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Comparative carbon footprints: The case of online and onsite learning of undergraduate program in Environmental Science, Chulalongkorn University, Thailand.

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**ปีการศึกษา** 2563

**คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย**

SENIOR PROJECT

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| **Project title** | **Comparative carbon footprints: The case of online and onsite learning of undergraduate program in Environmental Science, Chulalongkorn University, Thailand** |
| **Student name** | Miss Thanchanok Khoonnarong      Student ID 6033321623 |
| **Department** | Environmental Science |
| **Academic Year** | 2020 |

Faculty of Science, Chulalongkorn University

# Comparative carbon footprints:
# The case of online and onsite learning of undergraduate program in Environmental Science, Chulalongkorn University, Thailand

การเปรียบเทียบรอยพิมพ์คาร์บอน: กรณีการเรียนการสอนแบบออนไลน์และออนไซต์
ของหลักสูตรระดับปริญญาตรี สาขาวิทยาศาสตร์สิ่งแวดล้อม
จุฬาลงกรณ์มหาวิทยาลัย ประเทศไทย

Thanchanok Khoonnarong

A Senior Project Submitted in Partial Fulfillment of the Requirement for

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| **Department** | Environmental Science |
| **Academic Year** | 2020 |

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Accepted by the Department of Environmental Science, Faculty of Science, Chulalongkorn University in Partial Fulfilment of the Requirements of the bachelor's degree.

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| **ปีการศึกษา** | 2563 |

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**บทคัดย่อ**

รอยพิมพ์คาร์บอนหรือการปล่อยก๊าซเรือนกระจกจำนวนมากที่มาจากกิจกรรมต่าง ๆ ของมนุษย์เป็นสาเหตุสำคัญของภาวะโลกร้อน ซึ่งเป็นภัยคุกคามต่อโลก ณ เวลานี้ ด้วยการแพร่ระบาดของโรคโควิด-19 ทำให้กิจกรรมในชั้นเรียนของมหาวิทยาลัยถูกปรับเปลี่ยนรูปแบบจากออนไซต์ (ในสถานที่) เป็นออนไลน์ ซึ่งอาจจะส่งผลให้รอยพิมพ์คาร์บอนเปลี่ยนแปลงไป ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์ในการประเมินและเปรียบเทียบระหว่างรอยพิมพ์คาร์บอนจากการเรียนการสอนแบบออนไลน์และออนไซต์ในหน่วยของตันคาร์บอนไดออกไซด์เทียบเท่าต่อชั่วโมง โดยใช้หลักสูตรวิทยาศาสตรบัณฑิตสาขาวิชาวิทยาศาสตร์สิ่งแวดล้อมของจุฬาลงกรณ์มหาวิทยาลัยในปีการศึกษา 2562 และ 2563 เป็นกรณีศึกษา รอยพิมพ์คาร์บอนจากชั่วโมงการบรรยายและการศึกษาด้วยตนเองของนิสิตแต่ละชั้นปีถูกคำนวณจากข้อมูลการใช้พลังงาน/เชื้อเพลิงจากห้องเรียน อุปกรณ์การเรียน การพิมพ์และถ่ายเอกสาร และการเดินทาง ร่วมกับข้อมูลการใช้กระดาษ แบบสอบถามทางเว็บไซต์ถูกใช้เป็นเครื่องมือหลักในการรวบรวมข้อมูล ผลการศึกษาแสดงให้เห็นว่า รอยพิมพ์คาร์บอนเฉลี่ยจากการเรียนการสอนแบบออนไลน์และออนไซต์ของนิสิตทุกชั้นปีในหลักสูตรฯ มีค่าเท่ากับ 0.050 และ 0.040 ตันคาร์บอนไดออกไซด์เทียบเท่าต่อชั่วโมง ตามลำดับ ซึ่งส่วนใหญ่เป็นผลมาจากการใช้พลังงานในห้องเรียน คิดเป็น 96% และ 80% ตามลำดับ โดยเครื่องปรับอากาศเป็นอุปกรณ์ที่มีอิทธิพลมากที่สุด นอกจากนี้ การใช้พลังงานจากการเดินทางสำหรับกรณีการเรียนการสอนแบบออนไซต์ คิดเป็น 13% เท่านั้น เนื่องจากนิสิตนิยมใช้บริการระบบขนส่งสาธารณะหรือการเดิน จากการวิเคราะห์ความแปรปรวนสองทางพบว่า ปัจจัยรูปแบบการเรียนการสอนและชั้นปีของนิสิตไม่ส่งผลให้รอยพิมพ์คาร์บอนแตกต่างกันอย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95%



**คำสำคัญ**: รอยพิมพ์คาร์บอน, การปล่อยก๊าซเรือนกระจก, การใช้พลังงาน, การเรียนแบบออนไลน์, การเรียนแบบออนไซต์

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## ABSTRACT

The huge amount of carbon footprints or greenhouse gas emissions from various human activities is the important cause of global warming, currently threatening humanity. With the spread of the COVID-19 pandemic, universities have been forced to switch class activities from onsite to online learning approaches. It could lead to changes in carbon footprints. Therefore, this study aimed to estimate and then compare the carbon footprints between onsite and online scenarios in the unit of tonnes of carbon dioxide equivalent per hour (tonnes $CO_2e$/hr.). The undergraduate program in environmental science at Chulalongkorn University, Thailand, in the 2019 and 2020 academic years were used as the case studies. The carbon footprints from lecture and self-learning activities for students in each class year were estimated based on the energy/fuel consumptions in environmental settings, personal devices, printing and photocopying, and transportations, plus the amount of paper used. The web-based questionnaires were used as the main tool to collect data. The results showed that the average carbon footprint for onsite and online learning scenarios was about 0.050 and 0.040 tonnes $CO_2e$/hr. respectively, which the major carbon footprints were from the energy consumptions in environmental setting (96% and 80% respectively). Air conditioners were the most contribute appliances. For the onsite learning scenario, moreover, the energy consumptions in transportations were accounted for only about 13%, because most students used public transits or walking. The two-way analysis of variance revealed that learning scenario and class year were not factors contributing significant differences in average carbon footprints.


**Keywords:** Carbon footprints, Greenhouse gas emission, Energy consumptions, Online learning, Onsite learning.

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# CHAPTER I

# INTRODUCTION

## 1. Introduction

### 1.1 Background

Global warming is an urgent problem for all countries around the world. The occurrence and consolidation of carbon dioxide ($CO_2$) and other greenhouse gases (GHG) in the atmosphere causes the atmosphere to absorb sunlight and solar rays that bounce off the Earth's surface, and cause a rise in global temperature. Consequently, the climate systems are changed in many ways invent more frequent and/or intense extreme weather events and related natural disasters. The ecosystems and natural habitat are also changed to the point that poses threats not only to plants and wildlife but directly to people (MacMillan, 2016; Intergovernmental Panel on Climate Change [IPCC], 2006).

There is a strong link between global warming and $CO_2$ emissions. We can estimate the relative global warming contribution due to the atmospheric emission of a kg of particular greenhouse gas compared to the emission of a kg of $CO_2$. With this concept, we can develop a measure of the exclusive total amount of carbon dioxide emissions that are directly and indirectly caused by an activity or are accumulated over the life stages of a product, called carbon footprints. Carbon footprints refer to the greenhouse gas (GHG) emissions from activities, products or individuals through transportation, consumption. Generally, carbon footprints are expressed as a carbon dioxide ($CO_2$) equivalent in tons (Li et al., 2021). Nowadays, many organizations integrate carbon footprint assessment in their environmental management planning. Universities are one type of organization that requires a concrete footprint to be appropriately assessed, as a wide range of greenhouse gas emissions activities is carried out each semester. Because the university uses energy to cool buildings, as well as powerful computers and lights. Especially the main activities such as teaching, learning management, and 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. So many universities have leaders in promoting sustainability and studying greenhouse gas emission assessments to find ways to reduce greenhouse gas emissions and to become ‘green university’. However, these indicators do not reflect the carbon footprint of instructional management.

With the spread of COVID19, all university's learning programs are forced to make a transition from onsite to online. It is a huge change in instructional management as well as carbon emissions. However, only a few studies have been conducted to investigate the comparative carbon footprints of online versus onsite learnings. Many aspects remain unclear. In this present work, the carbon footprints based on energy consumptions for onsite and online learning activities in the undergraduate program in Environmental Science will be estimated and then compared. The results of the study may expand the scope of the Green University assessment and provide important information on reducing or managing carbon.

## 1.2 Research Objectives

1.2.1 To measure the energy consumptions for onsite and online learning activities in the undergraduate program in Environmental Science, Faculty of Science, Chulalongkorn University.

1.2.2 To assess the carbon footprints from measured energy consumptions for onsite and online learning activities.

## 1.3 Expected outcomes

Information from this study will be helpful for the development or improvement plans to reduce or manage carbon footprint per student in undergraduate program in Environmental Science, Chulalongkorn University. The study itself is also an example of the carbon footprint assessment for other programs in Chulalongkorn University.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Global warming and greenhouse gas emissions

Global warming is the long-term heating of Earth's climate system observed since the pre-industrial period due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere. (NASA, 2020)

Greenhouse gases are gases in the atmosphere such as water vapor, carbon dioxide, methane and nitrous oxide that can absorb infrared radiation, trapping heat in the atmosphere. Greenhouse gas include $CO_2$, $CH_4$, $N_2O$, HFC, PFC, $SF_6$ and $NF_3$. This greenhouse effect means that emissions of greenhouse gases due to human activity cause global warming. (Wigley, Jones, and Kelly 1981)

The problem of carbon emission is more pronounced specifically in universities with large populations and large spatial sizes, whose design requires the use of automobiles to travel from one place to another within the campus. Similarly, the teaching and learning service delivery, as well as the residential and administrative activities also involve high energy demand for lighting, cooling, and running appliances, while, the movement of vehicles within the campus consumes a high amount of fossil fuel energy, whose consumption also results in the emission of carbon dioxide.

Therefore, focusing on achieving a reduction of carbon emission from energy use in university campuses by encouraging low carbon emission through the involvement of the universities and achieving energy sustainability within the campus by the reduction of carbon dioxide emission may benefit global energy sustainability and remedy the current problems of global warming.(Abdul-Azeez and Ho 2015)

## 2.2 Carbon footprint

Carbon footprint is the total amount of carbon dioxide and other greenhouse gases such as methane, laughing gas etc. emitted from products or services (in accordance with ISO 14040) throughout their life cycle. The source of such gas comes from activities such as the use of electricity, the use of fossil fuels. Processes in industrial or agricultural sectors, etc. Carbon footprint measures the quantitative impact of products and services from human activities on the environment. Using an indicator that is Global Warming Potential (GWP).

### 2.2.1 Calculation of Carbon footprint

A carbon footprint measures the total greenhouse gas emissions caused directly and indirectly by a person, organization, event or product.

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 factors are needed for the calculation of GHG emissions as shown in the following equation: Activity data - a factor that quantifies an activity used to calculate the emissions generated. (Janangkakan, Chavalparit, and Kanchanapiya 2011)

$$\textit{GHG emission} = \textit{Activity data} \times \textit{Emission factor}$$

Acquisition of activity data is divided into primary information is a collection of courses Classrooms and the number of students in the Department of Environmental Science Chulalongkorn University And secondary data, which will be a questionnaire survey from students in all four years on teaching and learning behavior such as using paper, Section of course, etc.

Acquisition of Emission factor is the secondary data gathered and obtained from the website of Thailand greenhouse gas management organization (TGO) (TGI, 2019;

Styrene et al. 2021) and power of electronic from another studies.(Roth et al. 2004; Desroches et al. 2014; Clément, Jacquemotte, and Hilty 2020)

GHG emissions for transportation calculated from the equation:

*GHG emission = (Distance/The rate of fuel consumption from traveling) x Emission factor*

Based on the principles of the organization's carbon footprint assessment from Thailand greenhouse gas management organization (TGO).(TGI, 2019)

**2.3 Green university assessment**

University Indonesia (UI) initiated a world university ranking in 2010, later known as UI GreenMetric World University Rankings, to measure campus sustainability efforts. It was intended to create an online survey to portray sustainability programs and policies in universities around the world.

Guideline of UI GreenMetric World University Ranking that is the first and only university rankings in the world that measure each participating university's commitment in developing an 'environmentally friendly' university. The rankings look at 6 indicators of each university such as Setting and Infrastructure (SI), Energy and Climate Change (EC), Wastes (WS), Water (WR), Transportation (TR), Education (ED). A categories and weighting of points are SI 15%, EC 21%, WS 18%, WR 10%, TR 18%, ED 18%.

The focus of this study on energy consumption and classroom activity is close to two indicators:

(2.3.1) Energy and climate change (EC)

The university's attention to the use of energy and climate change issues is the indicator with the highest weighting in this ranking. In the questionnaire, we define several indicators for this particular area of concern, i.e. energy-efficient appliances usage, the implementation of smart buildings/automation buildings/intelligent buildings, renewable energy usage policy, total electricity usage, energy conservation programs, elements of green buildings, climate change adaptation and mitigation programs, greenhouse gas emission reductions policy, and carbon footprint. Within these indicators, the universities are expected to increase their efforts in energy efficiency in their buildings and to care more about nature and energy resources.

Purchased electricity is Indirect GHG emissions resulting from the generation of the electricity purchased and used by the institution

(2.3.2) Education (ED)

(2.3.2.1) Number of courses/subjects related to sustainability offered

The number of courses/subjects the contents of which are related to sustainability offered at your university. Some universities have already tracked on how many courses/subjects are available for this. The definition of the extent to which a course can be seen as related to sustainability (environmental, social, economic) or both, can be defined according to your university's situation. If a course/subject contributes in more than a minor or passes way to increase awareness, knowledge, or action related to sustainability, then it counts. The number of courses/subjects can be counted by specifying related sustainability keywords used in the subjects. For example, environmental chemistry is the subject for the study program of chemistry.

(2.3.2.2) Total number of courses/subjects offered

It is the total number of courses/subjects offered at your university yearly. This information will be used to calculate to what extent environment and sustainability education have been defined in your university teaching and learning.

(2.3.2.3) The ratio of sustainability courses to total courses/subjects

(2.3.2.4) Total research funds dedicated to sustainability research (in US Dollars)

(2.3.2.5) Total research funds (in US Dollars)

The average total research funds per annum over the last 3 years. This information will be used to calculate the percentage of environment and sustainability research funding to the overall research funding.

(2.3.2.6) Number of scholarly publications on environment and sustainability published

(2.3.2.7) Number of scholarly events related to environment and sustainability

(2.3.2.8) Number of student organizations related to environment and sustainability

(2.3.2.9) Existence of a university-run sustainability website

## 2.4 The undergraduate program in Thailand

In Thailand, Ministry of Education Announcement on Undergraduate Curriculum Standards, 2015 stipulated that Educational management system using a bipolar system, with 1 academic year divided into 2 parts. 1 regular semester for a period of not less than 15 weeks.

Number of credits uses a 4-digit numerical system, N (X-Y-Z).

N is the total number of credits.

X is the number of hours per week spent in lecture-based instruction. Lecture course which takes at least 15 hours to give lectures or discuss a problem per regular semester Shall be equal to 1 credit.

Y is the number of hours per week spent on a non-lecture course. Non-lecture course or Practical course that takes practice, trial, or at least 30 hours per semester. Is equal to 1 credit semester system.

Z is the number of self-study hours per week.

**2.5 Related research**

The International Association of Universities has made it a priority to develop sustainable higher education. The United Nations' report Our Common Future shows the multilateralism and interdependence of nations in the search for a sustainable path (UN, 1987), or people's continuous efforts to attain a sustainable society. correspondingly, the Sustainable Development Goals (SDGs) developed by the United Nations General Assembly in 2015 provide clear guidelines and targets for all countries around the world to adopt in accordance with their own priorities and the environmental challenges of the world at large. (Yañez, Sinha, and Vásquez 2020)

Janangkakan et al., 2011 presented the carbon footprint evaluation of an academic institution, direct and indirect greenhouse gas (GHG) emissions were calculated. The objective of this research was to evaluate the GHG emissions of the Department of Environmental Engineering, Chulalongkorn University and to develop 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 the year 2009 was 138.6 $tCO_2e$/yr. and the average carbon footprint per person was 1.08-ton carbon (tC). From the calculation, energy consumption was considered as the biggest source of CO2 emission that generated 85.2 $tCO_2e$ annually.

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. 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.

Yukhunthiwat K., 2014 evaluate $CO_2$ emission from travelers’ behavior within Chulalongkorn university using the principle of carbon footprint. The main target group of this part was travelers who use personal cars. Data was collected by means of origin-destination surveys and license plate surveys in order to estimate the number of travel activities. The second section was to evaluate $CO_2$ emission from transportation activities between home. Data was collected by interviewing a sample in order to determine the proportion of traveling patterns, distances of each pattern, and average trips in each week. From this case study, there were greenhouse gas emissions of 10,675.40 Tons-$CO_2$e in total, of which 984.40 Tons-$CO_2$e from section 1 calculate and 9,691 Tons-$CO_2$e from section 2. Research results could help the university to better manage and plan for sustainable transportation.

Li et al., 2015 developed a novel methodology for estimating an average student's personal carbon footprint and deployed it at a university in Shanghai. Given the scarcity and uncertainty of existing information, we created and administered an online structured survey to capture students' energy consumption patterns, behavioral tendencies, and willingness to engage in energy conservation. These analyses can help identify student behavior changes that will be most effective at reducing aggregate carbon emissions. Awareness campaigns may be effective, given that 87% percent of respondents said they engaged in energy-saving behavior. Survey responses and carbon footprint calculations were also used to identify actions the university could take to reduce emissions, both now and in terms of upgrades as the campus develops and Chinese living standards continue to rise.

Roy et al., 2008 summarizes the methods and main findings of a study of the environmental impacts of providing higher education (HE) courses by campus-based and distance/open learning methods. based, print-based and online distance learning courses – covering travel, paper and print consumption, computing, accommodation, and campus site impacts. Results were converted into energy and $CO_2$ emissions per student per 100 hours of degree study.

Suwartha & Sari, 2013 said numerous daily activities university include teaching, researching, and community engagement. Universities also contribute greenhouse gas emissions due to the various people and goods being transported to and from the campus. Universities have different types, functions, sizes, complexities, energy needs, electricity consumption, waste generation, water and materials consumption, public transportation, and education activities; thus, they have significant impacts on the environment. Therefore, over the past two decades, there have been increased discussions regarding the need to consider sustainability in academic institutions. To appreciate and acknowledge universities that have made strong commitments to sustainable efforts, the UI GreenMetric World University Rankings were developed in 2010 as a tool to support developing green universities (Suwartha and Berawi 2019)

The significant impact of the UI GreenMetric ranking is shown in the increasing number of participants covering regions of North America, South America, Europe, Africa, Asia, and Australia, and Oceania. Many participating universities express through their website's sincere gratitude and pride that their continuous sustainability efforts have been acknowledged by being listed in the rankings. The International Ranking Expert Group (IREG) has also shown appreciation for the UI GreenMetric ranking as a global sustainable ranking for universities

Therefore, based on the above findings, the UI GreenMetric has been acknowledged globally as the only one sustainability ranking that is simple and accessible and that serves as a benchmark and guide, particularly for helping universities in developing countries create sustainable universities and sustainable futures.

In 2020, universities from 83 countries around the world are currently enrolled in the ranking of green universities by UI GreenMetric rankimg. In Thailand there are over 37 universities participating, for example Mahidol University, Kasetsart University Including Chulalongkorn University etc.

CHAPTER III

MATERIALS AND METHODS

## 3.1 Scope of the study

3.1.1 The selected undergraduate program in Environmental Science

Environmental Science at Faculty of Science, Chulalongkorn University, Thailand was chosen as a case study for this project. According to the QS World University Ranking 2021, this program was ranked #151-200 best in the world (Topuniversities, 2021) based upon academic and scholar reputations as well as research impact. Moreover, the UI GreenMetric Ranking of World Universities 2020 placed the University as 111$^{th}$ best in the world (UI GreenMetric, 2020) with outstanding on the energy usage, waste management and eco-friendly transportation aspects. These rankings may reflect the motivations and determinations to become a sustainable academic ecosystem. Thus, the carbon footprint estimation for this program could be considered as the inevitable and crucial key element.

3.1.2 The scenarios of online and onsite learning

The selected undergraduate program is typically four-year long based on onsite learning, which requires students to attend classes at specific rooms and times of day. However, the program has been forced to be based on online learning as much as allowable during the spread of COVID-19, since January 2019. So, the students have to spend most of study times in virtual classes, either asynchronous and synchronous, using their electronic devices. For the purposes of the carbon footprint comparisons, this study set the onsite and online learning scenarios based on the snapshot data in 2019 and 2020 academic years respectively.

In the scenario of onsite class, we keep historical data. We use the information of onsite learning in 2019 as it is the year that still learning at university. The data used as the primary data from the questionnaire of the students in the four years and graduate of the Department of Environmental Science, which includes transportation activities between accommodation and university, the type of electronic equipment used in the study, the amount of paper used for study, the time self-learning etc., and the data from electrical appliances from the survey collected data from each classroom. In addition, in this section, there will be inquiries about student travel and accommodation. The secondary data section consists of emission factors of electricity and papers Including the power of various electrical machines.

In the scenario of an online class, we are using data from the 2020 academic year as this is the year that the university will need to provide online education based on the COVID 19 situation. The data used as the primary data from the questionnaire of the students in the four years of the Department of Environmental Science, which includes the type of electronic equipment used in the study, the amount of paper used for study, the time self-learning, and How about online learning environmental, etc. We set the online learning environment to use air-conditioned rooms, use a fan room, and do not use both of them. and with the spread of COVID19, all university's learning programs are forced to make a transition from onsite to online to reduce exposure from travel. Therefore, there is no information on the part of the travel

3.1.3 The estimation of carbon footprint

This study estimated the carbon footprint per student per hour for onsite and online learning based on three sectors: (1) the energy consumptions in class, (2) the energy consumptions in transportation, and the amount of papers used in class. Related data for each component were mainly retrieved from the 1st -, 2nd-, 3rd-, and 4th-year students in the program for each learning scenario using a web-based questionnaire, as shown in the appendix. This questionnaire was reviewed by the corresponding faculties in the selected program. Other related data were acquired from internal stakeholders and literature review. Noted that both learning scenarios considered the energy consumptions in the same set of classes, which only lecture classes were taken into account for simplicity purposes. Moreover, the online learning scenario assumed no transportation.

The estimates from each sector were converted and then sum to obtain total carbon footprint as total greenhouse gas emissions ($kgCO_2e$), using specific.

## 3.2 Data collection and analysis

### 3.2.1 Questionnaire sampling

This study used an opportunity sampling to collect data. All students in the selected program in the 2019 and 2020 academic years were invited to complete the web-based questionnaire.

To estimate the energy consumption of online classes and onsite classes, we set a questionnaire to identify the number of electronic devices used from activities in classroom. In the case of learning onsite, we asked respondents, about What electronic devices did they use in the lecture class for each course? Including electronic equipment used in self-learning. In the case of an online class, we set questionnaires as well as an onsite class but will add questions about the online learning environment.

For each learning scenario, the target respondents were determined by using Yamane's formula with an error 5% and with a confidence coefficient of 95% (Kuswanto, Hadi Pratama, and Ahmad 2020). It was found that the number of respondents should be 120 people divide in to 70% in each year. However, due to the COVID 19 situation, communication made it more difficult, resulting in fewer respondents than expected.

The number of respondents for each year group and type of study is shown in Table 3.1

**Table 3.1** Statistical characteristic of survey targets

| | | Type of study | | Total |
|---|---|---|---|---|
| | | Onsite | Online | |
| **Year** | 1st | 9 | 10 | 19 |
| | 2nd | 15 | 9 | 24 |
| | 3rd | 28 | 15 | 43 |
| | 4th | 13 | 28 | 41 |
| **Total** | | 65 | 62 | 127 |

3.2.2 Energy consumptions in class

This study estimated the energy consumptions in class as electric consumptions from three components: environment settings, personal devices, and printing/photocopying, using the following equation:

$$\text{Electric consumption (kWh)} = \text{Electric Power (kW)} \times \text{Operating Hour (h)} \qquad (1)$$

The electric powers for environment settings were referred to electronic devices installed in a classroom. For onsite learning scenario, light bulb, air conditioner, projector, desktop, and audio system were taken into considerations. For online learning scenario, only light bulb and air conditioner were accounted. This data was acquired from the internal stakeholders. The energy powers for personal devices were referred to tablet, laptop, or desktop used by a student.  This data was extracted the questionnaires. The electric powers for printing/photocopying were referred to printer or photocopier used by a student. This data was acquired from literature review. Table 3.2 shows the summary of electric powers data used this study. (Roth et al. 2004; Desroches et al. 2014; Clément, Jacquemotte, and Hilty 2020,)

**Table 3.2** the summary of electric powers data used

| Type of electric | Unit | Electric powers |
|---|---|---|
| BTS/MRT | kWh/km-car | 2.56 |
| CU POP bus | kW | 82 |
| Desktop | kW | 0.066 |
| Fans | kW | 0.045 |
| Ipad mini | kW | 0.00247 |
| Ipad | kW | 0.00227 |
| Ipad air | kW | 0.00327 |
| Ipad pro | kW | 0.00318 |
| Laptop | kW | 0.032 |
| Light bulb | kW | 0.100 |
| Photocopying | kW | 0.18 |
| Printing | kW | 0.016 |

The light bulb power is calculated using the standard light intensity in the classroom, which is 300 lux.(Sirinapa, Jantarkot; Yingsawad 2017) and Standard area size 20 square meters.(bsa, 2016) . As for the power of the air conditioner, the BTU value of the air conditioner from the questionnaire will be converted to the power factor (kW).(Fay 1967)

The operating hours for environmental settings and personal devices were determined based on designed hours for each subject. For example, a typical lecture class for three credits requires a student to spend 3 hours for in-class lecture and 6 hours for self-study. The operating hours for printing/photocopying were calculated based on pages of lecture notes and printing speed (page per minute, ppm).

3.2.3 Energy consumptions in transportation

This study estimated the energy consumptions in transportation based on fuel (electric) consumption by mode and travel distance (time) from residence to university. These data were extracted from the questionnaire and Google Map. This study divided the modes of transportation into 8 categories: walk, bike, motorcycle, passenger car, taxi, public bus, Metropolitan Rapid Transit (MRT)/Bangkok Mass Transit (BTS), and electric transits in university (bus and 3-wheeler).

For walk and bike, the fuel consumptions were set to be zero.

For passenger car, taxi, motorcycle, and bus, the fuel consumptions were estimated using the following equation:

$$\text{Fuel consumption (L)} = \text{Distance (Km)} / \text{Fuel consumption rate (Km/L)} \qquad (2)$$

Noted that the fuel consumption rate was retrieved from Thailand greenhouse gas management organization (TGO), ). (TGI, 2019) as shown in Table 3.3.

For MRT/BTS and electric transits in university, the electric consumption were estimated using the following equation:

$$\text{Electric consumption (kWh)} = \text{Travel time (h)} \times \text{Electric power (kW)} \qquad (3)$$

Noted that all estimates were then scaled to per person using maximum capacity for each mode of transit. For purpose of simplicity, this study assumed no transit between residence and university. The questionnaire asked students for the mode of transit that they used the most for traveling back and forth to their residences.

3.2.4 Amount of papers used in class

This study extracted the amount of the paper used in class, either from the questionnaire, and then converted into the weight in unit of kilogram by assuming that each sheet is typical office A4 paper size with a grammage of 80 g/m$^2$.

**Table 3.3** The rate of fuel consumption from traveling with different types of vehicles.

| Type of car | Fuel | Unit | The rate of fuel consumption from traveling |
|---|---|---|---|
| Average cars of all sizes | Benzene | Km/L | 14.763 |
| LPG car | LPG | km/L | 8.929 |
| Bus | Diesel | Km/L | 2.850 |
| Average 4-stroke motorcycles of all sizes | Benzene | Km/L | 37.640 |

The BTS, MRT and CU POP bus do not use fuel.

(3.2.5) Emission factor

Emission factor is the secondary data gathered and obtained from the website of Thailand greenhouse gas management organization (TGO) (TGI, 2019; Styrene et al. 2021)

The emission factors used in the calculations in this study consisted of emission Factors of Electricity and Paper as in Table 3.4

**Table 3.4** The emission factor is derived from secondary data for the carbon footprint assessment.

| Name | Unit | Total Emission factor [kg$CO_2$e/unit] |
|---|---|---|
| Electronic, grid mix 2016-2018; LCIA method IPCC 2013 GWP 100a V1.03 | kWh | 0.4999 |
| Paper | Kg | 0.6677 |
| Mobile Combustion (On road) | | |
| Gas/ Diesel Oil | L | 2.7403 |
| Liquified Petroleum Gas | L | 1.7273 |
| Motor Gasoline | L | 2.2325 |

## 3.3 Data analysis

(3.3.1) Calculation of Carbon footprints

This study estimated the individual carbon footprint as the total GHG emissions based on the energy consumption in class, the energy consumption in transportation, and the amount of paper used in class for each student, as follow: (Roy, R., Potter, S., & Yarrow, K., 2008; Janangkakan, 2011; Li, Tan, & Rackes, 2015)

$$\text{GHG emission} = \Sigma\ (\text{Activity} \times \text{Emission factor}) \qquad (4)$$

The activity was referred to the electric consumptions in class (transportation for MRT/BTC and electric transits in university), the fuel consumption in transportation, and the weight of paper used in class. The corresponding emission factors were retrieved from literature review, as shown in Table 3.3.

The individual carbon footprints were then normalized by hour of study of each student for the purpose of comparisons across class years and learning scenarios.

The calculation of GHG emissions of transportation as shown in the following equation:

$$\text{GHG emission} = (\text{Distance/The rate of fuel consumption from traveling}) \times \text{Emission factor} \ (5)$$

In the case of electric vehicles, calculate with equation (5) based on the principles of the organization's carbon footprint assessment from Thailand greenhouse gas management organization (TGO).(TGI, 2019)

In this present study, the acquisition of activity data is electronic power of electricity, electric power of electric devices or paper weight from the questionnaire survey, the acquisition of Emission factor is the secondary data gathered and obtained from the website of Thailand greenhouse gas management organization (TGO) (TGI, 2019; Styrene et al. 2021)

Table 3.5 shows a summary of student energy behaviors and GHG emission calculation for each type of study.

**Table 3.5** Student energy behaviors and GHG emission calculation summary

<table>
<tr><th rowspan="2">Category</th><th rowspan="2"></th><th colspan="2">Subcategory</th><th colspan="2">Activity</th><th colspan="2">Calculate</th></tr>
<tr><th>Onsite</th><th>Online</th><th>Onsite</th><th>Online</th><th>Onsite</th><th>Online</th></tr>
<tr><td rowspan="3">Academics</td><td>Environmental setting (Classroom)</td><td>Electronic appliances use in classroom</td><td>Electronic appliances use in room/house</td><td>Power for electronic appliances divided by classroom occupancy</td><td>Power for electronic appliances of each respondent.</td><td rowspan="4">GHG/hour for average academic activities and transportation.</td><td rowspan="4">GHG/hour for average academic activities</td></tr>
<tr><td rowspan="2">Studying</td><td colspan="2">Lecture class</td><td colspan="2" rowspan="2">Power for electronic devices use.<br>Number of paper use and Power for printing and photocopying.</td></tr>
<tr><td colspan="2">Self-study</td></tr>
<tr><td>Transportation</td><td>Daily commuting</td><td>Commuting by walk, car, bus, BTS, MRT or CU POP bus</td><td>-</td><td>GHG for Commuting</td><td>-</td></tr>
</table>

3.2.6 Carbon footprint comparisons

This study performed the descriptive analyses to explain underlying patterns of the estimated carbon footprints per student per hour across class years and learning scenarios. This study also performed two-way ANOVA to determine whether there is any significant difference of the average carbon footprints across class years and learning scenarios at a confidence level of 95%.

# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Average of energy consumption for student.

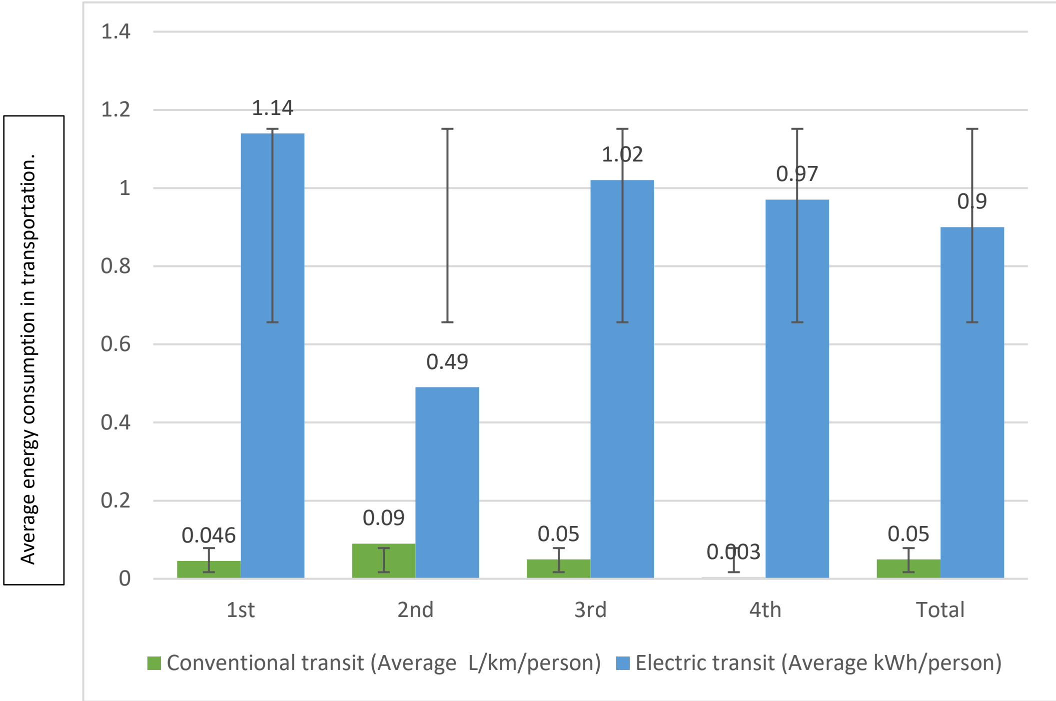
### 4.1.1 The energy consumption in transportation

In the questionnaire, we defined the commute section only for onsite scenario to calculate energy consumption for commuting to university. Table 4.1 indicates that on average, the ratio of respondents using MRT/BTS is the highest at 26.15% and the average travel distance is 26.7±8.10 km. The 4$^{th}$ year students are the most people who use this method of traveling. The ratio of respondents going by CU pop bus, walking and bus is 21.54%, 20.00% and 15.39% respectively, the average travel distance is 4.4±0.28, 2.45±0.58, and 30.55±22.82 km. respectively. The SD value is expected to be more or less depending on the service distance of each vehicle type.

**Table 4.1** Travel method and travel distance for onsite class.

| Travel method to university | Ratio of respondents (%) | Distance (Average±SD, kilometers) |
|---|---|---|
| Walking | 20 | 2.45±0.58 |
| Bicycle | 0 | 0.00±0.00 |
| Motorcycle | 9.23 | 4.23±5.68 |
| Personal car | 6.15 | 35.45±31.21 |
| Taxi | 1.54 | 0.75±1.5 |
| Bus | 15.39 | 30.55±22.82 |
| MRT/BTS | 26.15 | 26.7±8.10 |
| CU POP bus | 21.54 | 4.4±0.28 |

**Figure 4.1** Average energy consumption in transportation.




From Figure 4.1 showing the average energy consumption from traveling by students in the Department of Environmental Science, it was found that the use of a car can be divided into two types, vehicles that use combustion fuels and electric vehicles. where the total energy consumption from a conventional transit is 0.05 liters/km/person and the 2$^{nd}$ year class uses the most energy from this type and 4$^{th}$ year class is the year that uses the least amount of energy from this type of vehicle, only 0.003 liters/km/person. while the total energy consumption from electric transit is 0.90 kWh/person and the year that uses the most energy from this type of car is the 1$^{st}$ year class. The average energy consumption in transport for each class year includes different energy consumption and standard daiviation as shown in Table 4.2

**Table 4.2** Average energy consumption in transportation.

| Year | Combustion cars (Average ± SD L/km/person) | Energy cars (Average ± SD kWh/person) |
|---|---|---|
| 1st | 0.046±0.26 | 1.14±1.28 |
| 2nd | 0.09±0.28 | 0.49±1.12 |
| 3rd | 0.05±0.27 | 1.02±1.21 |
| 4th | 0.003±0.01 | 0.97±1.07 |
| **Total** | 0.05±0.25 | 0.90±1.20 |

4.1.2 The energy consumption in academics

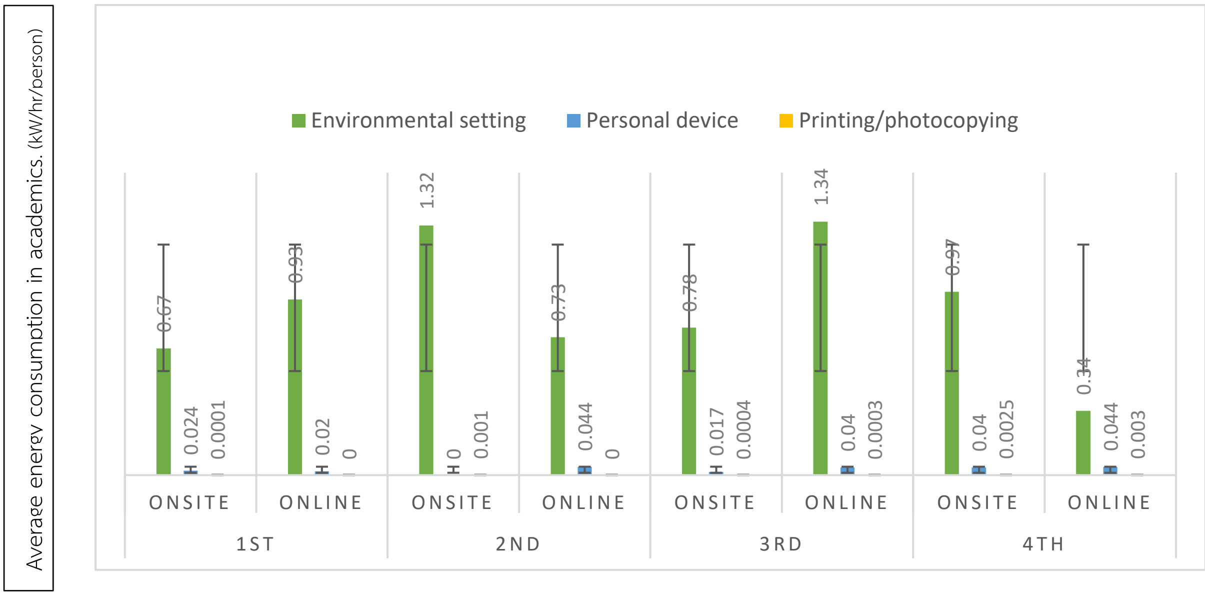
In 2018, global energy-related $CO_2$ emissions got to a historic high of 33.1 Gt (Wang et al., 2020). Energy use is the one of important factors affecting sustainable urban development and is closely related to energy security and global climate change challenges (Meng et al., 2019). Therefore, it is requisite to investigate energy consumption and $CO_2$ emissions.

Table 4.3 Average energy consumption in academics

| Academic | 1st | | 2nd | | 3rd | | 4th | |
|---|---|---|---|---|---|---|---|---|
| | Onsite | Online | Onsite | Online | Onsite | Online | Onsite | Online |
| Environmental setting | 0.67±0.00 | 0.93±1.92 | 1.32±0.00 | 0.73±1.37 | 0.78±0.00 | 1.34±1.35 | 0.97±0.00 | 0.34 ±0.38 |
| Personal device | 0.024±0.02 | 0.020±0.01 | 0.020±0.01 | 0.044±0.021 | 0.017±0.02 | 0.04±0.03 | 0.04±0.04 | 0.044 ±0.025 |
| Printing/ photocopying | 0.0001±0.0002 | $7.7 \times 10^{-5}$ ±0.0002 | 0.001±0.002 | 0.00±0.00 | 0.0004±0.001 | 0.0003 ±0.0005 | 0.0025±0.004 | 0.003± 0.016 |

Note: unit of average energy consumption in academics is kilowatts/hour/person

**Figure 4.2** Average energy consumption in academics.




Average energy consumption in academics by students in all 4 years, classified by type of study. As shown in Table 4.3. Energy consumption in the academic divide by Environmental setting, Personal device and printing/photocopying. which can be shown to be easier to understand as shown in Figure. 4.2

Energy cconsumption of environmental Settings, it was found that the average energy consumption in onsite learning of all classes, the value depends mainly on the number of people in the classroom. If any classroom has a large number of students joining together. The energy consumption per hour of each student will be reduced. 1$^{st}$ year, used energy from environmental setting 0.67 kW/hr./person which is considered the least because it is a year of study at all Mahamakut building, so many students share a room. Average energy consumption from environmental setting of most online learning is less than online learning except for the 2$^{nd}$ year and 4$^{th}$ year because the onsite learning of the 2$^{nd}$ year is the class year which is mainly the year that they study at the Mahamakut Building and the General Science Building. As a result, some subjects have the same number of students in the classroom as they are limited to students in the Department of Environmental Science only. The same is true for the 4th year with limited coursework in the general science building.

Online learning, on the other hand, is that all students study in their own homes or dormitories, so that the use of electricity in this area is not shared with others. It also depends on the student's behavior in using electrical appliances in each year. $4^{th}$ the year that uses energy from the least environmental setting is 0.33 kW/hr./person because it was found that there were students who did not activate both air conditioners and fans. Including the choice to turn on the fan in the study.

The energy consumption of personal devices was found that in the onsite learning, the $3^{rd}$ year was the lowest energy consumption from personal electronic devices, which was 0.017 kW/hour/person. Because students choose to use devices with low power. including a number of students who do not use personal device and it is also related to the number of study hours used. As part of online learning, it is necessary to add equipment for video conferences as well. As a result, for the most part, the average cost of online learning for personal devices is higher than onsite learning.

And the last part is energy consumption for printing and copying. The energy consumption for printing and copying of on-site and online learning is similar. when comparing the hourly average, it was found that the power consumption of printing and photocopying was very low in this area. This is because the behavior of using personal electronic devices in education results in students using less paper.

4.1.3 Amount of papers used in class

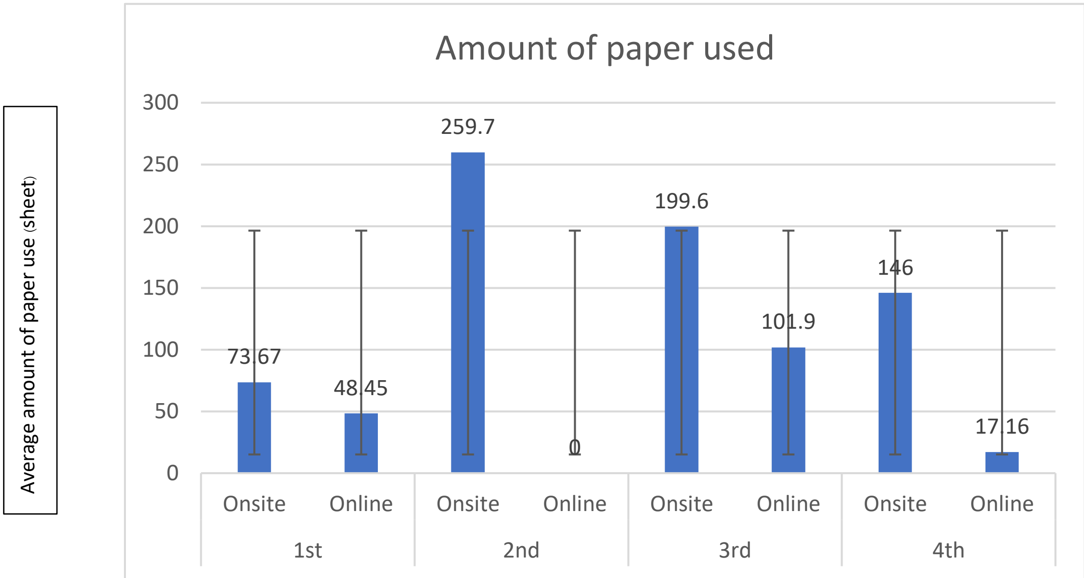
Carbon footprint of used of paper because carbon footprint assessment of printing is also closely related to both of the key issues of the study, namely the use of energy and materials. (Pihkola et al. 2010) Therefore, besides calculating GHG emissions by printing or photocopying, it must be calculated GHG emission from the amount of paper too. The amount of paper used varies according to the behavior of the students in each year. From the survey, it was found that students in the Department of Environmental Science use paper for online learning more than online learning. As shown in the Figure 4.3, it was found that 2nd year students used 259.7

sheets of paper for online learning. Instead of using paper at all. The large standard deviation (Table 4.4) is thought to be due to the large number of non-paper students.

**Table 4.4** Average amount of paper used each type of study and year class.

| Paper use | 1st | | 2nd | | 3rd | | 4th | |
|---|---|---|---|---|---|---|---|---|
| | Onsite | Online | Onsite | Online | Onsite | Online | Onsite | Online |
| Amount of paper used (Avg±sd sheet) | 73.67±99.1 | 48.45±128.6 | 259.7±271.5 | 0.00±0.00 | 199.6±272.6 | 101.9±188.7 | 146 ±127.4 | 17.16 ±36.42 |

**Figure 4.3** Average amount of paper used each type of study and year class.




## 4.2 Student's carbon footprint

### 4.2.1 Total carbon footprint

This study assesses the carbon footprints from measured energy consumptions for onsite and online learning activities. With the scope of travel method and classroom learning only, it was found that Table 4.4 in the onsite class emitted a total GHG of 0.040 $tCO_2e$/hr. caused by learning activities and travelling to university was 87% and 13% respectively. While online learning releases more GHG than 0.050 $tCO_2e$/hr., which is caused by learning only, because it is study at home or dormitory so students do not need to travel to study at the university.

**Table 4.5** total carbon footprint in online and onsite learning of undergraduate program in Environmental Science, Chulalongkorn University.

| Activities | | Onsite | | Online | |
|---|---|---|---|---|---|
| | | $tCO_2e$/hr. | % of total | $tCO_2e$/hr. | % of total |
| Academics | Electronic appliances | 0.032 | 80 | 0.048 | 96 |
| | electronic devices use | 0.0009 | 2 | 0.0013 | 2.6 |
| | Printing/photocopying | 0.002 | 5 | 0.0007 | 1.4 |
| Transportation | | 0.0052 | 13 | 0 | 0 |
| Total | | 0.040 | | 0.050 | |

4.2.1.1 Carbon footprint of energy consumption in transportation

Total GHG emission of energy consumption in transportation was 0.0052 $tCO_2e$/hr. accounts for 13 percent of the carbon footprint of all onsite learning activities. From the survey, it was found that students in the Department of Environmental Science. Popular ways to travel by BTS/MRT.

Most students choose a way to travel by taking the BTS/MRT. This is the way to travel with the lowest carbon footprint next below walking and cycling with zero emissions. From the behavior of choosing the travel method, resulting in the average carbon footprint was 0.05 $tCO_2e$/year, lower than the average carbon footprint of transportation studied at Suan Sunandha University Which was 0.40 $tCO_2e$/year. (Utaraskul 2015) However, this comparison cannot be directly compared. Due to the different number of hours, SSRU reports as per year. including having the different scopes of study but this study was an hourly study of GHG emissions. Still, travel's GHG emissions remain in the same direction, with a relatively small proportion of GHG emissions.

When the change from onsite to online learning, the carbon footprint of travel was less influential. Which corresponds to UK universities' Carbon Footprints during the COVID-19 lockdown found that reducing travel cuts GHG emissions less than expected.(Filimonau et al. 2021)

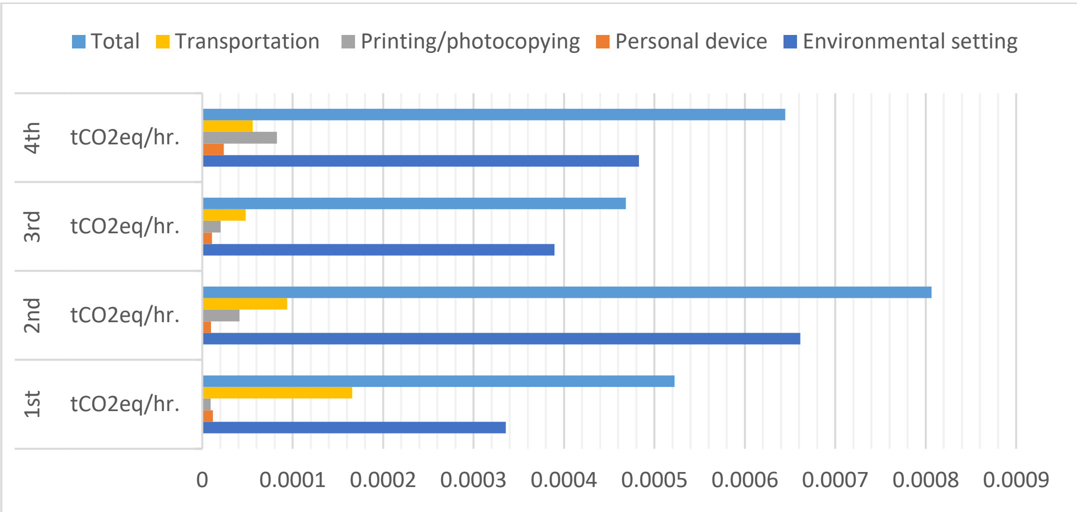
4.2.1.2 Carbon footprint of energy consumption in academics

The key factor that determines GHG emissions in both types of study is energy consumption in academics. Thus, the carbon footprint of energy consumption in the classroom accounts for the largest proportion of both onsite and online learning. The total greenhouse gas emissions of onsite and online learning were 0.0349 and 0.050 $tCO_2e$ respectively, accounting for 87% of onsite learning activities and 100% of online learning activities.

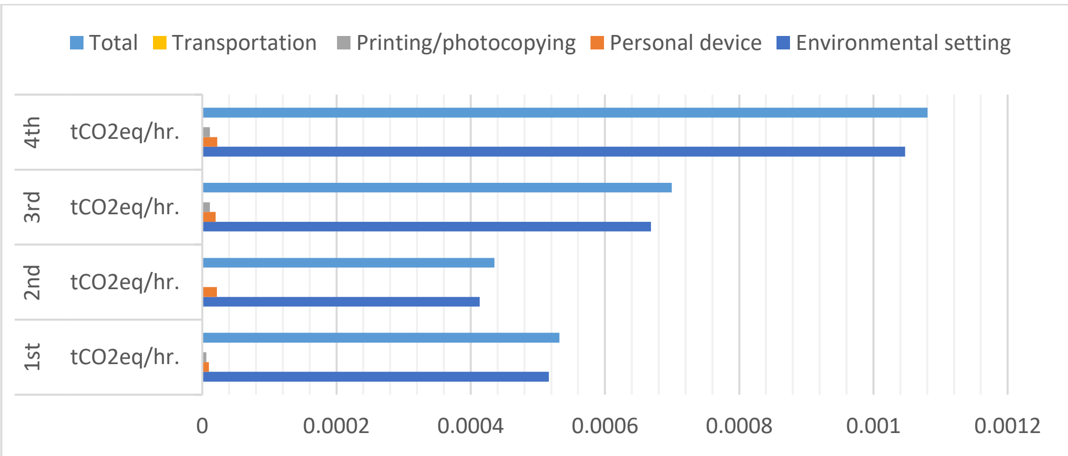
GHG emission by energy consumption in academics are divided into three sections: environmental setting, personal device and printing/photocopying. found that the use of electricity from the environmental setting accounted for the largest share of the greenhouse gas emissions of onsite and online learning, accounting for 80% and 96.88%, respectively. This is consistent with the study of Aroonsrimorakot et al., 2013 that evaluates the carbon footprint of faculty of environment and resource studies, Mahidol University, Salaya Campus, Thailand. Sources that emit the most greenhouse gases are the use of electric energy, including a case study of the department of Environment Engineering, Chulalongkorn University, energy consumption they considered as the biggest source of GHG emissions in the department is the function of the location. The energy consumption in an office is from various electric equipment such as air-conditioning, lighting, computers, and copy machines (Janangkakan, Chavalparit, and Kanchanapiya 2011). The main device that influences GHG emissions in the classroom is air conditioners. As I said This comparison cannot be directly compared. Due to the different number of hours, SSRU's are reported annually. As well as having the different scopes of the study, SSRU's study studies student behavior throughout the day. But this study was studied only in the classroom and lesson review. The trend of student's behavior is different resulting in the average GHG emissions of electrical appliances of Environmental Science students approximately 0.28 $tCO_2e$/year, which is approximately 1.05 $tCO_2e$/year less than the SSRU study. (Utaraskul 2015)

4.2.2 Carbon Footprint for each year class

**Figure 4.4** Average GHGs emission of behavior surveys data from onsite (A) and online (B) learning.




(A)




(B)

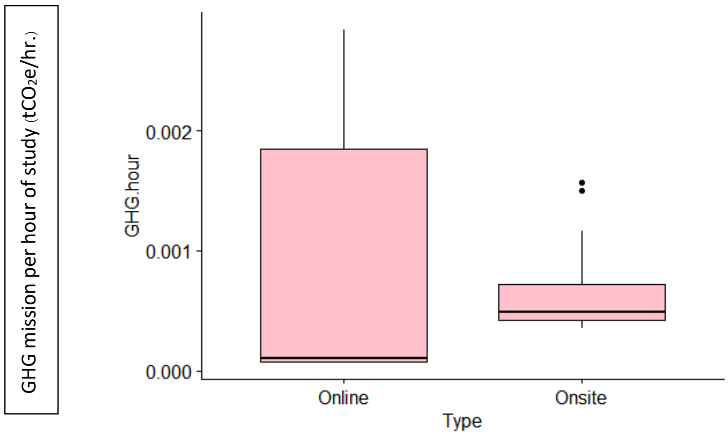
Figure 4.4A shows the onsite learning behavior surveys data reveal that the primary reasons for these differences are that academics terms, especially environmental setting, and paper use. The difference in GHG emissions of environmental settings in classrooms is due to different study hours and the number of students in the classroom for each year class. From the calculations, it is found that $1^{st}$ year emits the lowest carbon per hour. Because the number of students studying in each subject room is largest. in terms of paper usage students in each year use paper in their studies clearly differently. $3^{rd}$ and $4^{th}$ years are the years that use a lot of paper. Because there are still some students who do not use electronic devices in their studies. And most choose the proportion of GHG emitting photocopies overprinting.

In the online learning (Figure 4.4B) term, the academics part is still the primary reason for differences especially electronic appliances use and electronic devices used. Because the $4^{th}$ year is the year that use air conditioning throughout the study hours the most. resulted in this year class with the highest GHG emissions. While the $2^{nd}$ year class is the year with the lowest GHG emissions, this is due to the fact that most of the study environments are fan-intensive throughout study hours. as well as the use of low-power air conditioners in regular onsite learning.

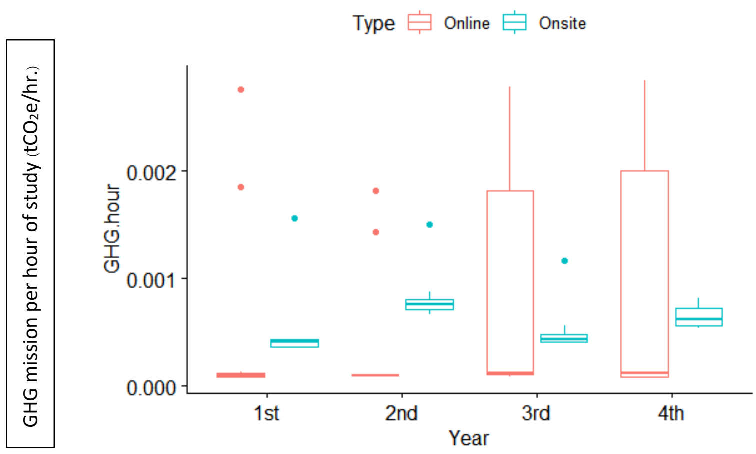
Most of the electronic devices used in classrooms have similar electric power. Because most students use various iPad models in learning but in online learning, Additional electronic equipment for video conferences is required. Each person uses a different device, for example, a computer, a laptop, or an iPad, etc. resulting in GHG emissions for the use of different electronic devices. $1^{st}$ year is the year in which GHG minimal emitted due to the use of low-power iPads for studying, taking notes, and self-study. $4^{nd}$ year is the year in which the laptop is used mainly for video conferencing and for self-study. Therefore, it has the highest proportion of GHG emissions from electronic devices.

### 4.3 Carbon footprint comparison

Comparison of GHG emissions between the type of study, year class, and both can be briefly explained from Figure 4.5




(A)




(B)

**Figure 4.5** Box plots of the comparison between GHG/hour emissions and (A) the class type and (B) and both the type of study and the year class.

The statistical analysis of GHG emissions for type of study of Department of Environmental Science, Chulalongkorn university (Figure 4.5A) shown that online learning has highest emission and we can see outliers of GHG emissions in on-site learning. This is because respondents travel long distances by personal cars.

I analyzed significant differences of carbon footprint between the type of study and year class of student in Department of Environmental Science, Chulalongkorn university by 2-way ANOVA (Figure 4.5B) and found that GHG emission of the type of study not significant different ($P = 0.247$). GHG emission of each year was not significant different ($P = 0.157$) and for the GHG emission of both the type of study and the year class was not significant different ($P = 0.201$).

## 4.4 Carbon reduction and suggestion

the university can undertake actions to help reduce the average student's carbon footprint. First and foremost, the university should allocate classrooms to suit the number of students studying in that course. including choosing the electricity that saves electricity as much as possible. Air conditioners have the greatest influence on the power consumption in the classroom, so choosing the size of the air conditioner with the right power is appropriate for the size of the room. In online class, students should reduce the use of air conditioners. Adapted to use a fan instead, including drinking water to cool down.

In addition, although the use of paper is the lowest proportion of emissions. But still influences carbon emissions in classes universities should campaign to reduce the use of paper. which may ask for cooperation from the course instructor or find incentives to campaign for students to print paper rather than photocopying. Results indicate that reducing paper consumption behavior is strongly influenced by habit and, marginally significant, by intention. (Sopha 2013)

In transportation, universities can reduce travel-related carbon emissions by developing walkable campus communities. The facility is located near the public transit station. and arrange for a suitable shuttle service traveling by train with a low price will be an incentive for students to use it.

In addition to an awareness campaign to try to influence student behavior by universities, educating and raising human awareness is another key factor in reducing GHG emissions.

# CHAPTER V

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

This study estimates the energy consumptions for onsite and online learning activities in the undergraduate program in Environmental Science, Faculty of Science, Chulalongkorn University. And assess the carbon footprints from measured energy consumptions for both learning activities. It was found that energy consumption had an effect on the GHG emission rate.

In terms of onsite learning, the energy consumption in transportation was found that most of the students popular to use BTS/MRT for traveling at 26.15% and the travel distance are 26.7±8.10 km and no use of bicycles to travel at all. The total energy consumption from a conventional transit is 0.05 liters/km/person while the total energy consumption from electric transit is 0.90 kWh/person. And in terms of using electricity in academic is the most power consumption that divided into 3 parts: environmental setting, personal devices and printing/photocopying by Environment setting considered the largest proportion. When using energy consumption to find the carbon footprint, it was found that the onsite class emitted a total GHG of 0.040 $tCO_2e$/hr. caused by learning activities and traveling to university was 87% and 13% respectively. When stratified by years class, it was found that the $2^{nd}$ year was the year with the highest average carbon footprint, 0.00081 $tCO_2e$/hr. This is followed by $4^{th}$ year, $1^{st}$ year, and $3^{rd}$ year with average carbon footprints 0.00064, 0.00052, and 0.00047 $tCO_2e$/hr. respectively.

In terms of online learning, this part does not commute calculate because of learning at home or a dormitory. The most online learning power consumption is energy consumption from academics divided into 3 parts: environmental setting, personal devices and printing/photocopying by environment setting still the largest proportion. The carbon footprint from energy consumption found that the online class emitted a total GHG of 0.050 $tCO_2e$/hr., which is caused by learning only. When stratified by years class the $4^{th}$ year was the year with the highest average carbon footprint, 0.0011 tCO2e/hr. This is followed by 3rd year, 1st year, and 2nd year with carbon footprints 0.0007, 0.0005, and 0.0004 $tCO_2e$/hr. respectively.

From the 2-way ANOVA data differentiation, it was found that the mean comparison of each data was not significantly different all of them therefore, the type of study and the year of study does not affect GHG emission.

It is likely that the carbon footprint in future studies will decrease as more organizations are now paying more attention to environmental impact. As a result, some electronic devices and appliances in the classroom have less power. Including the behavior of using paper that has decreased as the use of electronic devices increases. However, the carbon reduction in universities requires cooperation from all sectors. whether from the university or the cooperation of personnel in the university.

## 5.2 Recommendations

To assess the carbon footprints in classroom or university in the future assess the carbon footprints may increase the number of respondents to a wider. It covers personnel from all sectors, whether it is students, professors, or employees in the department. including expanding the scope to cover practical learning. In addition, there may be an onsite measurement of the electrical power by measuring the actual power instead of looking at the product label or may be use the power from the electricity bill.

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# APPENDIX

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Example for questionnaire survey (2 Year class)

**Part 1** Video explaining the questionnaire

Have you watched the video for the questionnaire?

( ) Yes                    ( ) No

**Part 2** Questionnaire explanation

**Part 3** Learning activities in the onsite classroom of the students of the Department of Environmental Science, Faculty of Science Chulalongkorn University.

1. Accommodation and transportation

1.1 In the case that the university opens for teaching as usual, where do you live? Please specify the dormitory name or house number clearly.

_____________________________________________________________________________.

1.2 What method do you use to travel to and from the university as the main method?

( ) Walking

( ) Public transport

( ) Driving/Passenger Cars, Motorcycles

1.3 From item 1.2, what type of vehicle did you choose?

( ) Walking

( ) Bicycle

( ) Motorcycle

( ) Personal car

( ) Taxi

( ) Bus

( ) MRT/BTS

( ) CU POP BUS/ Muvmi

2. Learning activities in the lecture classroom

2.1 What kind of electronic device do you mainly use for studying?

( ) Not used

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) other ________________________________________.

2.2 If you do not use only the electronic device 2.1 in the study alone What additional electronic devices do you use?

( ) use only one type

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) other ________________________________________.

2.3 Please specify the proportion of use 'Main Electronic Devices to Other Electronic Devices' in the Lecture Classroom

| | 100%: 0% | 75%: 25% | 50%: 50% |
|---|---|---|---|
| Gen phys 1 (2304101) | | | |

| | | | |
|---|---|---|---|
| Calculus 1 (2301113) | | | |
| Gen Chem 1 (2302111) | | | |
| Gen Bio 1 (2303101) | | | |
| Calculus 2 (2301114) | | | |
| Com prog (2301170) | | | |
| Gen chem 2 (2302112) | | | |
| Gen Bio 2 (2305101) | | | |
| Gen Phys 2 (2304101) | | | |

2.4 You use paper. (Only teaching documents not counting notepaper) in the lecture room of any subject and use approximately how many sheets of paper per term.

| | 0 sheet | 1-50 sheets | 51-100 sheets | 101-150 sheets | 151-200 sheets | More than 200 sheets |
|---|---|---|---|---|---|---|
| Gen phys 1 (2304101) | | | | | | |
| Calculus 1 (2301113) | | | | | | |
| Gen Chem 1 (2302111) | | | | | | |
| Gen Bio 1 (2303101) | | | | | | |
| Calculus 2 (2301114) | | | | | | |
| Com prog (2301170) | | | | | | |
| Gen chem 2 (2302112) | | | | | | |
| Gen Bio 2 (2305101) | | | | | | |
| Gen Phys 2 (2304101) | | | | | | |

If using more than 200 sheets, please specify the approximate amount of paper used per term.

________________________________________________________________________.

2.5 In the case of using paper (Only teaching documents Excluding notepaper) How much is the proportion of 'print paper per copy'?

| | 0%: 0% | 0%: 100% | 25%: 75% | 50%: 50% | 75%:25% | 100%: 0% |
|---|---|---|---|---|---|---|
| Gen phys 1 (2304101) | | | | | | |
| Calculus 1 (2301113) | | | | | | |
| Gen Chem 1 (2302111) | | | | | | |
| Gen Bio 1 (2303101) | | | | | | |
| Calculus 2 (2301114) | | | | | | |
| Com prog (2301170) | | | | | | |
| Gen chem 2 (2302112) | | | | | | |
| Gen Bio 2 (2305101) | | | | | | |
| Gen Phys 2 (2304101) | | | | | | |

3. Self-study activities (Self-learning)

self-learning (self-learning) is divided into homework. and reviewing the lessons of each course.

3.1 What electronic device do you mainly use for homework and lesson review?

( ) Not used

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ________________________________________.

3.2 If you do not use only the electronic devices in item 3.1 in learning What additional electronic devices do you use?

( ) use only one type

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ________________________________________.

3.3 Please specify usage proportion. 'Main electronic devices to other electronic devices' in the lesson review.

| | 100%: 0% | 75%: 25% | 50%: 50% |
|---|---|---|---|
| Gen phys 1 (2304101) | | | |
| Calculus 1 (2301113) | | | |
| Gen Chem 1 (2302111) | | | |
| Gen Bio 1 (2303101) | | | |
| Calculus 2 (2301114) | | | |
| Com prog (2301170) | | | |
| Gen chem 2 (2302112) | | | |
| Gen Bio 2 (2305101) | | | |
| Gen Phys 2 (2304101) | | | |

3.4 How many sheets of paper do you use to send homework and review lessons in each course per term? (Only teaching documents does not include notepaper)

| | 0 sheet | 1-50 sheets | 51-100 sheets | 101-150 sheets | 151-200 sheets | More than 200 sheets |
|---|---|---|---|---|---|---|
| Gen phys 1 (2304101) | | | | | | |
| Calculus 1 (2301113) | | | | | | |
| Gen Chem 1 (2302111) | | | | | | |
| Gen Bio 1 (2303101) | | | | | | |
| Calculus 2 (2301114) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Com prog (2301170) | | | | | | |
| Gen chem 2 (2302112) | | | | | | |
| Gen Bio 2 (2305101) | | | | | | |
| Gen Phys 2 (2304101) | | | | | | |

If using more than 200 sheets, please specify the approximate amount of paper used per term.

____________________________________________________________________________.

2.5 In the case of using paper (Only teaching documents Excluding notepaper) How much is the proportion of 'print paper per copy'?

| | 0%: 0% | 0%: 100% | 25%: 75% | 50%: 50% | 75%:25% | 100%: 0% |
|---|---|---|---|---|---|---|
| Gen phys 1 (2304101) | | | | | | |
| Calculus 1 (2301113) | | | | | | |
| Gen Chem 1 (2302111) | | | | | | |
| Gen Bio 1 (2303101) | | | | | | |
| Calculus 2 (2301114) | | | | | | |
| Com prog (2301170) | | | | | | |
| Gen chem 2 (2302112) | | | | | | |
| Gen Bio 2 (2305101) | | | | | | |
| Gen Phys 2 (2304101) | | | | | | |

**Part 4** Learning activities in the online classroom of the students of the Department of Environmental Science, Faculty of Science Chulalongkorn University.

4. Learning environment

4.1 In the case of 'most' online teaching, what is the learning environment? (Requires you to study at your dormitory/home)

( ) Turn on air conditioning throughout the study hours.

( ) Turn on the fan during study hours.

( ) Both air conditioner and fan are not turned on.

4.2 In the event that you open the air conditioner How many btu (btu) is open air conditioner? (If the air conditioner is not turned on, can - at all)

______________________________________________________________________________.

5. Learning activities in the lecture classroom

5.1 Which electronic devices do students mainly use for online learning? (device using video conference)

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ________________________________________.

5.2 Any student use of electronic devices to take notes as the main content.

( ) Not used

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ________________________________________.

5.3 If you do not use only the electronic device item 5.2 in learning What additional electronic devices do you use?

( ) use only one type

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) other ________________________________________.

5.4 Please specify the proportion of use 'Main Electronic Devices to Other Electronic Devices' in the Lecture Classroom

| | 100%: 0% | 75%: 25% | 50%: 50% |
|---|---|---|---|
| Anal chem 1(2302241) | | | |
| Fund solid waste (2308366) | | | |
| Sci research meth (2308498) | | | |
| Gen biochem (2301310) | | | |
| Environmental soil sci (2308451) | | | |
| Fund a poll (2308309) | | | |
| Intro Haz Waste (2308320) | | | |
| ENV Noise (2308357) | | | |
| Envi remed tect (2308418) | | | |
| FUND RES/ENVI MGT (2308401) | | | |
| ENV MGT SYS (2308421) | | | |
| Project Proposal (2308399) | | | |

5.5 You use paper. (Only teaching documents not counting notepaper) in the lecture room of any subject and use approximately how many sheets of paper per term.

| | 0 sheet | 1-50 sheets | 51-100 sheets | 101-150 sheets | 151-200 sheets | More than 200 sheets |
|---|---|---|---|---|---|---|
| Anal chem 1(2302241) | | | | | | |
| Fund solid waste (2308366) | | | | | | |
| Sci research meth (2308498) | | | | | | |
| Gen biochem (2301310) | | | | | | |
| Environmental soil sci (2308451) | | | | | | |
| Fund a poll (2308309) | | | | | | |
| Intro Haz Waste (2308320) | | | | | | |
| ENV Noise (2308357) | | | | | | |
| Envi remed tect (2308418) | | | | | | |
| FUND RES/ENVI MGT (2308401) | | | | | | |
| ENV MGT SYS (2308421) | | | | | | |
| Project Proposal (2308399) | | | | | | |

If using more than 200 sheets, please specify the approximate amount of paper used per term.

__________________________________________________________________________.

5.6 In the case of using paper (Only teaching documents Excluding notepaper) How much is the proportion of 'print paper per copy'?

| | 0%: 0% | 0%: 100% | 25%: 75% | 50%: 50% | 75%:25% | 100%: 0% |
|---|---|---|---|---|---|---|
| Anal chem 1(2302241) | | | | | | |
| Fund solid waste (2308366) | | | | | | |
| Sci research meth (2308498) | | | | | | |
| Gen biochem (2301310) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Environmental soil sci (2308451) | | | | | | |
| Fund a poll (2308309) | | | | | | |
| Intro Haz Waste (2308320) | | | | | | |
| ENV Noise (2308357) | | | | | | |
| Envi remed tect (2308418) | | | | | | |
| FUND RES/ENVI MGT (2308401) | | | | | | |
| ENV MGT SYS (2308421) | | | | | | |
| Project Proposal (2308399) | | | | | | |

6. Self-study activities (Self-learning)

self-learning (self-learning) is divided into homework. and reviewing the lessons of each course.

6.1 What electronic device do you mainly use for homework and lesson review?

( ) Not used

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ________________________________________.

6.2 If you do not use only the electronic devices in item 3.1 in learning What additional electronic devices do you use?

( ) use only one type

( ) Ipad

( ) Ipad mini

( ) Ipad air

( ) Ipad pro

( ) Laptop

( ) Desktop

( ) other ___________________________________________.

6.3 Please specify usage proportion. 'Main electronic devices to other electronic devices' in the lesson review.

| | 100%: 0% | 75%: 25% | 50%: 50% |
|---|---|---|---|
| Anal chem 1(2302241) | | | |
| Fund solid waste (2308366) | | | |
| Sci research meth (2308498) | | | |
| Gen biochem (2301310) | | | |
| Environmental soil sci (2308451) | | | |
| Fund a poll (2308309) | | | |
| Intro Haz Waste (2308320) | | | |
| ENV Noise (2308357) | | | |
| Envi remed tect (2308418) | | | |
| FUND RES/ENVI MGT (2308401) | | | |
| ENV MGT SYS (2308421) | | | |
| Project Proposal (2308399) | | | |

6.4 How many sheets of paper do you use to send homework and review lessons in each course per term? (Only teaching documents does not include notepaper)

| | 0 sheet | 1-50 sheets | 51-100 sheets | 101-150 sheets | 151-200 sheets | More than 200 sheets |
|---|---|---|---|---|---|---|
| Anal chem 1(2302241) | | | | | | |
| Fund solid waste (2308366) | | | | | | |
| Sci research meth (2308498) | | | | | | |
| Gen biochem (2301310) | | | | | | |
| Environmental soil sci (2308451) | | | | | | |
| Fund a poll (2308309) | | | | | | |
| Intro Haz Waste (2308320) | | | | | | |
| ENV Noise (2308357) | | | | | | |
| Envi remed tect (2308418) | | | | | | |
| FUND RES/ENVI MGT (2308401) | | | | | | |
| ENV MGT SYS (2308421) | | | | | | |
| Project Proposal (2308399) | | | | | | |

If using more than 200 sheets, please specify the approximate amount of paper used per term.

_____________________________________________________________________.

6.5 In the case of using paper (Only teaching documents Excluding notepaper) How much is the proportion of 'print paper per copy'?

| | 0%: 0% | 0%: 100% | 25%: 75% | 50%: 50% | 75%:25% | 100%: 0% |
|---|---|---|---|---|---|---|
| Anal chem 1(2302241) | | | | | | |
| Fund solid waste (2308366) | | | | | | |
| Sci research meth (2308498) | | | | | | |
| Gen biochem (2301310) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Environmental soil sci (2308451) | | | | | | |
| Fund a poll (2308309) | | | | | | |
| Intro Haz Waste (2308320) | | | | | | |
| ENV Noise (2308357) | | | | | | |
| Envi remed tect (2308418) | | | | | | |
| FUND RES/ENVI MGT (2308401) | | | | | | |
| ENV MGT SYS (2308421) | | | | | | |
| Project Proposal (2308399) | | | | | | |

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