emissions due to lack of data. Moreover, no chemical fertilizer was used because of no garden area to maintain under this department.

For scope 2, the GHG emissions from only energy consumption attributed to the purchased electricity by the department.

For scope 3, others indirect emissions referred as optional scope were divided into transportation, material use, and landfill waste. For the transportation, the daily commuting vehicles and staff travel were taken into the account. For the material used, consumable materials, e.g. paper, ink and water use were accounted, the fact that they are the main type of materials used regularly in the department.

The GHG emission sources of this study are summarized as follows (Table 4.5):

1) Direct emission

- Vehicles fleet
- Wastewater
  - Wastewater treatment operation

2) Indirect emission (Energy)

- Purchased electricity

3) Other indirect emissions

1. Transportation
   - Research travel
   - Ground travel
2. Material use
   - Paper
   - Ink
   - Water use
3. Waste disposal
   - Solid waste

Table 4.5 GHG emission sources classify by scope and emission category

Scope	Emission Category	Source	
		Location	Equipment
Scope 1: Direct	Vehicles fleet		
	Wastewater	PPC building & Chamchuri 4 building	Calculate from water use
Scope 2: Energy indirect	Energy use (Purchased Electricity)	@ **PPC** Office: 6 office rooms Laboratory: 13 laboratories Others: 1 computer room 5 meeting rooms 1 library 15 restrooms	Air-Conditioner Lighting system Office equipment
		@ **Office of the President** Office: 25 office rooms Meeting room: 7 meeting rooms Others: 12 restrooms 2 stored rooms	Air-Conditioner Lighting system Office equipment
Scope 3: Other indirect	Material use	Office	Water , Paper and Ink
		Laboratory	Paper
	Waste Disposal	2 buildings	Solid waste
	Transportation	Daily Commute	Reported in the data based were questionnaire

4.3 Data Collection

4.3.1 Energy Use

Electricity consumption in the organization was collected from the electricity database of Chulalongkorn University (www.et.prm.chula.ac.th). The energy used in the PPC and the Office of the President, were collected from the electricity consumption of each the department in the fiscal years (FY) 2011-2013 (October 2011 – September 2013). The total energy consumption in the PPC and the Office of the President were 1,006,012 and 361,387 kWh per year, respectively as shown in Table 4.6 and 4.7, which are equal to 83,834 and 30,115 kWh per month, respectively. Figures 4.5 show the electricity consumption of the PPC from FY 2011 to 2013 and electricity consumption of the Office of the President from FY 2011 - 2013 are shown in Figure 4.6.

Table 4.6 Electricity purchased from PPC during FY 2011-2013

Month	**Energy consumption (kWh)**		
	2011	**2012**	**2013**
Oct	80,780	65596	84080
Nov	82,020	98340	104640
Dec	96,140	87891	79800
Jan	79,150	54349	87680
Feb	79,150	86160	80240
Mar	87,700	102780	79960
Apr	88,180	72280	93400
May	60,220	104100	82680
June	84,960	67560	76840
Jul	80,080	105720	72220
Aug	90,740	100300	92600
Sept	84,080	66360	79260
Total	**993,200**	**1011436**	**1013400**
Average	**1,006,012**		

Table 4.7 Electricity purchased from Office of the President FY 2011-2013

Month	Energy Consumption (kWh)		
	2011	2012	2013
Oct	31400	21000	30400
Nov	19800	20400	36400
Dec	32200	21400	40040
Jan	29600	31600	33400
Feb	13400	16200	39200
Mar	38800	38400	19600
Apr	16000	26800	35800
May	25600	21800	37600
June	41800	36222	39200
Jul	42000	29000	39200
Aug	42000	25400	15900
Sept	22400	26600	47600
Total	**355,000**	**314,822**	**414,340**
average	**361,387**		

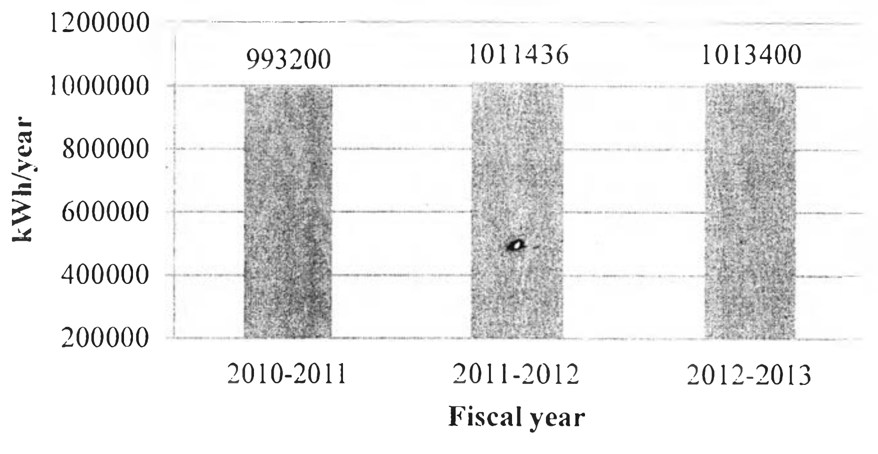

Figure 4.5 The PPC's electricity consumption during FY 2011 - 2013

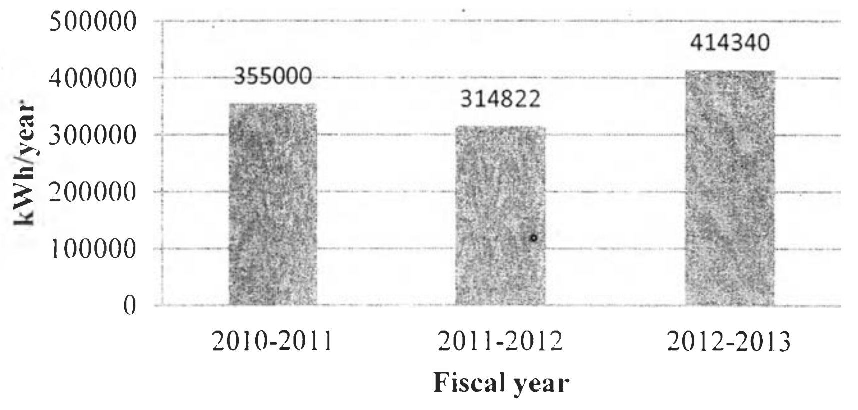

Figure 4.6 The Office of the president's electricity consumption during FY 2011 – 2013.

The purchase electricity information from FY 2011 to 2013 shows that the electricity consumption continued steady in each year due to the number of staff in this department has been constant over the period.

4.3.2 Transportation

The transportation in this study refers to vehicles fleet and daily commutes of the faculty and staff members (i.e., trips taken by faculty, staff or graduate student travel, paid by the PPC or themselves).

The GHG emissions from the vehicles fleet were calculated from the mileage of the College and the Office of the President cars, while the daily commuting were calculated from the faculty and staff commuting by private vehicles or public transportation. A number of kilometers driven by the staff and students were obtained by the survey questionnaire as shown in Figure 4.7. and 4.8.

ข้อมูลการเดินทาง

คำชี้แจง : โปรดทำเครื่องหมาย / ลงในช่อง ( ) หน้าข้อความตามความเป็นจริง

1. เพศ ( ) 1. ชาย ( ) 2. หญิง

2. อายุ

( ) 1. ต่ำกว่า 20 ปี ( ) 2. 20 – 30 ปี ( ) 3. 31 – 40 ปี

( ) 4. 41 – 50 ปี ( ) 5. 50 ปีขึ้นไป

3. ตำแหน่ง

( ) 1. อาจารย์

( ) 2. พนักงาน

( ) 3. นิสิตปริญญาเอก

( ) 4. นิสิตปริญญาโท

4. พาหนะในการเดินทางมาวิทยาลัย(ส่วนใหญ่)

( ) 1. BTS ( ) 2. Taxi ( ) 3. เดิน ( ) 4. มอเตอร์ไซค์รับจ้าง

( ) 5. รถโดยสารประจำทาง ( ) 6. รถส่วนตัว ( ) 7.อื่น ๆ โปรดระบุ............................

5. ข้อมูลรถส่วนตัว (สำหรับผู้ที่ใช้รถส่วนตัวในการเดินทางมาวิทยาลัย)

( ) 1. รถเก๋ง ( ) 2. รถกระบะ ( ) 3. รถจักรยานยนต์ ( ) 4. รถจักรยาน

6. ยี่ห้อและรุ่นรถ (สำหรับผู้ที่ใช้รถกระบะ, รถเก๋ง และรถจักรยานยนต์) โปรดระบุ

ยี่ห้อรถ......................................(เช่น Honda, Mazda, Yamaha เป็นต้น)

รุ่นรถ.. (เช่น Civic, Mazda3, Fino เป็นต้น)

7. เชื้อเพลิง (สำหรับผู้ที่ใช้รถส่วนตัวในการเดินทางมาวิทยาลัย)

( ) 1. แก๊ส LPG ( ) 2. แก๊ส NGV

( ) 3. น้ำมันดีเซล ( ) 4. น้ำมันแก๊สโซฮอล 91 ( ) 5. น้ำมันแก๊สโซฮอล 95

7. ระยะทางในการเดินทาง โปรดระบุ

เดินทางมาวิทยาลัยด้วยระยะทางประมาณ......................................กิโลเมตร

เดินทางมาจากเขต.....................................

Figure 4.7 The PPC's questionnaire form.

ข้อมูลการเดินทาง

คำชี้แจง : โปรดทำเครื่องหมาย / ลงในช่อง ( ) หน้าข้อความตามความเป็นจริง

1. เพศ ( ) 1. ชาย ( ) 2. หญิง

2. อายุ

( ) 1. ต่ำกว่า 20 ปี ( ) 2. 20 – 30 ปี ( ) 3. 31 – 40 ปี

( ) 4. 41 – 50 ปี ( ) 5. 50 ปีขึ้นไป

3. ตำแหน่ง

( ) 1. อาจารย์

( ) 2. พนักงาน

4. พาหนะในการเดินทางมาทำงาน

( ) 1. BTS ( ) 2. Taxi ( ) 3. เดิน ( ) 4. มอเตอร์ไซค์รับจ้าง

( ) 5. รถโดยสารประจำทาง ( ) 6. รถส่วนตัว ( ) 7.อื่น ๆ โปรดระบุ...........................

5. ข้อมูลรถส่วนตัว (สำหรับผู้ที่ใช้รถส่วนตัวในการเดินทางมาทำงาน)

( ) 1. รถเก๋ง ( ) 2. รถกระบะ ( ) 3. รถจักรยานยนต์ ( ) 4. รถจักรยาน

6. ยี่ห้อและรุ่นรถ (สำหรับผู้ที่ใช้รถกระบะ, รถเก๋ง และรถจักรยานยนต์) โปรดระบุ

ยี่ห้อรถ......................................(เช่น Honda, Mazda, Yamaha เป็นต้น)

รุ่นรถ... (เช่น Civic, Mazda3, Fino เป็นต้น)

7. เชื้อเพลิง (สำหรับผู้ที่ใช้รถส่วนตัวในการเดินทางมาทำงาน)

( ) 1. แก๊ส LPG ( ) 2. แก๊ส NGV

( ) 3. น้ำมันดีเซล ( ) 4. น้ำมันแก๊สโซฮอล์ 91 ( ) 5. น้ำมันแก๊สโซฮอล์ 95

7. ระยะทางในการเดินทาง โปรดระบุ

เดินทางมาทำงานด้วยระยะทางประมาณ.......................................กิโลเมตร

เดินทางมาจากเขต.....................................

Figure 4.8 The Office of the President's questionnaire form.

4.3.3 Material Use

Material used in this study are mainly consumable materials which are used and changed regularly such as paper, ink or toner and tab water.

4.3.3.1 Paper

The consumption of paper are varied depending organization activity. Offices generally use paper for report, internal memos, letters, faxes and photocopies. While academic activity class and research laboratories, papers are usually used for teaching, examination sheets and reports and documents. It is normally purchased by the organization in ream unit. The quantity of paper purchased each year was recorded by the administrative office as shown in Table 4.8 and Table 4.9.

Table 4.8 Quantity of the PPC's paper used in FY 2011- 2013

Fiscal Year	Quantity(reams)
2011	400
2012	600
2013	650

In the PPC, the purchased paper in FY 2013 was 650 reams, which is equal to 1,625 kg (1 ream = 2.5 kg by weight measured).

Table 4.9 Quantity of Office of the President's used paper in FY 2011- 2013

Fiscal Year	Quantity(reams)
2011	490
2012	500
2013	480

In Office of the President, the purchased paper in FY 2013 was 480 reams, which is equal to 1,200 kg.

The amount of paper consumption was calculated by the followed Equation (1)

Weight of paper (kg) = No. ream of paper x Weight of one ream

(1)

4.3.3.2 Water Use

Water use was collected from the water consumption database of Chulalongkorn University, retrieved from www. et.prm.chula.ac.th

The tap water use of the organizations in the fiscal year 2011-2013 (October 2011 – September 2013) showed that the total water consumption were about 12,046 m^3 and 8440 m^3 per year as shown in Table 4.10 and Table 4.11.

Table 4.10 Tap water used from the PPC

Month	**Quantity(m^3)**		
	2011	**2012**	**2013**
Jan	1,092	805	759
Feb	1,309	1,025	955
Mar	1,086	944	773
Apr	1,203	849	758
May	957	887	683
June	1,319	1,140	1,160
Jul	1,580	913	1,520
Aug	1,334	1,410	1,207
Sept	1,327	1,089	870
Oct	929	870	724
Nov	671	784	793
Dec	908	797	710
Sum	**13,715**	**11,513**	**10,912**
Average		**12,046**	

Table 4.11 Tap water used in the Office of the President

Month	**Quantity(m^3)**		
	2011	**2012**	**2013**
Jan	1,176	978	500
Feb	1,265	650	1,001
Mar	1,064	961	772
Apr	762	946	732
May	671	1,097	585
June	448	783	244
Jul	631	584	649
Aug	494	530	628
Sept	552	419	649
Oct	580	511	628
Nov	601	492	642
Dec	1,007	464	626
Sum	**9,251**	**8,415**	**7,656**
Average	**8,440**		

The tap water use of the 2 organizations in the fiscal year 2011-2013 (October 2011 – September 2013) are shown in Figure 4.9 and 4.10.

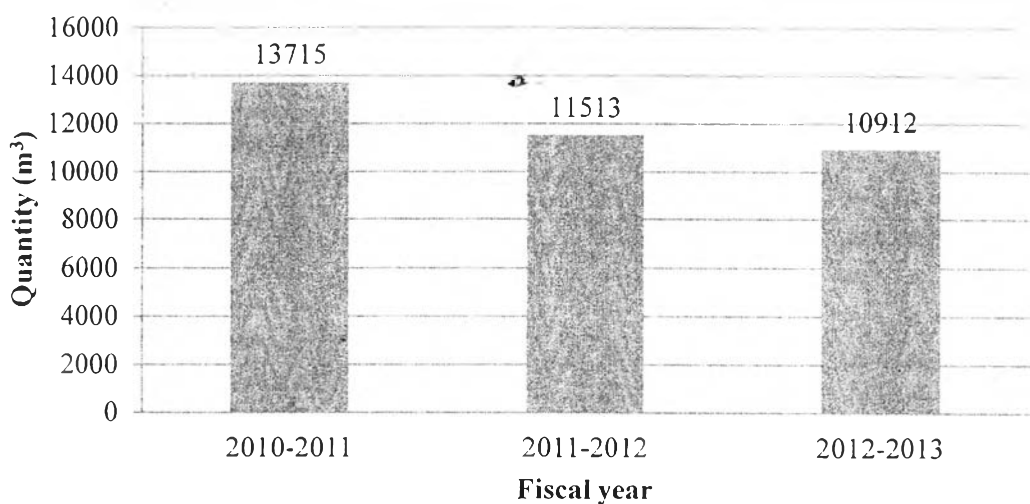

Figure 4.9 Tap water used in the PPC.

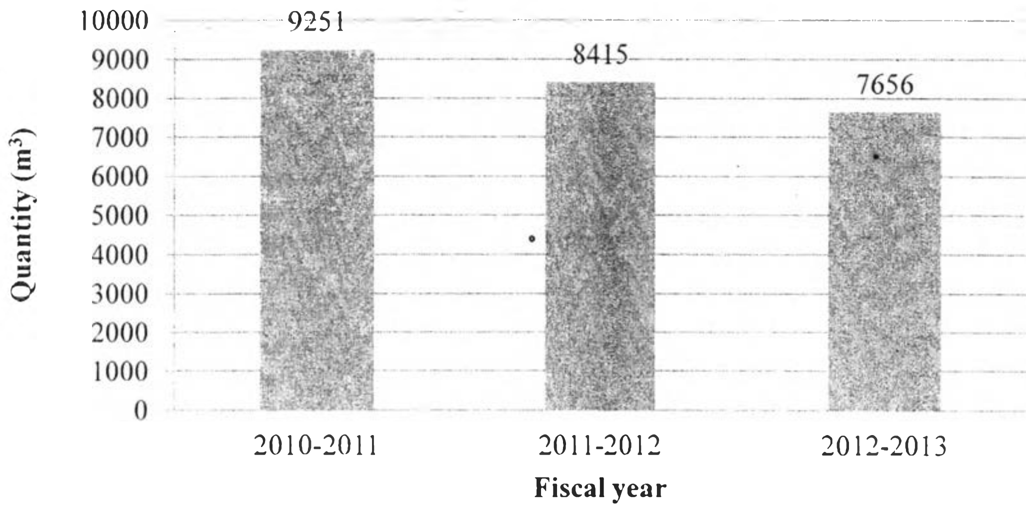

Figure 4.10 Tap water used in the Office of the President

4.3.4 Waste Disposal

4.3.4.1 Solid Waste

Amount of solid waste in this study was calculated by sum of all wastes discarded from the organizations. Solid waste from the department is typically sent to a landfill, resulting in the release of methane gas though the anaerobic decomposition of the organic waste materials. Methane is 25 times higher GHG than carbon dioxide. In this study, the amount of solid waste was estimated by quantity of solid wastes generated within 5 working days (Table 4.12 and 4.13) and calculated to be the average 1,260 kg/month and 21 kg/month for the Office of the President.

In this work, the quantity of solid waste was calculated based on 240 working days as given in the following Equation (2):

$$\text{Landfill waste (kg)} = \text{No. day (d)} \times \text{Landfill waste (kg/d)} \quad (2)$$

Table 4.12 The amount of solid waste generated within 5 working days of the PPC.

Day	**Quantity (kg/day)**
Monday	34
Tuesday	43
Wednesday	36
Thursday	54
Friday	41
Average	42

Table 4.13 The amount of solid waste generated within 5 working days of the Office of the President.

Day	**Quantity (kg/day)**
Monday	7
Tuesday	9
Wednesday	15
Thursday	6
Friday	5
Average	7

4.3.4.2 Wastewater

the amount of wastewater can be estimated from the amount of water consumption (the principle of Pollution Control Department) the following Equation (3):

$$\text{Quantity of wastewater} = \text{Quantity of freshwater} \times 80\,\% \quad (3)$$

The wastewater of the 2 organizations in the fiscal year 2011-2013 (October 2011 – September 2013) are shown in Figure 4.11 and 4.12

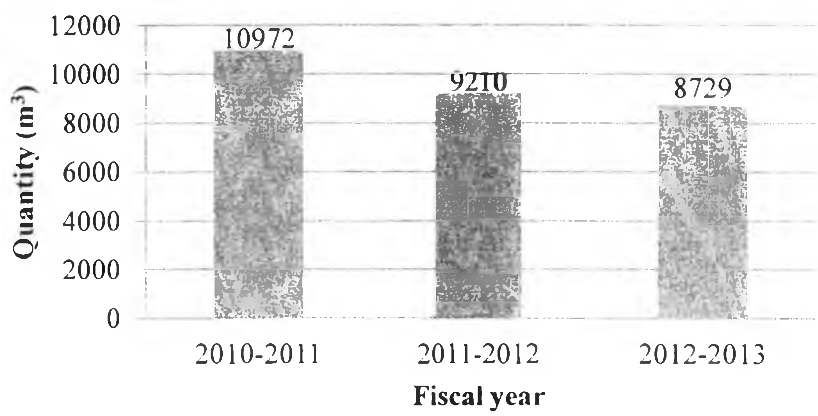

Figure 4.11 The PPC's waste water releasing from FY 2011 - FY 2013.

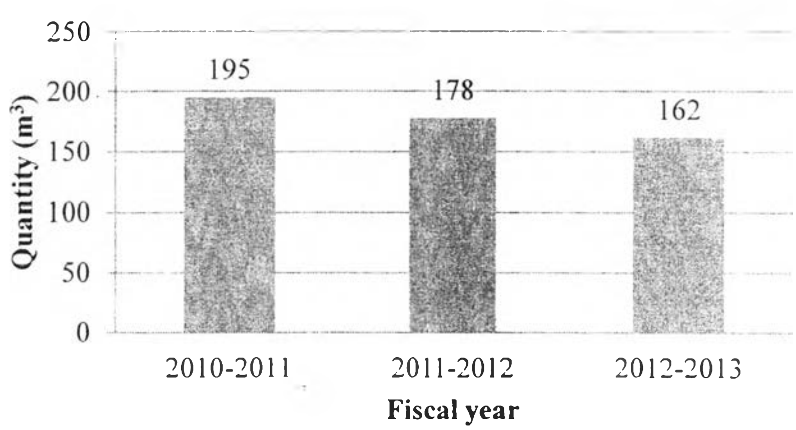

Figure 4.12 The Office of the President's waste water releasing from FY 2011 – FY 2013.

4.4 Result of GHG Emissions from the PPC Information

This study was to access the total emission of greenhouse gases (GHGs) from various activities in the organization. The GHG emissions can be calculated as the following Equation (4):

$$\text{GHG emission} = \text{Activity data} \times \text{Emission factor} \quad (4)$$

Where:

Activity Data = Activity data in units that will help to calculate the emissions generated (unit of activity)

Emissions Factor (EF) = Emission factor for each activity data to converts activity data to emission value ($kgCO_2$/unit of activity)

4.4.1 Carbon Footprint from Electricity Consumption

Emissions from the electricity consumption of the organization were calculated using emission factors of the power pool average in kilowatt hours. The GHG emissions related with electricity generation were calculated according to the following Equation (4) (TGO, 2011):

$$\text{GHG emissions } (kgCO_2e/y) = \text{Electricity } (kWh/y) \times EF \ (kgCO_2e/kWh) \quad (4)$$

Where:

GHG emission = GHGs production due to electricity demands ($kgCO_2e$)

Electricity = Electricity consumption (kWh)

EF = GHG emission factor of fuel for producing electricity ($kgCO_2e/kWh$)

Electricity was gathered for all electricity equipment in offices rooms, classrooms, meeting rooms and others (restrooms, laboratories and computer room). So that calculation the GHG emissions of electricity consumption within this organization. it is important to know the organization's total electricity consumption. Data of electricity consumption data of the PPC and Office of the President from FY 2011-2013 are shown in Table 4.14 and Table 4.15, Figure 4.13 and Figure 4.14.

Table 4.14 GHG emissions from purchased electricity by the PPC in FY 2011-2013

Month	Energy Consumption (kWh)			GHG Emissions (kgCO_2e)		
	2011	**2012**	**2013**	**2011**	**2012**	**2013**
Oct	80,780	65,596	84,080	46,957	38,131	48,876
Nov	82,020	98,340	104,640	47,678	57,165	60,827
Dec	96,140	87,891	79,800	55,886	51,091	46,388
Jan	79,150	54,349	87,680	46,010	31,593	50,968
Feb	79,150	86,160	80,240	46,010	50,085	46,644
Mar	87,700	102,780	79,960	50,980	59,746	46,481
Apr	88,180	72,280	93,400	51,259	42,016	54,293
May	60,220	104,100	82,680	35,006	60,513	48,062
June	84,960	67,560	76,840	49,387	39,273	44,667
Jul	80,080	105,720	72,220	46,551	61,455	41,981
Aug	90,740	100,300	92,600	52,747	58,304	53,828
Sept	84,080	66,360	79,260	48,876	38,575	46,074
Total	993,200	1,011,436	1,013,400	577,347	587,948	589,089

Table 4.15 GHG emissions from purchased electricity by the Office of the President in FY 2011- 2013

Month	Energy Consumption (kWh)			GHG Emissions (kgCO_2e)		
	2011	**2012**	**2013**	**2011**	**2012**	**2013**
Oct	31,400	21,000	30,400	18,253	12,207	17,672
Nov	19,800	20,400	36,400	11,510	11,859	21,159
Dec	32,200	21,400	40,040	18,718	12,440	23,275
Jan	29,600	31,600	33,400	17,206	18,369	19,415
Feb	13,400	16,200	39,200	7,789	9,417	22,787
Mar	38,800	38,400	19,600	22,554	22,322	11,393
Apr	16,000	26,800	35,800	9,301	15,579	20,811
May	25,600	21,800	37,600	14,881	12,672	21,857
June	41,800	36,222	39,200	24,298	21,056	22,787
Jul	42,000	29,000	39,200	24,415	16,858	22,787
Aug	42,000	25,400	15,900	24,415	14,765	9,243
Sept	22,400	26,600	47,600	13,021	15,463	27,670
Total	355,000	314,822	414,340	206,362	183,006	240,856

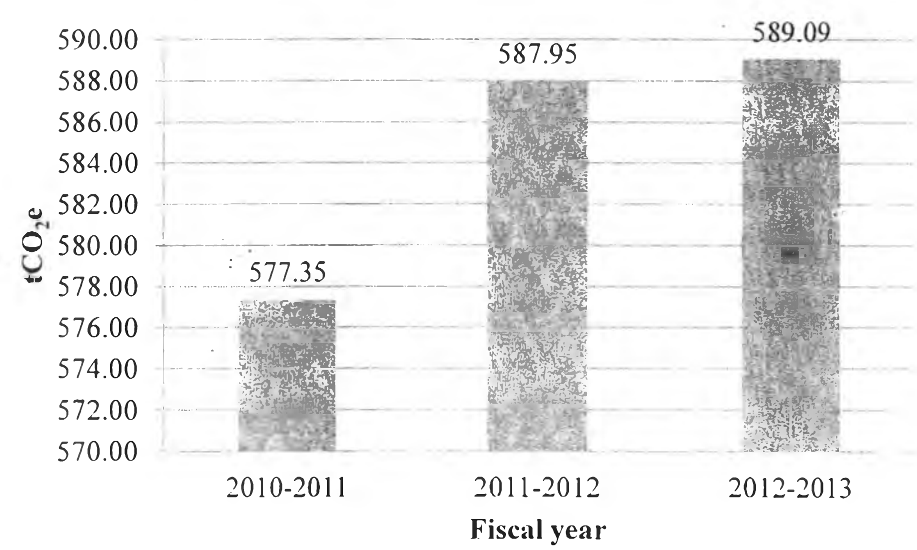

Figure 4.13 GHG emissions from purchased electricity by the PPC in FY 2011 – 2013.

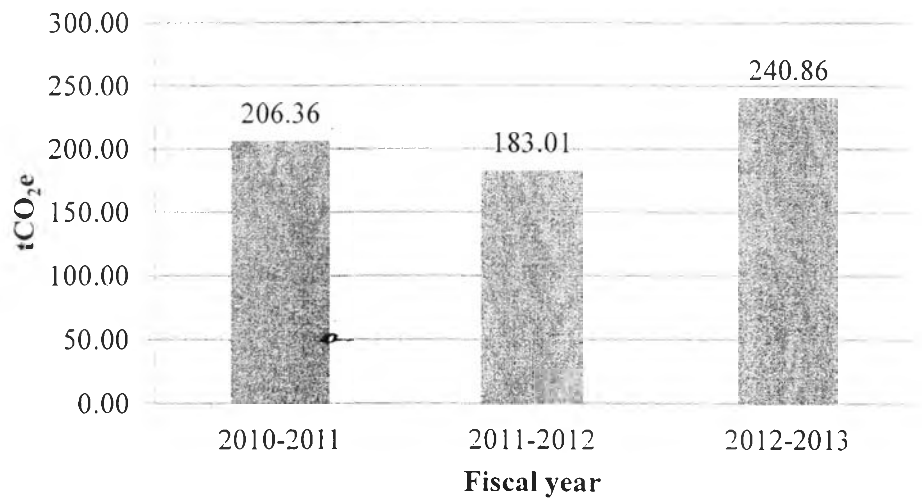

Figure 4.14 GHG emissions from purchase electricity of the Office of the President in FY 2011 – 2013.

4.4.1.1 GHG Emissions Classified by Various Electrical Equipment

In the PPC, the total energy can be estimated from energy consumption of each appliances in the department. The type of equipment can be classified into 3 main types; air-conditioners, lighting system and other electric appliances. The result showed that the department released 589.09 tCO_2e emissions from energy consumption in 2013. It was estimated that around 78 % of these emissions resulted from energy consumption by air-conditioning system, 8 % by the lighting system and 14 % from other electric appliances (e.g., laboratory instruments, offices equipment and elevator) as shown in Table 4.16 and Figure 4.15.

Table 4.16 GHG emissions from electrical equipment by the PPC in 2013

Electrical Equipment	Annual Energy Consumption (kWh/year)	GHG Emissions (tCO_2e)	Percent of the Footprint (%)
Air-conditioner	788,679	458.46	78
Other electric appliances	138,920.04	80.75	14
Lighting system	85,800.96	49.88	8

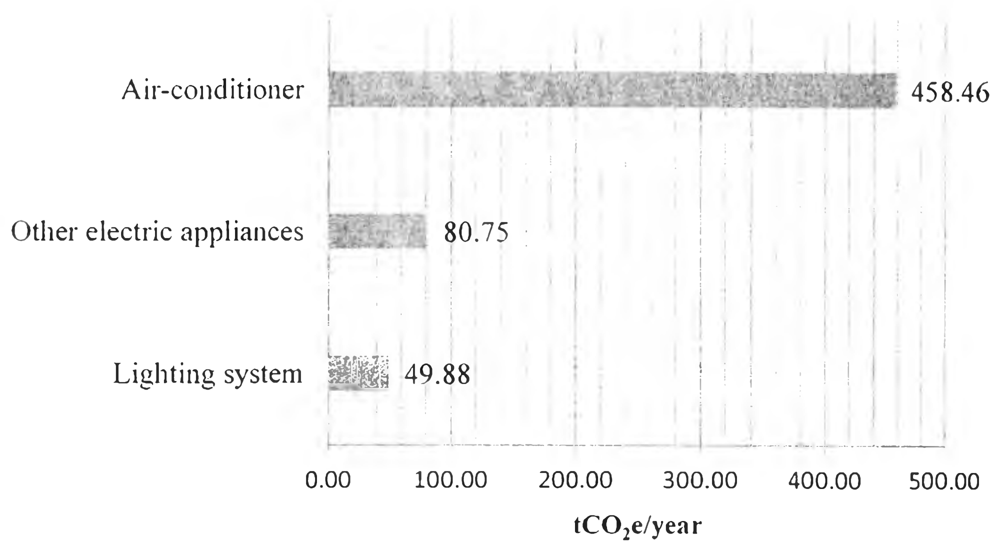

Figure 4.15 Proportion of GHG emissions from electrical equipment.

In Office of the President, the type of equipment can be classified into 3 main types of the equipment similar to those from the PPC, which are air-conditioners, lighting systems and other electric appliances. The result showed that the department annually released 240.86 tCO_2e emissions in 2013. It was estimated that around 63 % of these emissions resulted from energy consumption by air-conditioning system, 9 % by the lighting system and 28 % from other electric appliances (e.g., laboratory instruments, offices equipment and elevator) as shown in Table 4.17 and Figure 4.16.

Table 4.17 GHG emissions from electrical equipment by Office of the President in 2013

Electrical Equipment	Annual Energy Consumption (kWh/year)	GHG Emissions (tCO_2e)	Percent of the Footprint (%)
Air-conditioner	259,171.54	151.74	63
Other electric appliances	116,468.94	67.44	28
Lighting system	38,699.52	22.50	9

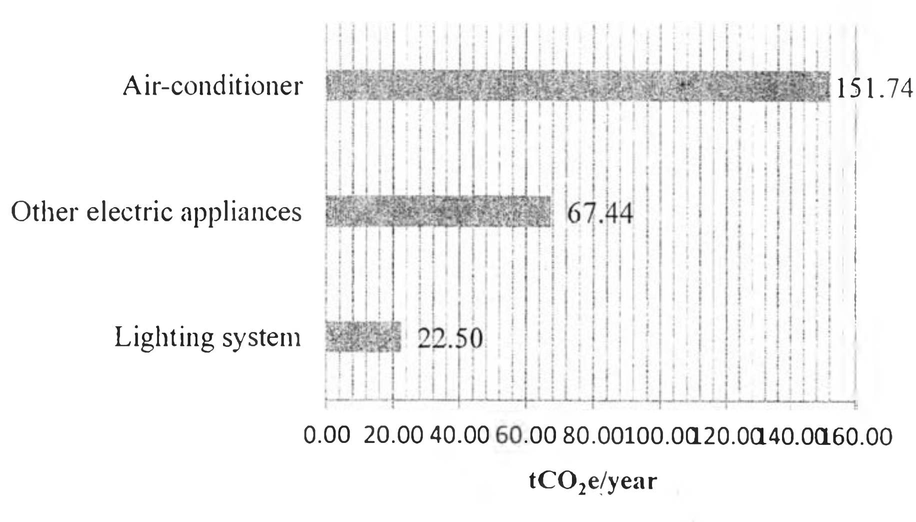

Figure 4.16 Proportion of GHG emissions from electrical equipment.

4.4.1.2 GHG Emissions from Electricity Consumption per Area.

The PPC contains 6 office rooms, 13 laboratories, and others such as meeting rooms, restrooms and etc. The College has 8 floors and the floor area is 700 m^2/floor for 1st and 2nd floor and for the 3th to 8th floor has 750 m^2/floor. The GHG emissions per area of each floor were calculated based on energy consumption in FY 2013 as shown in Table 4.18.

Table 4.18 GHG emissions/area from each floor

Floors	Floor Function	Population (person)	Area (m^2)	Annual Energy Consumption (kWh)	GHG Emissions ($kgCO_2e$)	GHG Emissions/Area ($kgCO_2e/m^2$)
1	Laboratory	7	700	3,607	2,096	3.00
2	Office	41	700	4,687	2,724	3.89
3	Classroom	89	750	3,217	1,869	2.49
4	Laboratory	15	750	23,860	13,869	18.49
5	Laboratory	19	750	9,393	5,460	7.28
6	Laboratory	18	750	16,290	9,469	12.63
7	Laboratory	16	750	19,470	11,318	15.09
8	Library	15	750	3,927	2,282	3.04

The Office of the President has 7 floors with the total area of 4259 m^2. Moreover, It has 3 main office rooms, 8 meeting rooms and others such as reception rooms.. The GHG emissions from electrical consumption based on data from per area, from FY 2013 are shown in Table 4.19.

Table 4.19 GHG emissions/area from each floor

Floors	Floor Function	Population (person)	Area (m^2)	Annual Energy Consumption (kWh)	GHG Emissions ($kgCO_2e$)	GHG Emissions/ Area ($kgCO_2e/m^2$)
1	Recreational area	Empty	608	13,740	7,987	13.13
2	Meeting room	75	608	69,057	40,143	65.97
3-7	Office	40	3,042	331,543	192,726	63.35

4.4.2 Carbon Footprint from Materials Use

In this study, the materials accounted in Scope 3 are paper and water use. These materials are dominant material used in the organization.

As a result, paper and water uses in the PPC emitted 4,761 and 288 $kgCO_2e$, respectively. The total emissions were 5,049 $kgCO_2e$ as shown in Table 4.20.

Table 4.20 The PPC's GHG emissions by material use in 2013

Material	Quantity (Unit/year)	GHG Emission Factor (kCO_2e/unit of material)	Emissions ($kgCO_2e$)
Paper	1,625 kg	2.93	4,761
Water use	10,912 m^3	0.0264	288
Total			5,049

As a result, paper and water use in Office of the President emitted 3,516 and 202 kgCO_2e, respectively. The total emissions were 3,718.12 kgCO_2e as shown in Table 4.21.

Table 4.21 The Office of the President's GHG emissions by material use in 2013

Material	**Quantity (Unit/year)**	**GHG Emission Factor (kCO_2e/unit of material)**	**Emissions (kgCO_2e)**
Paper	1,200 kg	2.93	3,516
Water use	7,656 m^3	0.0264	202
Total			3,718

4.4.3 Carbon Footprint from Waste

4.4.3.1 Waste Water

Wastewater is generated from staff and student activities. The GHGs emissions of organic degradation from an aerobic wastewater treatment unit (not well managed) was considered in this study.

The amount of wastewater can be estimated from the 80% of raw water consumption (the principle of Pollution Control Department). The GHG emissions from the wastewater treatment (WWT) were calculated from operation and effluent. Since methane released WWT system to the atmosphere without capturing, the methane emission from the aerobic operation in this study was included in the calculation. Table 4.22 the BOD loading as design criteria for building and the BOD effluent (the Pollution Control Department).

Table 4.22 BOD concentration in the domestic (Pollution Control Department)

Wastewater treatment plant in domestic	BOD (mg/l)
Before treatment	200
After treatment	50

The GHG emissions from aerobic wastewater treatment is calculated based on BOD removal and CH_4 emissions as given:

(1) Organic constituent in wastewater is calculated in terms of BOD loadings by the following Equation (5)

$$\text{BOD loading}_{removal} = \text{BOD loading}_{input} - \text{BOD loading}_{output} \quad (5)$$

Where;

BOD loading $_{input}$ (kgBOD/year) = Wastewater (m^3) x BOD in effluent (mg/l) x 0.001

BOD loading $_{output}$ (kgBOD/year) = Wastewater (m^3) x BOD before treatment (mg/l) x 0.001

BOD remove by treatment unit = A-B

(2) CH_4 emission factor

CH_4 emission factor for each domestic wastewater treatment/discharge pathway or system is calculated by the following Equation (6) (IPCC, 2006):

$$EF_j = B_0 \times MCF_j \quad (6)$$

Where;

EF_j = emission factor, kg CH_4/kg BOD

j = each treatment/discharge pathway or system

B_0 = maximum CH_4 producing capacity, $kgCH_4/kgBOD$

MCF_j = methane correction factor (fraction)

Table 4.23 Data requirement for calculating emission factor of wastewater (IPCC, 2006)

Wastewater		
Parameters	**Values**	**Unit**
B	0.6	$kgCH_4/kgBOD$
MCF	0.3	-
EF	0.18	$kgCH_4/kgBOD$

(3) Total CH_4 emission from wastewater is calculated as the following Equation (7) (IPCC, 2006):

$$CH_4 \text{ Emissions } (kgCH_4/y) = EF \times \text{Total organics in wastewater}$$
$$\text{GHG Emissions } (kgCO_2/y) = CH_4 \text{ Emissions} \times GWP \quad (7)$$

*GWP of CH_4 = 25 (IPCC, 2007)

Result from the calculation of GHG emissions from the PPC's wastewater treatment plant was found that 235.62 $kgCO_2e$/year as shown in Table 4.24

Table 4.24 Calculation of BOD removal and GHG emissions from the PPC

Type of waste	BOD input (mg/l)	BOD output (mg/l)	Wastewater (m^3/y)	BOD Remove (kgBOD/y)	Emission Factor ($kgCO_2e$/kgBOD)	GHG Emissions ($kgCO_2e$/y)
Waste water	200	50	8,729	1,309	0.18	235.62

Result from the calculation of GHG emissions from the Office of the President 's wastewater treatment plant was found that 235.62 $kgCO_2e$/year as shown in Table 4.25

Table 4.25 Calculation of BOD removal and GHG emissions from Office of the President

Type of waste	BOD input (mg/l)	BOD output (mg/l)	Wastewater (m^3/y)	BOD Remove (kgBOD/y)	Emission Factor ($kgCO_2e$/kgBOD)	GHG Emissions ($kgCO_2e$/y)
Waste water	200	50	162	24	0.18	4.4

4.4.3.2 Solid Waste

The PPC generated about 10.08 tons of total solid waste per year. According to IPCC Chapter 2 (2006), the PPC solid waste can be separated to each component and the solid waste components and GHG emission are presented in Table 4.26.

Table 4.26 GHG emissions from each type of solid waste from the PPC

Composition	%	Quantity (kg)	EF ($kgCO_2e/kg$)	Emission
Glass	4.00	403.20	2.32	935.42
Rubber	0.90	90.72	3.13	283.95
Paper	12.90	1,300.32	2.93	3,809.94
Plastic	7.20	725.76	2.32	1,683.76
Wood	9.50	957.60	3.33	3,188.81
Textile	2.70	272.16	2.00	544.32
Food	43.50	4,384.80	2.53	11,093.54
Metal	3.30	332.64	2.32	771.72
Other	16	1,612.80	2.32	3,741.70
			Sum	26,053.17

For the Office of the President the solid waste generated about 2.22 tons per years. As the IPCC Chapter 2 (2006), solid waste of the Office of the President can be separated based on waste proportion and GHG emissions as shown in Table 4.27.

Table 4.27 Solid waste composition and GHG emissions from each type of solid waste from the Office of the President

Composition	%	Quantity (kg)	EF (kgCO2e/kg)	Emission
Glass	4.00	88.80	2.32	206.02
Rubber	0.90	19.98	3.13	62.54
Paper	12.90	286.38	2.93	839.09
Plastic	7.20	159.84	2.32	370.83
Wood	9.50	210.90	3.33	702.30
Textile	2.70	59.94	2.00	119.88
Food	43.50	965.70	2.53	2,443.22
Metal	3.30	73.26	2.32	169.96
Other	16	355.20	2.32	824.06
			Sum	5,737.90

4.4.4 Carbon Footprint from Transportation

4.4.4.1 Vehicles Fleet

The GHG emissions from the vehicles fleet were estimated by their mileage vehicles as shown in Table 4.28 and Table 4.29. A number of kilometers driven by the staff were obtained from motor vehicles registered in 2004 and 2008 and they were used to estimate GHG for 2013. The emissions from the use of transportation by the department's faculty and staff members were computed by an average consumption in one day from the motor vehicle. The following Equations used to calculate vehicles fleet are given below (8), (9):

$$\text{Distance traveled (km/d)} = \text{Total day of car used} \times \text{Total mileage} \quad (8)$$

Where

Total day of car used: count by first date of registration motor vehicle to the date of recorded mileage.

Total mileage : Count by the mileage of car

$$\text{Quantity of fuel (l/y)} = \frac{\text{Distance traveled (km/d)} \times \text{working day (d/y)}}{\text{Fuel economy (km/l)}} \quad (9)$$

$$\text{GHG Emissions} = \text{Quantity of fuel (l/y)} \times \text{Emission factor (kgCO}_2\text{/l)}$$

Table 4.28 GHG emissions from vehicles fleet in FY 2013 by the PPC

Cars	**Vehicle Type**	**Fuel Consumption (L/d)**	**Emission Factor ($kgCO_2eq$ /L)**	**Emission ($kgCO_2eq$ /L)**	**Total Emission in 1 year**
Toyota vios	Car	3.50	2.24	7.84	1,883
Nissan	Van	7.73	2.74	21.22	5,093

Table 4.29 GHG emissions from vehicles fleet in FY 2013 by the Office of the President

Cars	**Vehicle Type**	**Fuel Consumption (L/d)**	**Emission Factor ($kgCO_2eq$ /L)**	**Emission ($kgCO_2eq$ /d)**	**Total Emission (2013)**
Toyota Ventury	Van	3.76	2.7446	10.31	2,475
Toyota Ventury	Van	7.28	2.7446	19.97	4,793
Toyota Ventury	Van	3.22	2.7446	8.83	2,120
Toyota Ventury	Van	6.01	2.7446	16.50	3,959
Toyota Altis	Car	4.64	2.2376	10.39	2,493
Toyota Altis	Car	0.72	2.2376	1.61	387
Toyota Altis	Car	2.06	2.2376	4.60	1,105
Toyota Altis	Car	1.74	2.2376	3.90	936
Toyota Altis	Car	2.22	2.2376	4.96	1,190
Toyota Vios	Car	0.75	2.2376	1.68	404
Toyota Vios	Car	1.12	2.2376	2.51	602
Toyota Vios	Car	4.00	2.2376	8.95	2,149
Toyota Vios	Car	1.06	2.2376	2.38	572
Toyota Camry	Car	0.81	2.2376	1.81	434
Volkswagen Caravelle	Van	7.02	2.7446	19.28	4,626
					28,245

***Base on 240 working days**

4.4.4.2 Daily Commuting

The following Equation was used to calculate daily commute as given below (10):

GHG Emissions ($kgCO_2e$) = [Miles traveled (mile) x Emission factor ($kgCO_2$/mile)] + [Miles traveled (mile) x Emission Factor ($kgCH_4$/mile)] + [Miles traveled (mile) x Emission Factor (kg N_2O/mile)]	(10)

Since GHG emissions from daily commuting were calculated from the faculty, staff and student commuting by their private vehicles and public transportation. The emissions from mass transit were included but this work use the emission factor from the U.S.A country to estimate. A number of kilometers driven by the staff and student were obtained from the data survey in 2013 which were used to generate the 2013 GHG emissions. The data were gathered from the department's faculty, staff members and student by the questionnaire survey (Figure 4.7 and Figure 4.8). The information gathered from surveying were distance, fuel consumption and type of the transportation. This methodology complies with the Greenhouse Gas Protocol and TGO. The result showed that the distance from dairy commuting for the College was 393,960 kilometer per year and Office of the President was 216,720 kilometer per year. Therefore, the total GHG emission from the College commuting was 71,120 $kgCO_2e$/year as shown in Table 4.30 and Table 4.31 and 24,738 $kgCO_2e$/year from Office of the President as shown in Table 4.32.

Table 4.30 GHG emissions of staff and faculty daily commuting from the PPC

Vehicle Type	Carbon Emissions ($kgCO_2e$/year)
BTS	3.579
Taxi	0.000
Motorcycle	1,143
Public Transport	1,317
Small Gasoline Automobiles	13,037
Medium Gasoline Automobiles	17,032
Large Gasoline Automobiles	12,351

Table 4.31 GHG emissions of student daily commuting from the PPC

Vehicle Type	Carbon Emissions ($kgCO_2e/year$)
MRT	1.937
BTS	22.19
Taxi	672.6
Motorcycle	1,562
Public Transport	1,529
Small Gasoline Automobiles	14,666
Medium Gasoline Automobiles	7,780
Large Gasoline Automobiles	0.000

Table 4.32 GHG emissions of staff and faculty daily commuting from the Office of the President

Vehicle Type	Carbon Emissions ($kgCO_2e/year$)
MRT	2.85
BTS	0.00
Taxi	0.00
Motorcycle	3,962
Public Transport	1,584
Small Gasoline Automobiles	12,144
Medium Gasoline Automobiles	7,044
Large Gasoline Automobiles	0.00

4.5 Evaluation of Carbon Footprint

Based on the Greenhouse Gas Protocol (A Corporate Accounting and Reporting Standard, which is prepared by the World Resources Institute (WRI) and the World Business Council for Sustainable development (WBCSD), and Thailand national standard for organization by TGO.), GHG emissions are separated into three categories or "scopes". Scope 1 includes direct emissions from sources that are owned and controlled by the department. Scope 2 includes energy indirect emissions resulting from the purchased energy (electricity), and Scope 3 includes indirect emissions that are a result of activities related to the department, but are not owned or controlled by the department (such as, faculty members and student commuting). The GHG inventory data gathered from the Petroleum and Petrochemical College and Office of the President on FY 2013, which was from October 2012 to September 2013. Table 4.35 shows the emission from Scope 1, 2 and 3 of the organization. The result showed that electricity consumption (Scope 2) was considered to be the most significant source of GHG emissions, accounting for 589 tCO_2 or 84.33 % of total GHG emissions. The daily commuting was another significant emission source; it was estimated to produce 71,120 tCO_2 which accounts for 10.18 % of the overall GHG emissions. The GHG emissions from direct emissions, material use and solid waste equal to 7.212, 5.049 and 26.05 tCO_2/year, which accounting for 1.03 %, 0.73 % and 3.73 %, respectively as shown in Table 4.33 and Figure 4.16 and Figure 4.17. It can be seen that the total annual carbon footprint of the College was 698.524 tCO_2e.

Table 4.33 Carbon footprint of the PPC

Scope description	Emissions Source	Carbon Emissions (tCO_2e/year)	Percent of the Footprint
Scope 1 :Direct emissions	Wastewater treatment	0.236	0.03
	Transportation : vehicles fleet	6.976	1
Scope 2 : Energy Indirect emissions	Purchased electricity	589.09	84.33
Scope 3 : Indirect emissions	Transportation : Daily commuting	71.120	10.18
	Material use • Paper use • Water use	 4.761 0.288	 0.68 0.05
	Solid waste	26.05	3.73
	Total indirect emission	102.22	
Total		698.52	100

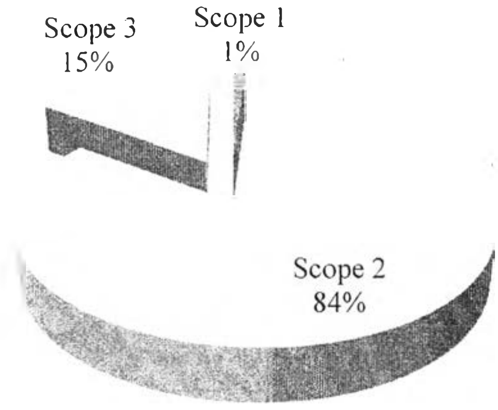

Figure 4.17 Proportion of the carbon footprint from each scope of the PPC.

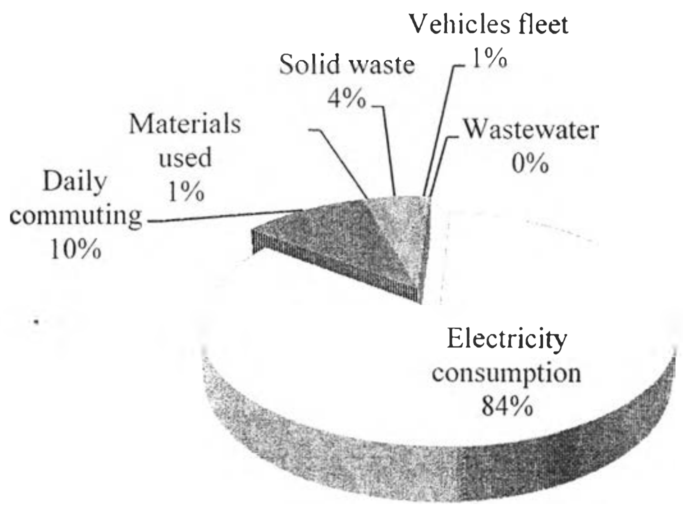

Figure 4.18 Proportion of the carbon footprint from all emission source of the PPC.

For Office of the President where this organization is operated for administration office of the CU. The result showed that electricity consumption was considered to be the most significant source of GHG emissions, accounting for 240.85 tCO_2/year. The daily commuting was another significant emission source; it was estimated to produce 24.738 tCO_2/year which accounts 79.412 % and 8.156 % of the overall GHG emissions, respectively. The GHG emissions from direct emissions, material use and solid waste were equal to 28.289, 3.718 and 5.738 tCO_2/year or 9.313 %, 1.226 % and 1.892 %, respectively as shown in Table 4.34. Figure 4.18 and Figure 4.19 present the percentage proportion of each scope of all emission sources. It can be seen that total annual carbon footprint in 2013 was 303.299 tCO_2e for the Office of the President.

Table 4.34 Carbon footprint of the Office of the President

Scope Description	**Emissions Source**	**Carbon Emissions (tCO_2e/year)**	**Percent of the Footprint**
Scope 1 :Direct Emissions	Wastewater treatment	0.0044	0.001
	Transportation : vehicles fleet	28.245	9.313
Scope 2 : Energy Indirect Emissions	Purchased electricity	240.856	79.412
Scope 3 : Indirect Emissions	Transportation : Daily commuting	24.738	8.156
	Material use • Paper use • Water use	 3.516 0.202	 1.159 0.067
	Solid waste	5.738	1.892
	Total indirect emission	9.456	
Total		303.299	100

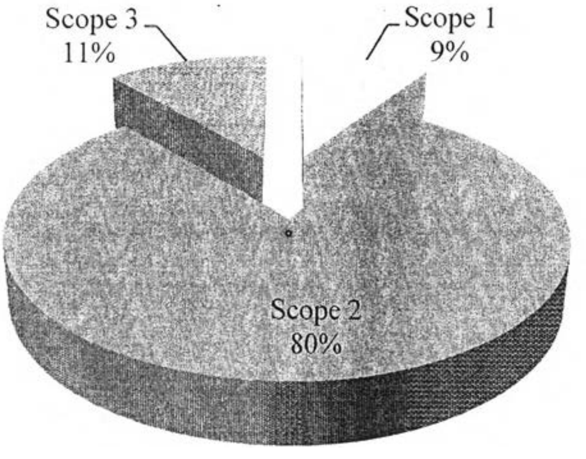

Figure 4.19 Proportion of the carbon footprint from each scope of the Office of the President.

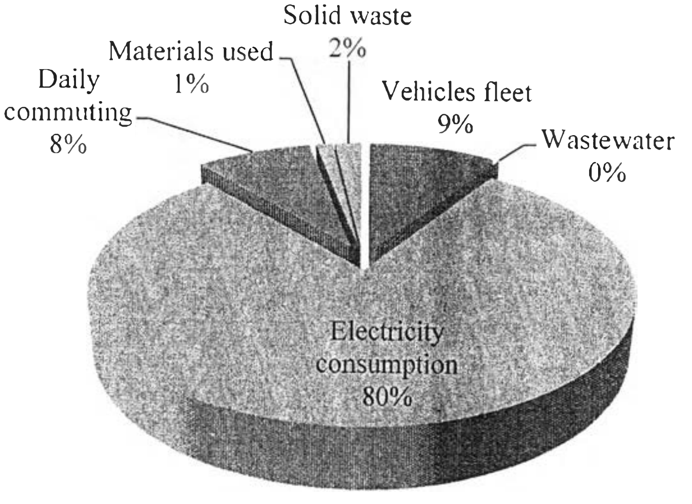

Figure 4.20 Proportion of the carbon footprint from all emission source of the Office of the President

4.6 Comparison of the GHG Emissions with different organization function

4.6.1 Carbon Footprint Classified by Scopes

As the key factor, the energy consumption and GHG emissions in the organization is the function of each place, whether it is an officer or class room or meeting room. The energy consumption is depended by various electric equipment which can be classified into 3 categories; air condition, lighting system and other appliances.

For the PPC, the result from the GHG calculations from Scope 1, generated from wastewater treatment and vehicles fleet, which was 7.212 tCO_2e/year or 1.03 % of overall GHG emissions. The vehicles fleet was the largest emission (97 %) in Scope 1 as shown in Figure 4.20. Scope 2, the largest contributor of GHGs of the department account for 589.090 tCO_2e/year. The source of emissions were the energy consumption from air-condition, lighting system and other appliances. Air-conditioners were the main source of energy consumption accounting for 78 % of energy use as shown in Figure 4.21. The results also demonstrated that air conditioner is the electrical equipment that release large amount of GHGs. The use of air-conditioners is caused by the air conditioner that is used to maintain the equipment for research study. From information survey, it was found that most of the air-conditioners in the department were used and also not being the energy saving type. Beside the proper maintenance measures, the replacement plan for obsolete and inefficiency equipment need to be consider as a immigration measure to reduce GHGs emissions. For Scope 3, the daily commuting was the second main source of GHG emissions from the College activity. The daily commuting attributed emissions of the Scope 3 about 71.120 tCO_2e annually. This accounts for 70 % of overall GHG emissions in this scope as shown in Figure 4.22.

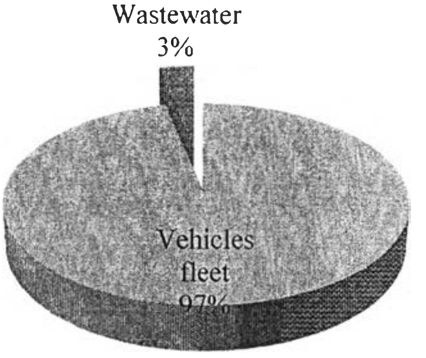

Figure 4 21 The emission contribution in scope 1.

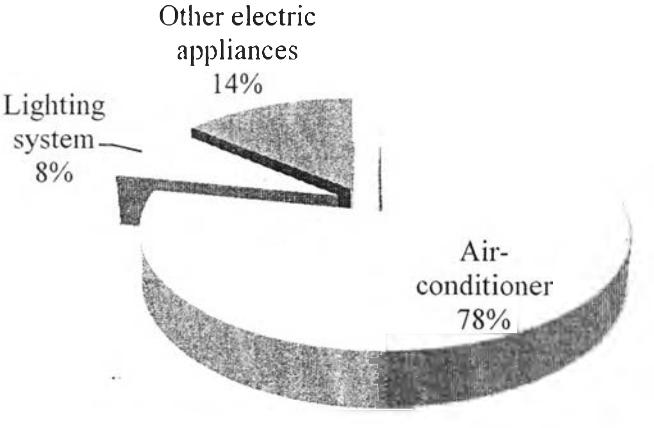

Figure 4.22 Carbon footprint of scope 2 by equipment.

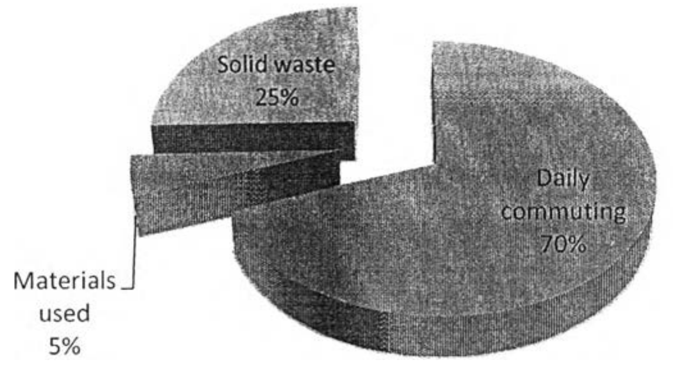

Figure 4.23 Distribution of carbon footprint of scope 3.

For Office of the President, the results from GHG calculations revealed as followed, The total emissions from Scope 1 are 28.29 tCO_2e/year, accounting for 9.31 % of overall GHG emissions of Office of the President. The vehicles fleet is the largest source of emission (99.98 %) as shown in Figure 4.23. For Scope 2, the largest contributor of GHGs of the department accounted for 240.856 tCO_2e/year, which mainly generated from energy consumption of air-condition, lighting system and other appliances. The GHGs calculations showed that air-conditioners are the main source of energy consumption accounting for 63 % of energy uses for electrical equipment as shown in Figure 4.24. The results also demonstrated that air conditioners was the electrical equipment that releases large amount of GHGs, and then the other electric appliances, The use of electric appliances are come from computers for routine working meeting. From the survey, it was found that most of the air-conditioners in the department were used and also not being the energy saving type; therefore, the department should implement several measures to reduce energy consumption from air-conditioners like the PPC. For instance, they can replace old item with newer energy-efficient model and turn off all equipment when they are not being used. For Scope 3, the daily commuting was the second main source of GHG emissions from the Office activity. The daily commuting related emissions was equal to 24.738 tCO_2e annually. It accounted for 72 % of overall GHG emissions in Scope 3 as shown in Figure 4.25.

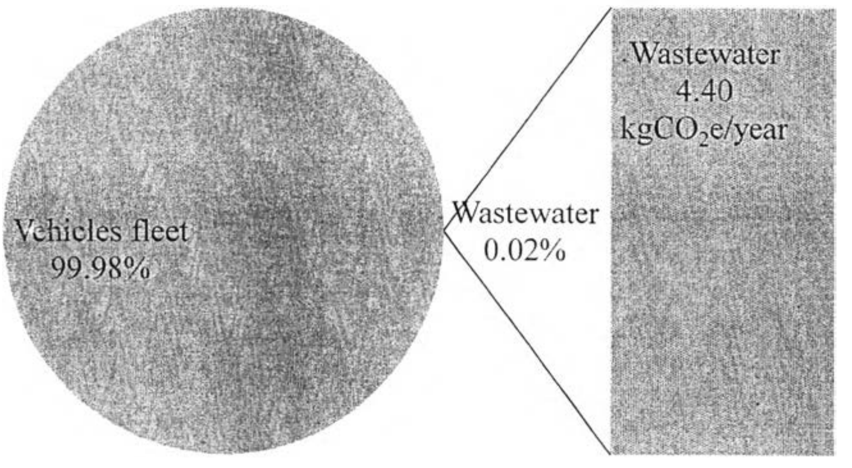

Figure 4.24 Distribution of carbon footprint of scope 1 emission.

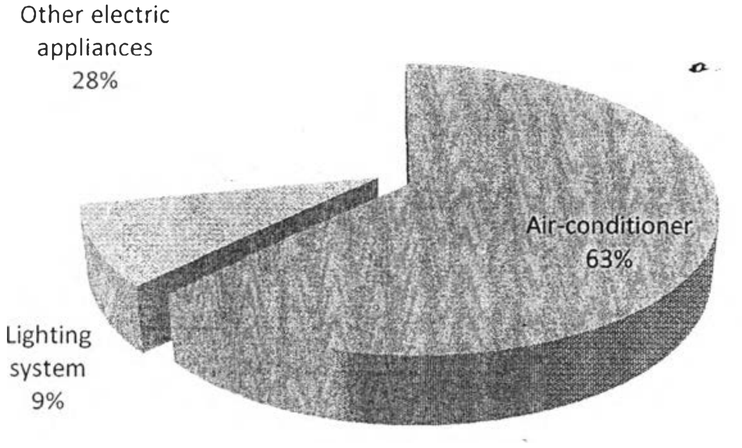

Figure 4.25 Distribution of carbon footprint of scope 2 by equipment.

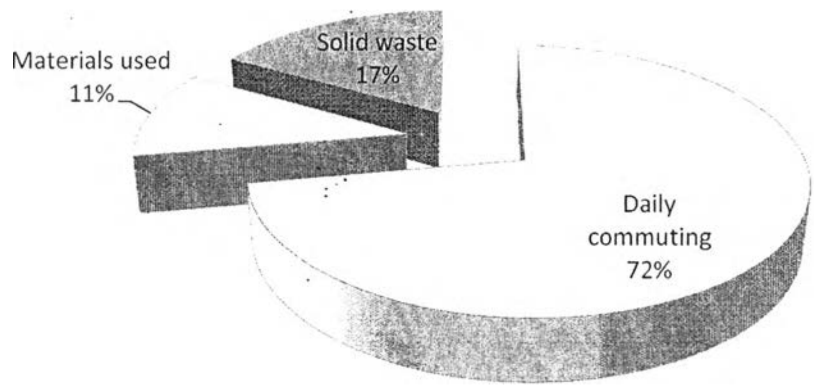

Figure 4.26 Distribution of carbon footprint of scope 3.

4.6.2 Comparison with the Previous Studies

Previous studies on university carbon footprint have reported in similar trends to those in this study (Pennsylvania, 2007; Purdue, 2007; the Department of Mechanical Engineering, Michigan state University, 2008; Hollins, 2008; Maryland, 2009). These studies classified GHG emission sources diffidently to match the specific types of sources present at each university, but as a whole, all sources were covered under the same scopes of the Greenhouse Gas Protocol and ISO 14069, 14064 part 1. Purdue (2007); Michigan State (2008); and Maryland (2009) that have been reported were the same major sources of GHG emissions; energy use evaluated for 57 %, 49 % and 41 % of their total GHG emissions, respectively. For Pennsylvania (2007) and Hollins (2008), purchased electricity, steam, heat, or/and hot/chilled water accounted for 60 % and 67 % of the total GHG emissions. In addition, three studies, namely, the University of Pennsylvania, Purdue University, and the department of Mechanical Engineering, Michigan State University reported their carbon footprint in terms of tC per person. The University of Pennsylvania and Purdue University reported a carbon footprint of 1.9 tC per person and 2.1 per person, respectively. While at the Michigan State (2008) reported a carbon footprint of 2.73 tC per person had a carbon footprint rather higher than those of the university of Pennsylvania and Purdue University. This larger amount can be attributed to the fact that the carbon footprint of Michigan State was evaluated only for a single academic, while those of the University of Pennsylvania and Purdue University were calculated for the entire university. For this work, the average carbon footprint per person is approximately 2.6 tC for the PPC and 7.2 tC for Office of the President. The comparison of the carbon footprint and the previous studies are shown in Table 4.35.

Table 4.35 Comparison this study with previous study

University	**University Carbon Footprint (CF)**		
	CF (tC Per Person)	**Major Sources to CF**	**CF (%)**
Purdue University (2007)	2.1	On-Campus Energy, Electricity	57 % 26 %
University of Pennsylvania (2007)	1.9	Electricity Steam	60 % 30 %
Hollins University (2003-2007)	-	Electricity On-Campus Energy	67 % 27 %
Department of Mechanical Engineering, Michigan State University (2008)	2.73	On – Campus Energy, Electricity, Transportation	49 % 31 % 19 %
University of Maryland, College Park (2001 – 2008)	2.02	On – Campus Energy, Transportation, Electricity	41 % 31 % 23 %
UCSI University, Malaysia (2008)	-	Electricity, Transportation	56 % 42 %
AIT Campus, Thailand (2009)	2.08	Transportation, Electricity	41 % 31 %
Petroleum and petrochemical College Office of the president	2.6 7.2	Electricity, The daily commuting Electricity, Vehicles fleet	84.3 % 10.2 % 79.4 % 9.3 %

4.7 Discussion of the GHG Emission in this Study

In this research, the function of the organization is divided into 2 Scopes; Teaching and Research department, and Administration department; as the representative of main department in Chulalongkorn University. The major function department activity of interest is Teaching and Research department while Administration department is minor department in this work.

The Petroleum and Petrochemical College (PPC) and Office of the President were used as representatives for teaching and research department and Administration department, respectively. The results presented that the PPC had emitted carbon footprint per person and per area at 2.6tC/person and 0.95 tC/m^2. On the other hand, the Office of the President had carbon footprint emission per person and per area about 7.2 tC/person and 0.50 tC/m^2, respectively. Although, the PPC has amount of carbon footprint per person less than the Office of the President, the PPC performs amount of overall carbon emissions higher than that of the Office of the President due to a number of population per area. The PPC has higher amount of population than the Office of the President (0.037 person/m^2 and 0.016 person/m^2). In comparison with the previous data, it can be seen clearly that the Office of the President has emitted more amount of carbon generated than the PPC, even if both of them have same sources of emission as regarded in 3 scopes.

Moreover, the results from this study show that the main GHGs emission is electricity consumption, is about 80 % of total GHG emissions. According to 28 institutes and 18 departments from Chulalongkorn University at 2013, the consumption is 80,385,941 kWh as GHG emission for 46,728.35 tCO_2e. Then the results from this work can be considered as the main GHG emissions from Chulalongkorn University, is the electricity consumption (80%). This information can be providing for energy management guideline in the future.

4.8 Carbon Footprint Reduction

The greenhouse gas (GHG) emissions of the department which were resulted by on-site and off-site activities. From the results, it can be concluded that the GHG emissions were mainly due to total energy consumption of the department.

As such, a proper and simple management strategies to reduce GHG emissions in which the department should include an energy conservation method. The major electric consumer is an air-conditioner. A comprehensive and integrated low carbon sustainability strategy is required 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. One important strategy is to promote energy efficiency awareness among staff and students in the department. Also, the energy conservation practices are necessary to promote as well.

Energy conservation methods for electric equipment such as turn off equipment when it is not needed and purchasing energy efficient equipment, such as those of "No.5 level," can decrease energy use by as much as 10 % (B.Janangkakan, 2013). It is also important to ensure that each piece of equipment has its energy management features activated. The installation of timers and occupancy sensors that help turn off equipment automatically when they are not needed. Every 1,000 kilowatt-hours (kWh) of electricity saved reduces the amount of carbon dioxide (greenhouse gas) from entering the atmosphere by about 450 $kgCO_2$ per year.

Typically, energy conservation measures are quantified in terms of cost savings. However, there are much more reasons to do an energy conservation than just saving money, it also reduces the amount of fossil fuels that are burned from power plant, which results in a decrease in overall the air pollutants that cause global warming and acid rain.

4.8.1 The Possible Options for Reduce GHG Emissions

From energy consumption is accountable for 84 % and 80 % of the department's GHG emissions, a decrease in emissions associated with energy use is critical to reducing the department's footprint. Quantities of options are available and can be distributed into those associated with reducing energy consumption and those associated with reducing carbon emissions during energy generation. The localized implementation of renewable energy is a possible option for this organization which some examples are explored below. Moreover, it can be concluded that GHGs emission are mainly because electricity consumption from air-conditioning and lighting system. Therefore, the proper and basic management to reduce GHG emissions in the organization is energy conservation strategies (Table 4.36). Energy conservation is the manner of decreasing the quantity of energy used. It may be completed through efficient energy use, which energy use is decreased while achieving a similar outcome, or by decreased consumption of energy services. Energy conservation may result in increase of financial benefit, environmental value. Individuals and organizations that are direct consumers of energy could set the mitigation measure to reduce energy costs and promote economic security.

4.8.1.1 Renewable Energy

- Solar energy is a gigantic energy source. Energy from the sun is sorted as the most important renewable energy. There are two main options: photovoltaic cells for power generation and solar water heating. Clean energy does not have any reaction which would cause environmental toxicity. Solar energy can be transformed into electricity directly. As Thailand is located near the equator, its potential for using solar energy is high level. The daily number of power across the country averages, around 4 to 4.5 kWh per square meter.
- The wastewater and solid waste from this work has the potential to be a clean energy source. Most of the waste biomass, such as wood, paper, food waste, can be used as fuel in power plants that are designed to use waste as fuel, for instance in a biogas fermentation tank. In this type of tank, methane gas is recovered as a renewable energy source for electric materials, which could decrease the carbon footprint of the organization

4.8.1.2 Energy Conservation (Electricity Use)

Because of this organization does not control the design, maintenance or operation of the physical building, there is little opportunity for it to choose energy-saving features and devices such as efficient air conditioning (energy saving No.5) and efficient lighting (with electronic ballast, motion sensors, model of fluorescent tubes and newer model of LED lighting system to reduce energy consumption. Nevertheless, changing the habits of the consumers of the organization to reduce consumption is feasible over a reasonable period of time and could be achieved with information campaign based on posters, emails, and the department website announcements. Reduction methods are shown in Table 4.36.

Table 4.36 Overall of recommendations in reduction methods

Save Energy Schemes	**Reduction Strategy**
Energy conservation	• Setting temperature (25 °C) • Setting room space suitable for natural light • Setting sleep mode for unused computer • Maintenance of Air conditioner 2 times per year and 1 time for lamp

Energy Efficiency	• Lighting system
	  • LED lamp
	  • Low loss Ballast
	  • Reflector
	  • Motion or Daylight sensor

Save energy schemes	Reduction strategy

Energy Efficiency	• Lighting system
	  • Lighting dimmer
	  • Timer
	  • Air-conditioner
	  • Energy Saving No.5
	  • Condenser Cooling Unit
	  • Evaporative Cooling
	  • Frame building
	  • Insulator
	  • Double Glazing
	  • Other equipment
	  • Use energy star equipment

Alternatives for the reduction of energy consumption, greenhouse gases emission and cost by using energy conservation for the electricity. There are many options available for reduce energy consumption in the organization such as: save energy No.5 air-conditioner; use high efficiency lamp; adopt in energy conservation management.

4.8.1.3 Transportation

Transportation was also found to be an important contributor to 11 and 17 % of the total GHG emissions of the department. Therefore, it should be receive particular attention to cope with reduction measures for carbon dioxide emission. Reduction strategies of transportation are shown in Table 4.37.

Table 4.37 Strategies for reducing transportation emissions

Emission Sources	**Reduction Strategies**
Vehicles Fleet	• Use of virtual meeting in some event that it possible to use
Daily Commuting	• Creation of incentives for employees to use car pool or other alternative methods for work commute, for instance walking, cycling or mass transit. • Suggestion for simulation project student to work on home 1 day per week

4.8.1.4 Material Use and Waste Disposal

For the small proportion of GHG emissions that was from waste and material uses, the 3R' s of reduce, reuse and recycle defines the main strategy that should be implemented whenever possible to reduce emissions.

The use of materials within the organization is suspect to decline, but emissions can be reduced by predominately recycled materials. The main of the organization's material emissions resulted from its use of paper. The production of paper 1 ton, it requires 17 tons of trees, 20 m^3 of water, 300 liters of baby oil, and 1,000 kW-hr of electric power. The recycled paper uses less 30 % farmed trees than normal paper. It was estimated that using one ream of recycled paper saves trees to absorb 2.75 kilograms of carbon dioxide from the atmosphere, which equals to the quantity of carbon for dioxide emitted from driving a car 9 km. Reduction strategies of material use and waste disposal are shown in Table 4.38.

Table 4.38 Strategy for reducing material use and waste emissions

Emission Sources	Reduction Strategies
Material Use	- Paper: - Adopt the 3R's (reduce, reuse and recycle) approach - Contact via email rather than on paper - Use both sides of paper before sending it to be recycled - Use recycling paper - Awareness raising for staff and student in the 3R's strategy - Water use

Table 4.38 Strategy for reducing material use and waste emissions (Cont.)

Emission Sources	Reduction Strategies
	- Use water saving devices - Install rain water collecting system Reduce the processing time of the motor or pump
Waste Disposal	- Solids waste disposal - Establish Recycling Bank for waste disposal

4.8.2 Management Scenario

For this work aimed to purpose scenarios to reduce the carbon footprint of the Petroleum and Petrochemical College and the Office of the President. Chulalongkorn University. The scenarios outlined in this document offer an opportunity to decrease the carbon footprint of the 2 organizations in Chulalongkorn University. In addition, possible options have been created to reduce the quantity of carbon-intensive energy which the departments generated by purchase and the amount of energy required from the departments. In the future, the options will be expanded to improvement of plan with more steps to reduce the university's carbon emissions with a manageable timeline. Furthermore, in the next 2, 5, and 10 years to name but a few, the university could realistically approve carbon reduction goals to be achieved.

4.8.2.1 Energy

Scenario 1: Energy Conservation

As the result, this study concentrated on reduction plans for electricity consumption. In this scenario, the PPC can promote energy saving program and increase in number of the PPC staff/faculty members and students awareness. The main sources electricity consumption was air-conditioners followed by other electricity appliances. Nevertheless, installation of light bulbs and LED tube and air-conditioners with turn off air-conditioner 15 minutes before finish work, to reduce the electricity consumption and GHG emissions due to it is a possible choice that we can apply in current situation. Electricity consumption can be reduced about 8.5 % of electricity consumption by the installation of LED tube and light bulbs (6.7 %) turn off air-conditioner before finish work 15 minutes (1.8 %). Furthermore, the PPC will be able to reduce amount of GHG emissions to 539,017 kCO_2e as shown in Table 4.40.

Table 4.39 Data information on scenario for electricity consumption

Data Information	**Current Electricity Consumption (kWh)**	**% Reduction**	**Scenario Electricity Consumption (kWh)**
Electricity Consumption	1,013,400	8.5	927,261

Table 4.40 Data information on scenario GHG emission on Electricity Consumption

Current GHG Emissions (kCO_2e)	**% Reduction**	**Scenario GHG emissions (kCO_2e)**
589,090	8.5	539,017

4.8.2.2 Solid Waste Generation

Scenario 2: Reduce, Reuse and Recycle campaign

Increasing awareness of the PPC 3Rs measures in part of reduce reuse and recycle of materials for activities of their daily routine using. It can help to reduce generation of solid waste such as paper, glass, plastic bottle and conjugate board. Assuming that the PPC has potential to reduce generation of solid waste for 30 %, the PPC will decrease amount of GHG emission to 18,237 kCO_2e as shown in Table 4.42.

Table 4.41 Data information on scenario of solid waste generation

Data Information	Current Solid Waste (kg)	% Reduction	Scenario Solid Waste (kg)
Solid Waste	10,080	30	7,056

Table 4.42 Data information on scenario of GHG emissions on solid waste generation

Current GHG Emissions (kCO_2e)	% Reduction	Scenario GHG Emissions (kCO_2e)
26,053	30	18,237

4.8.2.3 Water Consumption

Scenario 3: Promote water conservation and new faucet installation.

Installing new water saving appliances (e.g. dual Flush sanitary ware and new faucet which can close autonomous when unused. Furthermore, awareness of PPC, staff, faculty and student in terms of water saving can be done by; the PPC can be able to reduce up to 30 % by the Dual Flush sanitary ware (20 %) and new tap (10 %). If the PPC can reduce quantity of water consumption up to 30 %, the PPC would be able to decrease amount of GHG emissions to 367 kCO_2e from water consumption and wastewater as shown in Table 4.44.

Table 4.43 Data information on scenario of water consumption per year

Data Information	Current water Consumption (m^3)	% Reduction	Scenario Water Consumption (m^3)
Water Consumption	10,912	30	7,639

Table 4.44 Data information on scenario of GHG emissions on water consumption

Current GHG Emissions (kCO_2e)	% Reduction	Scenario GHG Emissions (kCO_2e)
524	30	367

The summary of each proposed scenario to reduce the GHG emissions is shown in Figure 4.37.

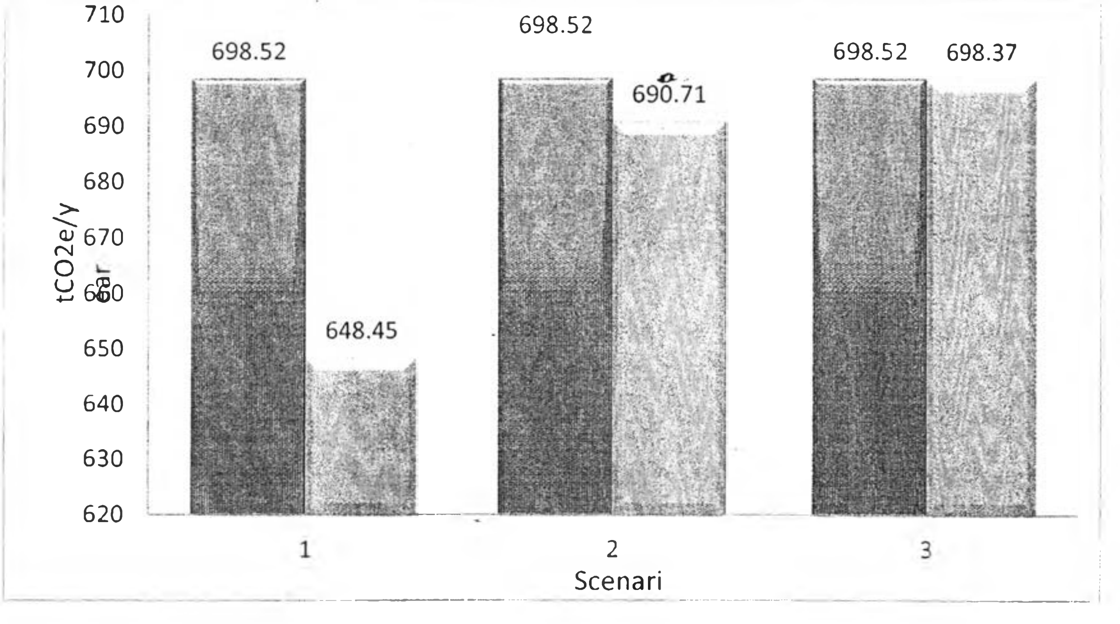

Figure 4.37 Comparing for reduction GHG emissions from each scenario.

In Figure 4.37, the results show that for the scenarios in the PPC model, the largest decreasing of GHG emissions is from Energy Conservation scenario (Scenario 1) due to the fact that it can reduce amount of GHG emissions from 698 to 648 tCO_2e/year by reducing 8.5 % of all energy consumption. The second largest is from Reduce, Reuse and Recycle campaign (Scenario 2), which it can decrease amount of GHG emissions from 698.524 to 690.71 tCO_2e/year by 30 % of generation solid waste reduction. The last scenario is promoting water conservation and new tap installation (Scenario 3); it can reduce quantity of GHG emissions from 698.52 to 698.37 tCO_2e/year accounting for 30 % of water consumption reduction.

4.8.3 Analysis of Possibility for Implementation of Scenarios

The motivation for the PPC towards low carbon campus, it is important to establish proper policy guidelines and evaluation tools. This study measured the current situation of GHG emissions using the PPC as a case study baseline year 2013. Also this work proposed potential scenarios for reduction of GHG emissions suitable for each aspect. This part describes advantage and disadvantages for each proposed scenario for identifying the most effective and policy for the situation of PPC.

4.8.3.1 Energy Conservation

Advantages:

- Raising awareness for electricity conservation
- Lighting system modification has been proved to efficiently reduce the use of electricity.

Disadvantages:

- High investment cost of lighting system retrofitting but it needs to be analyzed the cost-benefit and payback this measure.

4.8.3.2 Promote Reduce, Reuse and Recycle campaign

Advantages:

- The GHG emission can be reduced by the minimize resource and waste materials
- Benefits from selling recycle waste.

Disadvantages:

- It requires corrective of people to action the waste separation

4.8.3.3 Promote Water Conservation Measure and Water Saving Equipment Installation

Advantages:

- Decreased GHG emission from tap water used.
- Save money for payment on water consumption.

Disadvantages:

- High investment for water saving equipment installation.

The summary of advantages and disadvantages for each proposed scenario is shown in Table 4.45.

Table 4.45 Summary of advantages and disadvantages for each proposed scenario

Aspect	**Scenarios**	**Advantages**	**Disadvantages**
Energy	Electricity Conservation	Save money Save energy	High Investment
Solid Waste	3Rs	Reduce waste generation Gain money from waste recycled	Require disciplinary
Water consumption	Reduce consumption	Reduce payment	Require participation of people