Scope 3 Greenhouse Gas Emission

An Interactive Qualifying Project Report

Submitted to the Faculty of

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Abstract

This study determined an initial estimate of the Scope 3 greenhouse gas emissions caused by the travel of WPI faculty, staff, and students. The collection of data on transportation-related Scope 3 carbon emissions of Worcester Polytechnic Institute's students, faculty, and staff, in order to calculate WPI's carbon footprint, is important to making the university sustainable. We collected the data on student, faculty and staff travel using the data we got from the WPI's zip code file, surveys and provided it as the input to University of New Hampshire's campus carbon calculator (CCC). The output generated by the calculator is the amount of GHG emissions in metric tons of carbon dioxide. This amount constitutes WPI's carbon footprint, which we used as a means to compare with the emissions from Scope 1 and Scope 2 emissions on campus. We were able to recognize the effects carbon emission causing from all transportation-related Scope 3 emissions for WPI. We estimated and recorded WPI's Scope 3 emissions for the first time in WPI's sustainability projects and made recommendations for reducing transportation-related Scope 3 carbon emissions and getting a more accurate data for projects which need a study of our report. Using the results of this paper which is 26,500 tonnes of CO_2 and comparing it with other emission sources, WPI will be able to set reduction goals on its greenhouse gas emissions and become a more sustainable institution.

1. Introduction

Academic institutions play a vital role in helping the world adapt to a changing planet and to challenging issues such as the climate change which continues unabated. Rising global temperatures are expected to raise sea levels, and change precipitation and other climate conditions. Changing regional climate is projected to alter forests, crop yields, and water supplies. It can also affect human health, animals and many types of ecosystems. According to the statements by the United Nations Intergovernmental Panel on Climate Change (IPCC), humans are the main cause of global warming since it is the people who have been putting greenhouse gases into the atmosphere causing global temperatures to rise [1]. So, to keep track of the greenhouse gas emissions has never been more necessary.

Institutions of higher education are largely self-contained. Many have their own power plants, dining areas, transportation circuits, water systems and healthcare services which upon operation can cause a lot of global pollution. This understanding increases awareness to the institutions for environmental impacts of greenhouse gas emissions and transforms the concerns of the impact into action. In this study, we will display a broad analysis on WPI Scope 3 emissions. The contributors to the GHG emissions include Scope 1, 2, and 3 emissions [3].

Scope 1 includes direct emissions from sources owned or controlled by the university and includes emissions from mobile combustion, stationary combustion, process emissions, and fugitive emissions. Scope 2 consists of indirect emissions from purchased electricity and purchased thermal energy such as heated or chilled water. Scope 3 emissions are indirect emissions from all other sources that occur as the results of the university's operations but occur from sources not owned or controlled by the university such as wastewater management, water collection, and management, transportation-commuting, transportation-business, procurement of goods or services and supply chain.

For our Scope 3 emissions project, we will be measuring the travel-related CO_2 emissions. Upon completing our project, we can implement the WPI sustainability goals with our results from this project by increasing awareness of the environmental impacts of Scope 3 emissions, contributing financial and environmental sustainability and resilience of WPI and creating potential IQP opportunities on campus.

2. Goals and Deliverables

The main goal to be accomplished by this project is to provide an estimated amount of CO_2 equivalent emitted from Scope 3 sources for WPI. In this report, the constraints of the Scope 3 include (1) faculty, staff, and students commuting, (2) Air and road travel of international students/ out-of-state students, (3) Global Project Programs (IQPs and MQPs) and (4) faculty and staff business travel. Other major deliverables are measurements, surveys and calculation methods that can be implemented in future Scope 3 annual reports.

Since it will be the first report to account and measure the WPI Scope 3 emission, the report document itself will be a standard benchmark for further Scope 3 projects. This report will offer a comparison between WPI's sustainability performance and those of other institutions. Long-term outcomes include-

1) Increase awareness of the environmental impacts of Scope 3 emissions,
2) Contribute to the financial and environmental sustainability and resilience of the institutions,
3) Cost savings through reduction of emissions sustainably,
4) Persuade students to contribute to further sustainability projects locally and worldwide,
5) Create potential IQP opportunities on campus.

3. Background

This section explains the relevant background knowledge on the following topics: the general explanation of Greenhouse Gas (GHG), the consequences of GHG emissions, basic information of GHG protocols and international climate agreements, the definition of different GHG emission scopes, previous Scope 3 projects of other institutions/colleges and the WPI Sustainability Plan.

3.1 Greenhouse Gas (GHG)

Greenhouse Gas (GHG) comprises of any gaseous compounds that are capable of absorbing infrared radiation [2]. Some of the examples of GHG include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. GHG can enter into the atmosphere as a result of (1) natural activities such as decomposition of organic matters or (2) man-made activities such as the burning of fossil fuel and agriculture.

The "greenhouse effect" is the effect of atmospheric gases like carbon dioxide absorbing energy from the sun and earth and "trapping" it near the Earth's surface, warming the Earth to a temperature range that is hospitable for life. GHG is released into the atmosphere, it absorbs infrared radiation from the sunlight and transforms the energy into heat energy. The greenhouse effect increases the temperature of the Earth by trapping heat in our atmosphere. This keeps the temperature of the Earth higher than it would be if direct heating by the Sun was the only source of warming. When sunlight reaches the surface of the Earth, some of it is absorbed which warms the ground and some bounces back to space as heat. Greenhouse gases that are in the atmosphere absorb and then redirect some of this heat back towards the Earth. The greenhouse effect is a major factor in keeping the Earth warm because it keeps some of the planet's heat that would otherwise escape from the atmosphere out to space. In fact, without the greenhouse effect the Earth's average global temperature would be much colder and life on Earth as we know it would not be possible. In the early 1800s, “Greenhouse effect” is considered as a natural phenomenon [3]. However, due to the industrialization during the past two centuries, there has been a dramatic increase in GHG into the atmosphere [2]. This creates an imbalance between the input and the output of Earth’s energy, making the Earth’s temperature to rise.

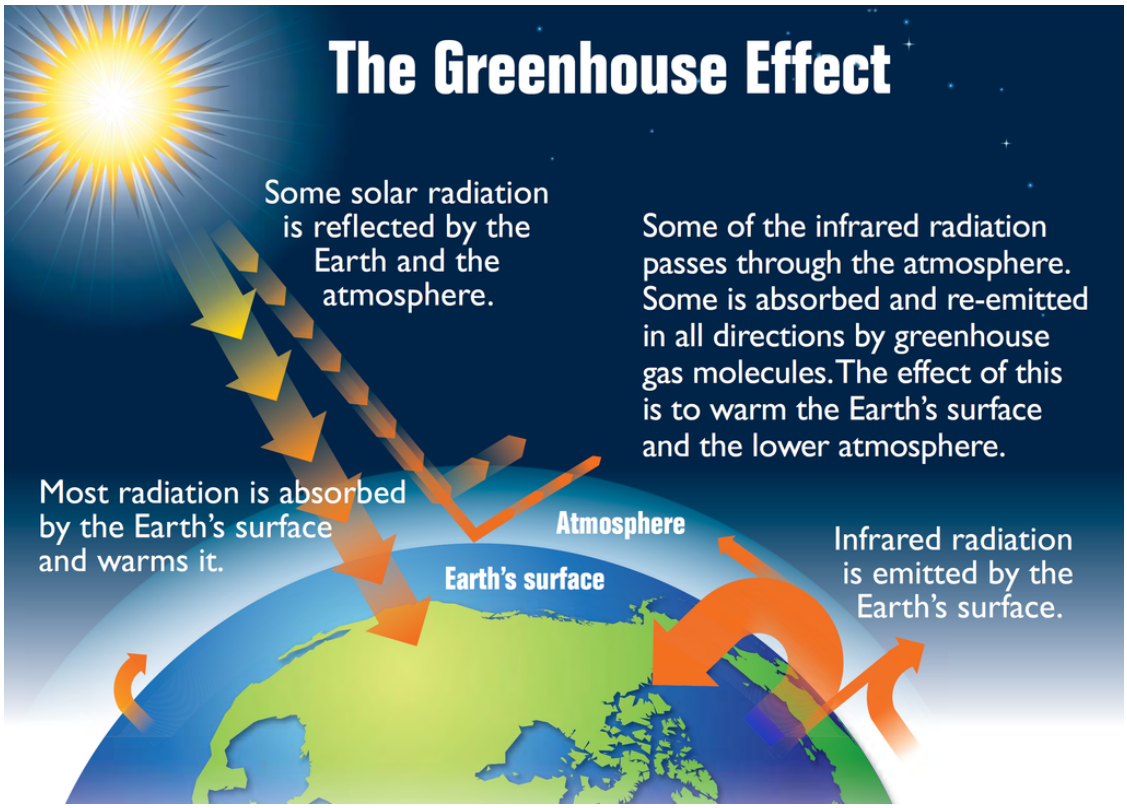


Figure 3.1 Schematic Diagram of Greenhouse Effect [30]

Since all of the GHGs have different lifetimes and rates of heat absorption, Global Warming Potential (GWP) is used as a parameter to compare the impact of different GHGs [5]. GWP is measured by the amount of energy emitted by 1 ton of a gas, relative to the energy emitted by 1 ton of carbon dioxide (CO_2) in a certain period of time [*EPA*]. According to EPA, GWP of different gases are usually measured within 100-year time. Carbon Dioxide Equivalent (CO_2e) is also a unit of measurement for carbon footprints of different GHGs using carbon dioxide as a benchmark [5]. Relationship between GWP and CO_2e is described as-

Amount of GHG x GWP = Amount CO_2e

For example, if 2 tons of methane (GWP =28) is produced from a factory, it is equivalent to producing 48 tons of CO_2

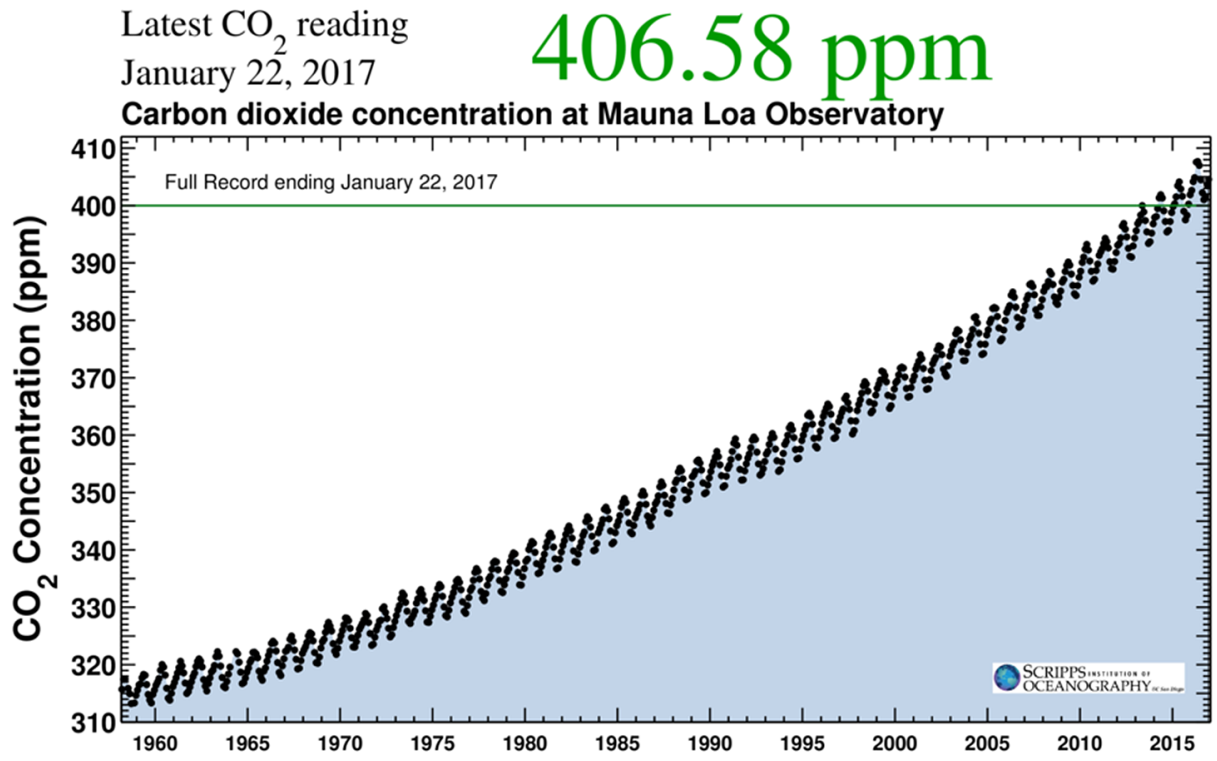
2 tons of methane x 28 = 28 tons of CO_2e

Table 3.1 Comparison of Global Warming Potential of Different Greenhouse Gases [14]

Common Name of GHGs	Chemical Formula	How it's produced	100-year time Global Warming Potential
Carbon Dioxide	CO_2	Burning of fossil fuel, Solid Waste (Tree, Wood Products), Deforestation, Soil Degradation	1
Methane	CH_4	Livestock, Agriculture, Production of Oil and natural gas, Organic Decay and Water	28-36
Nitrous Oxide	N_2O	Agricultural and Industrial Activities, Combustion of fossil fuel and waste	265-298
Fluorinated Gases	HFCs, PFCs, SF_6	Industrial Processes, commercial and household uses	-varies- With the highest value of 23500

3.1.1 GHG and Consequences

Since the industrial revolution in the 1800s, GHG concentration in the atmosphere has increased significantly. Figure 3.2 shows the concentration of naturally occurring GHG (Carbon Dioxide, Methane and Nitrous Oxide) in the atmosphere for the past 2000 years. Before the mid-1800s, the concentrations of CO_2 and CH_4 have never exceeded to 290 ppm and 790 ppb, respectively. Changes in GHG concentration in the atmosphere can influence the Earth's temperature [14]. According to NASA, the average Earth's temperature has increased by 1.7°F since 1880 [14]. The increase in Earth's surface temperature can trigger considerable amount of environmental alterations, such as melting of ice sheets, rising of sea-levels, weather anomaly, and temperature fluctuations.



ppm = parts per million

Figure 3.2 Concentration of carbon dioxide in the atmosphere [34].

3.2 Efforts to Quantify Greenhouse Gases

It is only after the 1970s that people became more aware of global warming and climate change [7]. Since then, it is crucial to find solutions and plans to reverse/ slow down the adverse global warming effects. One of the necessary steps is to account and report GHG emissions from different organizations and businesses [4].

In 1998, with the purpose of GHG reduction, GHG Protocol was created by the partnership of the World Resources Institute (WRI) and World Business Council (WBC). The aim of the GHG Protocol is to help identify and report the GHG emission sources. It provides standards, guidance, and tools to measure GHG emissions for different types of organizations. GHG Protocol is also responsible for developing internationally accepted and inclusive frameworks with transparent and credible manner [27].

GHG Protocol also breaks down the sources of emission into three different categories. These categories are known as Scope 1, Scope 2 and Scope 3.

Scope 1 includes direct emission sources that are owned or controlled by the organization. For example, combustion of fossil fuel for heating, combustion of fleet vehicles owned by organizations, usage of refrigerants and fertilizers.

Scope 2 consists of indirect energy sources. This includes consumption of electricity, steam, heat or cooling that is purchased from energy conversion of another organization.

Scope 3 comprises of emissions that result from the consequences of the organization's activities which are not controlled by the organization. Scope 3 covers all emissions which are not included in direct fuel consumption (Scope 1) and indirect fuel consumption (Scope 2). Since Scope 3 emission is not directly associated with the organization, this category has the potential of double counting the emission data making it less accurate [16].

According to AECOM (architecture, engineering, construction, operations, and management) technology corporation, sources of Scope 3 emissions include [16]-

1. Water supply
2. Wastewater management
3. Water collection and management
4. Transportation-Commuting
5. Transportation-Business
6. Procurement of goods or services
7. Supply chain

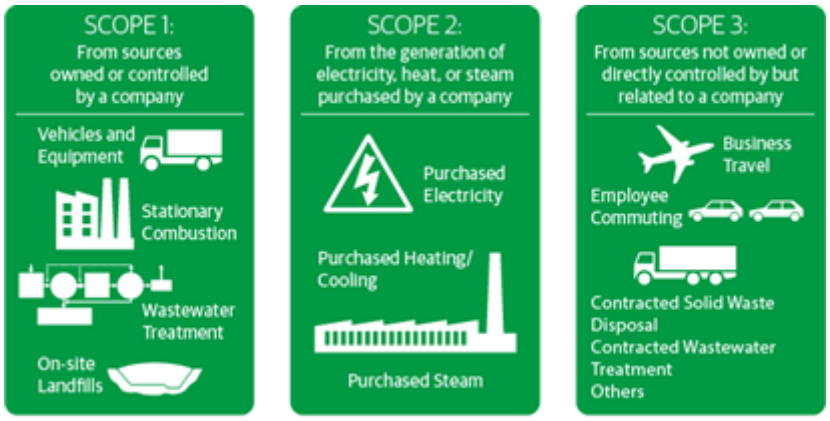


Figure 3.3 Sources of GHG for different scopes [21]

3.3 International Protocols/Agreements for GHG Reduction

3.3.1 Kyoto Protocol

The Kyoto Protocol was one of the first international climate change agreement, which is an extension of UNFCCC (United Nations Framework Convention on Climate Change) in 1997. It was created with the aim of setting a target for GHG reduction.

In the Kyoto Protocol, it is concluded that the developed countries hold greater responsibilities for the high-level GHG emission due to more than 150 years of industrial development. According to the Protocol, industrialized countries (developed countries) agreed to reduce their GHG emissions to 5.2% in 2000 and 29% in 2010 based on 1990 emission data [17]. This agreement came into force in 2005. 127 countries (the US not included) ratified the agreement [18].

Figure 3.4 Agreement Status of Kyoto Protocol (2005) [17].

3.3.2 Paris Agreement

In December 2015, the Paris Agreement was created by UNFCCC with the purpose of intensifying the climate change response. The agreement was to bring all the nations together to build up a strategy to combat climate change on a global scale and, to prevent the global temperature rise of 2°C.

Since Paris Agreement came to force on 4th November 2016, 146 countries (the US not included in final ratification) have ratified the agreement [19]. According to the agreement, all parties (countries) are required to report their GHG emissions data and Implementation Strategy. With the collective efforts of different countries, Paris Agreement aims to increase the ability to address climate change by providing assistance financially and technologically. This agreement also offers transparent frameworks that are compatible with both developed and developing countries.

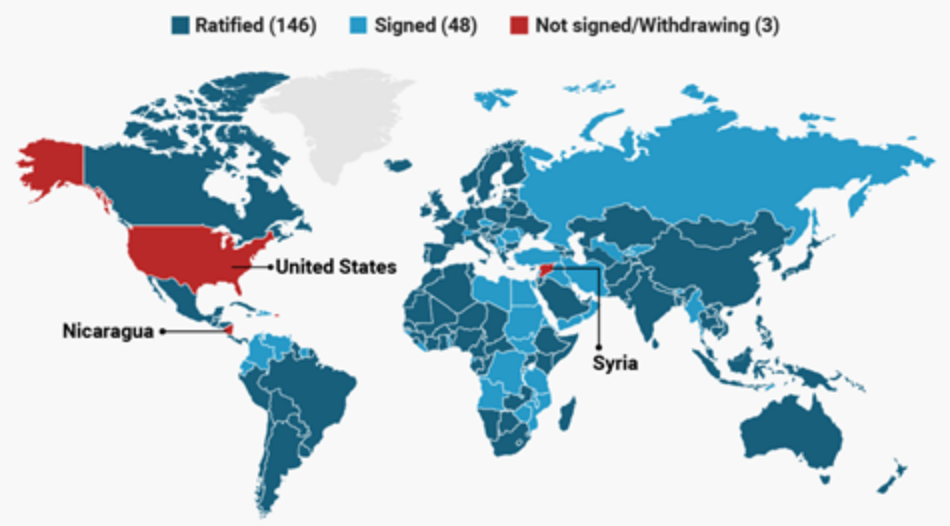


Figure 3.5 Agreement Status of Paris Agreement (2016) [19].

3.4 Previous Scope 3 Projects by Other Colleges/ Institutions

There have been quite a number of U.S and U.K institutions and colleges which accounted and reported their campus's Scope 3 emissions. Different institutions adopt different approaches and methods to determine Scope 3 emissions. In addition, different institutions cover different constraints of the scope, making the comparison more challenging.

3.4.1 Vassar College - Greenhouse Gas Reduction Plan

Vassar College has adopted the GHG reduction plan in 2004-2005 with the major objective of decreasing GHG emissions by an average of 4% annually. Although the calculation method for Scope 3 emissions isn't specified in the report, Vassar College Scope 3 covers (1) air travel, (2) trash recycling, (3) faculty/staff travel, (4) commuting. Vassar college reported a total of 5,094 metric tons of CO_2 emissions from Scope 3 related emissions. According to 2011 GHG reduction report, 22% of its total GHG emissions come from Scope 3 sources [22]. The plan also includes recommendations, such as improving the efficiency of heating/cooling system, purchasing carbon credits for air travel, and providing alternative commuting systems. As an overall emission, Vassar College was able to reduce its emissions 4% per year since 2004-2005.

3.4.2 California Institute of Technology - Measuring Caltech's Carbon Footprint

Caltech started measuring the carbon footprints of the campus since 2004. According to the report, "A Corporate Accounting and Reporting Standard", which is a protocol designed by World Resources Institute (WRI), has been followed [24]. They also used carbon footprint calculator called "CACP v5.0" [23]. However, only transportation is considered as a source of Scope 3 emission, and in 2007, only 12.6% of overall emission comes from Scope 3 which is 11878 metric tons of CO_2 emissions [24]. However, in 2016 report, there has been 6% increase in overall emissions compared to previous year.

3.4.3 Manchester Metropolitan University – Scope 3 Emissions Report

In 2015, Manchester Metropolitan University (MMU) published the Scope 3 emissions report. The university collected data on its own Scope 3 emissions related to operational waste, capital projects waste, water and wastewater, staff commuting, student commuting, business travel, student travel (home), procurement, leased residential (energy), electricity (transmission), fuel (WTT) and fugitive emissions. According to the report, 75% of the total CO_2 equivalent comes from Scope 3 emissions which is equivalent to 91,138 metric tons of CO_2 emissions [23]. The report also includes potential solutions to reduce the Scope 3 emissions. Unlike Vassar College's report, MMU includes supply chain emission as a source of Scope 3 emission [23].

3.4.4 University of Cambridge - footprinting, and Analysis of Scope 3 emissions

University of Cambridge collected the data of all factors affecting the university's Scope 3 emissions in 2014 with the help of the methodology published by the Higher Education Funding Council for England (HEFCE). The university recorded all the scope 3 emission factors provided by AECOM (architecture, engineering, construction, operations, and management) technology corporation such as water supply, wastewater treatment, waste collection and management, transport - commuting and business, procurement, electricity transmission and distribution losses (T & D), and well-to-tank (WTT) emissions for fuels. The total Scope 3 emissions for the reporting period financial year 2012/13 amounted to approximately 170,000 tonnes of CO_2 emissions.

3.5 WPI Sustainability Plan

WPI started its sustainability plan in FY14 (fiscal year). A major objective of this plan is to decrease the utility usage by 25% at the end of FY18. According to 2017 WPI GHG reduction plan, WPI has been measuring its Scope 1 and Scope 2 emissions since FY07. Although the amount of those emissions has been fluctuating due to campus activities (new buildings construction and renovations), there has been 7% decrease in total emissions in 2015 compared to previous year [WPI Sustainability Report, 15-16] to date. WPI has not accounted or measured its Scope 3 emissions. However, there has been a considerable number of accomplishments in implementing the GHG reduction plan. For example, numerous transportation alternatives such as SNAP and Gompei's Gears Bike has been established. WPI's goal includes reducing the gross Scope 1 and Scope 2 emissions by 20% by FY25.

4. Methodology

The main focus on calculating and estimating Scope 3 emission for our IQP project is "Transportation-related" emission. The transportation mode will be separated into two main types: ground and air transportation so that we can understand which type of emission is producing more and it will be easy to create a sustainability plan if we want to reduce the emission. We will mainly be collecting data and estimating the carbon emissions from the acquired data using Campus Carbon Calculator (CCC) from University of New Hampshire (UNH) [28]. The calculator is a tool to keep track of greenhouse gas emission for organizations and helps them understand the amount of emission produced by all types of Scopes in one place easily. It is used by most U.S Universities and Colleges that try to monitor the carbon emission and has two options that include online platform CCC and excel based spreadsheet CCC. To calculate the

amount of emission, total distance traveled miles are going to be used as input for both platforms. The online platform is used only to calculate emission for student study abroad section of air travel as it offers unlimited inputs of project center locations along with name and number of students. However, Excel-based CCC will be used for the rest of air travel sections and ground transportation.

4.1 Data

It is essential to acquire the distance in miles traveled made by students, faculty, and staff for any type of transportation to get WPI and WPI-related business trips. The distance in miles is the most important data needed for the estimation and calculation of Scope 3 in CCC. We will be discussing how we are going to gather the data, what type of methods we are going to use, and how we will categorize the data into those methods in this section.

4.1.1 Data Collection

In order to calculate the amount of Scope 3 emission in CCC platforms, we first categorized students, faculty, and staff into commuters, non-commuters, and students going to global project centers. We define "Commuter" as a person who comes from permanent address to WPI by any mode of transportation. As an example, if a student has his/her permanent address at Rhode Island and commutes to WPI from there, we assumed that person as a commuter. We define "Non-commuter" as a person who comes far from permanent address, lives near WPI campus area, and commutes to WPI. For example, an international student or U.S student from California comes from permanent address, lives at a house near WPI campus area, and comes to WPI by walking or driving. We assumed that all faculty and staff members are commuters and their WPI-related business travel and conference information are needed for WPI-related air travel section. Overall, we will need the data of distance miles traveled, frequency of going back to permanent address, type of transportation used, and the number of students, faculty, and staff.

We acquired the total number of students currently attending from "WPI's 2017 Fact Book"[29] released on October 1, 2017, which reports how many students are seeking which degrees, where they come from, and ethnicity for both undergraduate and graduate students of WPI yearly. That fact book only shows the number of students in total but does not indicate where the students come from. In order to get the zip code information for all students, faculty, and staff, we have to contact the WPI Registrar Office. With the help of our advisor Professor Orr, we managed to get information regarding the zip code data and the total number of students going to IQP project centers for this year from Mr. Daniel Richard, Associate Registrar of WPI Registrar Office. The distance between each location and WPI is calculated using google maps. As you can see in Table 4.1, '1' from column A refers to the undergraduate student and '5' refers to the graduate. Column 'D' shows the name of the city whereas column 'H' stands the country. This distance finding process between each city and WPI is made to all WPI bodies and IQP/MQP centers and the data is put separately as in column 'J' for students, faculty and staff, and project centers since we want to know the emission difference from those categories. All these distances are summed up and used in calculating the emission after the process is complete.

Table 4.1 Finding distance between each location and WPI

	A	B	C	D	E	F	G	H	I	J
1	1		PR	Tirana			AL	ALBANIA		4435.41
2	1		PR	Tirana			AL	ALBANIA		4435.41
3	1		PR	Tirana			AL	ALBANIA		4435.41
4	1		PR	Tirana		1001	AL	ALBANIA		4435.41
5	1		PR	Pogradec		7301	AL	ALBANIA		4488.04
6	1		PR	Seatons Village			AC	ANTIGUA AND BARBUDA		1638.19
7	1		PR	St. Georges			AC	ANTIGUA AND BARBUDA		1830.54

Although we acquired this data, it is still unclear that how many average round trips are made during a year and what types of transportation are used. Therefore, it is necessary to conduct a survey of students, faculties, and staff. We created two surveys; one for students and the other for faculty and staff. For the student survey, we asked questions such as “Are you undergraduate or graduate student?”, “Are you from inside MA or outside MA or outside the US?”, you can find more about survey questions and a few sample answers in Appendix C to differentiate the categories of students and their locations. However, we have a different approach for faculty and staff survey from which we would like to know more about the average round trip made per week, average weeks per year, and WPI-related travels including faculties going to project centers and attending conferences sponsored by WPI. In order to conduct an academic survey in WPI, we first had to get an approval from Institutional Review Board (IRB) of WPI [30]. IRB is the organization that reviews the application for research involving humans studies and various fields such as engineering, sociological, and physiological monthly. After getting approval from IRB, we were able to conduct the survey that asks the information of how many round trips are made to their permanent address per year(or) week, what mode of travel is used, and the zip codes of their address. The survey took part in an important role to analyze and calculate the average number of round trips made to different locations. To get as much survey data as possible, we reached out to our friends at WPI, went to the library and asked people to fill out the survey, and Professor Orr helped us in sending emails to faculty, staff, and graduate students.

4.1.2 Data Analysis

In this section, we are going to analyze the data we gathered and separate into two groups for calculation; air transportation and ground transportation. From students section, all commuters will go into ground transportation, non-commuters will include in both transportations, and lastly, students going to global project center will be put in the air transportation. Data for faculty and staff will be calculated in ground transportation except for WPI-related travel that will be in air and ground transportation. Since we mentioned about the commuters above, we know that they are not using air transportation to get back to their permanent addresses. Students coming to/from home includes non-commuters who use air transportation to come to WPI and going to global project centers will only be achieved by means of air travel. WPI-related air travel means travel made by faculty and staff for business-related travel such as going to IQP/MQP centers and conferences that are sponsored by WPI to go there.

4.2 Air Transportation

Air transportation produces a large amount of Scope 3 CO_2 emission and can be categorized into three main parts; (1) students coming to/from home, (2) going to IQP/MQP centers and (3) faculty and staff WPI-related air travel. In this section of air travel, the air distance refers to the distance between Boston and the destination. The ground transportation from Boston Logan Airport to WPI is counted for each air travel.

4.2.1 Air Travel from Home

In this section, we will be calculating and estimating the distance between permanent addresses and WPI for each WPI's along with the survey data. As mentioned in section 4.1, we have the total number of distance miles between everyone's permanent address and WPI. We categorized international and U.S students differently according to the survey conducted. Furthermore, we divided undergraduate and graduate air travels for these categories for the reason that the graduates can take online courses without coming to WPI. When we assume that all undergraduates will be coming to WPI, it will enhance and lead the data to go wrong easily if we assume the same way to graduates. The total air distance of one way from permanent address to WPI is calculated as mentioned above in section 4.1 and form the survey, the average round-trip back to home for each year is calculated as in the last column of table 4.2.

Table 4.2 Data of International Students Travel back Home

	A	B	C	D
1	International Student	Total Student	Total one-way distance(Miles)	Average RT/per year
2	Undergraduate	434	2561828.42	1.5
3	Graduate	578	4036650.1	1.36
4				

The second column from the table indicates the number of international students in undergraduate and graduate level that we get from the fact book. Column 'C' shows the total one-way distance we found using the Google Maps and country information from the zip code data. The result is multiplied with the average round trip to get the total distance, which acts as the final input to the last column of "Air" from "Student Travel to/from home" of CCC spreadsheet in table 4.3.

$$T_{Final} = T_{Total} * A_{RT} \quad \text{eq[4.1]}$$

$$A_{RT} = (S_{Data} / S_{Total}) * T_{Student} \quad \text{eq[4.2]}$$

where,

T_{Final} = Final one-way distance multiplied by average number of round-trip

T_{Total} = Total one-way distance for international students

A_{RT} = Average round-trip per year from survey

S_{Data} = Number of round trips filled out by survey respondents for different level (undergraduate or graduate) and type (International or U.S student)

S_{Total} = Total number of survey respondents by different level and type

$T_{Student}$ = Total number of students from factbook

Table 4.3 CCC Excel-based spreadsheet

--- Scope 3 Emissions Sources ---																						
Commuting - click here to enter data											Directly Financed Outsourced Travel							Study Abroad Travel	Student Travel to/from Home (OPTIONAL)				
Faculty / Staff Commuting					Student Commuting						Air Travel		Other										
Carbon-free Modes	Automobile	Bus	Light Rail	Commuter Rail	Carbon-free Modes	Automobile	Bus	Light Rail	Commuter Rail		Faculty / Staff	Students	Train	Taxi / Ferry / Rental Car	Bus	Alternative Fuel Bus	Personal Mileage Reimbursement	Air	Automobile	Carpool	Bus	Train	Air
Miles	Miles	Passenger Miles	Passenger Miles	Passenger Miles	Miles	Miles	Passenger Miles	Passenger Miles	Passenger Miles		Miles	Miles	Passenger Miles	Miles	Passenger Miles	Passenger Miles	Miles	Passenger Miles	Miles	Miles	Passenger Miles	Passenger Miles	Passenger Miles
-	-	-	-	-	-	-	-	-	-														
-	-	-	-	-	-	-	-	-	-														
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-	-	-	-	-	-	-	-	-	-														

Unlike the international student's air travel, US students air travel is further divided into outside Massachusetts and inside Massachusetts. Although we know that there will be no people using air transportation from within Massachusetts, we wanted to make sure that it will be proportional when we find the average percentage for ground transportation.

$$P = (N_{Rider} / N_{Student})*100\% \qquad \text{eq[4.3]}$$

$$N_{Student} = \text{Total Student - Commuting student} \qquad \text{eq[4.4]}$$

where,

P = Percentage of number of people used for specific mode of travel from survey

N_{Rider} = Number of people who used the specific mode of travel from survey

$N_{Student}$ = Number of non-commuting student from survey

As shown in table 4.4, we first subtract the number of commuting students from the total number of students in the survey to get the amount of non-commuting student, then find the percentage of people who used air travel by dividing the number of people who took the plane by the non-commuting student. Non-commuting mile is calculated by multiplying total one-way distance with the percentage of non-commuting student corresponding to each level. The final result of air mile is acquired by multiplying non-commuting mile with the percentage of people who used the plane. It is combined with total distance miles from international student and put into CCC excel-based spreadsheet.

Table 4.4 Data of U.S Students Travel back Home

Type of Student	Total Student	Non-commuting Student	Non-commuting student%	Car, Bus	Car,Bus %	Plane	Plane%
Undergraduate	61	55	90%	40	73%	8	15%
Inside MA	29	24	83%	18	75%	0	0%
Outside MA	32	31	97%	22	71%	8	26%
Graduate	49	23	47%	18	78%	4	17%
Inside MA	28	4	14%	4	100%	0	0%
Outside MA	21	18	86%	13	72%	4	22%

Types of Students	Total One-Way Distance (Miles)	Non-Commuting Miles	Car,Bus (Miles)	Plane(Miles)	Train(Miles)	Walk(Miles)
Undergraduate	1270398	1145441	833048	166610	41652	41652
Inside MA	79092	65455	49091	0	5455	5455
Outside MA	1191306	1154078	819023	297827	0	0
Graduate	295341	138629	108492.5278	24109.45061	12054.72531	0
Inside MA	24123	3446	3446	0	861.5285714	0
Outside MA	271218	232473	167897	51660.56571	17882.50352	0

4.2.2 Student Study Abroad

It is easy to estimate the emission produced by air travel to go to IQP/MQP centers using the data from Registrar Office. This can be achieved by (1)getting the round-trip distance from WPI to the project center, (2) putting that result in "Value" slot in figure 4.1 and a total number of students for each project center to the online platform "Campus Carbon Calculator" (CCC). Online platform offers the opportunity to trace back and change the round trip distance mile and the number of students going to each project center if any changes are required. For MQP centers, Registrar's Office did not have the details of students going to each location so that we used the data from our advisor that provides the number of students for certain project centers. Method of estimation for getting to MQP center is the same as that of IQP.

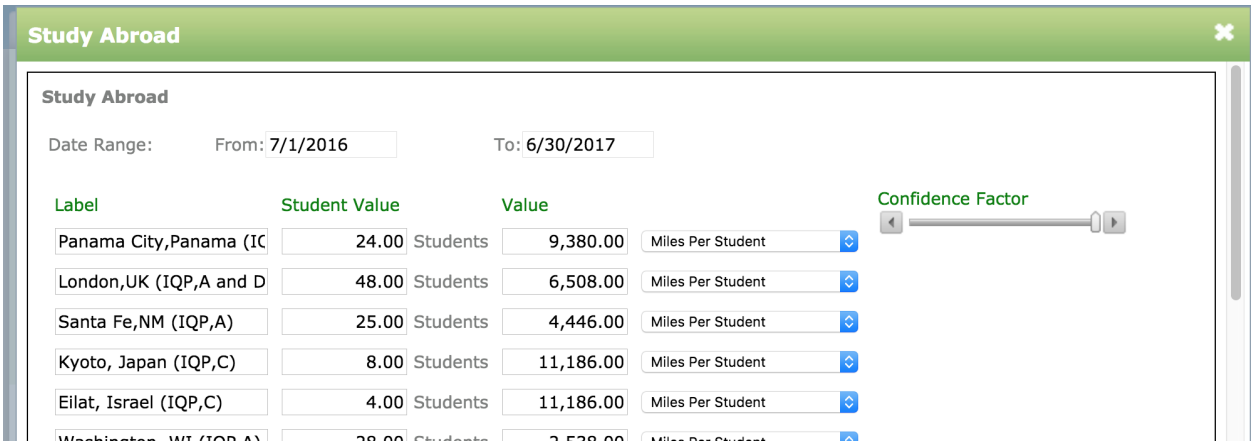

Figure 4.1 Data Entry on CCC online

4.2.3 WPI-Related Air Travel

This travel section is intended to estimate the emissions made by faculty and staff to attend conference and business travels related to WPI. It is calculated based only on the survey data with the total number of faculty and staff. In the survey, we asked about the number and name of destinations that took place in more than 50 miles from WPI for the past year. Using Google Maps, we calculated the distance from each location to WPI. The percentage of them who made air travel is obtained from the survey by dividing the number of respondents who made air travel with the total number of respondents.

$$T_{Total} = (S_{Traveller} / S_{Total}) * T_{Distance} * T_{People} \qquad \text{eq[4.5]}$$

where,
T_{Total} = Total amount of air distance
$S_{Traveller}$ = Number of people who took air travel from survey
S_{Total} = Total number of survey respondents
$T_{Distance}$ = Total number of distance miles traveled by survey respondents
T_{People} = Total number of Faculty and Staff

Using the formula above, we get the estimation of total air distance made by faculty and staff per year and put that result into Faculty/Staff "Directly Financed Outsourced Travel" where it is multiplied with emission factor of plane to get CO_2 emission.

	Directly Financed Outsourced Travel						
	Air Travel		Other				
r	Faculty / Staff	Students	Train	Taxi / Ferry / Rental Car	Bus	Alternative Fuel Bus	Personal Mileage Reimbursement
r	Miles	Miles	Passenger Miles	Miles	Passenger Miles	Passenger Miles	Miles
-							
-							

Figure 4.2 Data Entry in Excel-based CCC

4.3 Ground Transportation

Estimation of CO_2 emission for ground transportation is used with the Excel-based calculator. This type of transportation mainly includes student commuting and faculty and staff commuting. Carpool is calculated by dividing the total distance traveled by the number of people in the car. If five people in one car traveled for 100 miles, the carpool distance for each person will be 20 miles. As mentioned in air transportation section, graduate and undergraduate students do not have the same method to come to WPI. Most of the graduate class only takes place once a week while undergraduate has an average of four days a week. We also divided undergraduate and graduate level based on the locations such as inside MA, outside MA, and outside the U.S as we did in the survey. First of all, we count the number of students for these different zones from the zip code data. The method of calculation for both student and faculty and staff commuting is the same nevertheless we have to differentiate those two in order to know the emission by each group. Using the equation 4.3, we calculated the percentage of people who travel for each mode of transportation as in Table 4.5 and 4.6.

Table 4.5 Percentage of non-commuter students using different kinds of ground transportation

Type of Student	Total Student	Non-commuting Student	Non-commuting student%	Car, Bus	Car,Bus %	Plane	Plane%	Train	Train%
Undergraduate	61	55	90%	40	73%	8	15%	2	4%
Inside MA	29	24	83%	18	75%	0	0%	2	8%
Outside MA	32	31	97%	22	71%	8	26%	0	0%
Graduate	49	23	47%	18	78%	4	17%	2	9%
Inside MA	28	4	14%	4	100%	0	0%	1	25%
Outside MA	21	18	86%	13	72%	4	22%	1	8%

Table 4.6 Percentage of commuter students using different kinds of ground transportation

Type of Student	Total Student	Commuters	Commuter %	Walk	Walk %	Car	Car%	Bus	Bus%
Undergraduates	76	6	8%	2	33%	4	67%	0	0%
Inside MA	29	5	17%	2	40%	3	60%	0	0%
Outside MA	32	1	3%	0	0%	1	100%	0	0%
Outside USA	15	0	0%	0	0%	0	0%	0	0%
Graduate	103	25	24%	2	8%	20	80%	1	4%
Inside MA	48	22	46%	2	9%	18	82%	1	5%
Outside MA	22	3	14%	0	0%	2	67%	0	0%
Outside USA	33	0	0%	0	0%	0	0%	0	0%

We find the total number of commuters by proportionally multiplying the number of commuters from the survey with the total number of students from factbook from Figure 4.3 in each category. For example, in table 4.6, there are five commuters inside MA and total students of 29 live inside MA according to the survey. Total students who live in MA account for 1730 from the factbook. We find the percentage of commuters inside MA by dividing 5 by 29, then we multiply with 1730 resulting in the total of 298 commuters inside MA as in the third row of the third column in table 4.8. ((5/29)*1730) = 298

2017/18	Inside MA	Outside MA	Outside USA	Total
Undergraduates	1730	2177	434	4341
Graduates	893	683	578	2154

Figure 4.3 Number of students from factbook

Miles for each category are calculated by multiplying the percentage of each transportation and total one-way distance. The second row of total one-way distance in table 4.8, which is 79092 is multiplying by 17%, the percentage of commuters from table 4.6, to acquire the commuter distance in miles. The same method is used to calculate different transportation modes for commuter and non-commuter miles.

Table 4.7 Distance miles for non-commuting students

Types of Students	Total One-Way Distance (Miles)	Non-Commuting Miles	Car,Bus (Miles)	Plane(Miles)	Train(Miles)	Walk(Miles)
Undergraduate	1270398	1145441	833048	166610	41652	41652
Inside MA	79092	65455	49091	0	5455	5455
Outside MA	1191306	1154078	819023	297827	0	0
Graduate	295341	138629	108492.5278	24109.45061	12054.72531	0
Inside MA	24123	3446	3446	0	861.5285714	0
Outside MA	271218	232473	167897	51660.56571	17882.50352	0

Table 4.8 Distance miles for commuting students

Type of Student	Total one-way distance(Miles)	No. of Commuter	Commuter Miles	Walk(Mil	Car (Miles)	Bus(Passe	Train(Passe	er Miles)
Undergraduates	3832226	366	302544	100848	201696	0	0	
Inside MA	79092	298	13636	5455	8182	0	0	
Outside MA	1191306	68	37228	0	37228	0	0	
Outside USA	2561828	0	0	0	0	0	0	
Graduates	4331991	502	1051454	84116	841163	1402	160	
Inside MA	24123	409	11096	1009	9079	17	2	
Outside MA	271218	93	36984	0	24656	0	0	
Outside USA	4036650	0	0	0	0	0	0	

Finding distance process is the same as above for different modes of transportation in faculty and staff commuting. After finding the distance, we have to multiply each of the results with the average number

of round trips per year. For students, they commute to WPI for 28 weeks per year as there are four terms per year while faculty and staff make an average of 5 days a week and 45 weeks per year according to the survey as shown in Figure 4.6. After all these methods, we can put the total distance traveled along with the usage percentage for each mode of ground transportation to CCC spreadsheet.

Faculty/Staff

Total Number	Total Response	Car	Car%	Train	Train%	Walk	Walk%	EV	EV%	Carpool	Carpo	Average RT/wee	Weeks/yea
1331	107	76	71%	1	1%	7	7%	1	1%	21	20%	5	45

Figure 4.4 Faculty and Staff average round trip per year

5. Results

In this section, we will be explaining more about survey data analysis, data clarification, and calculation process of Scope 3 greenhouse gas. This section is divided into 5 subsections; (1)students commuting, (2)faculty/staff commuting, (3)students travel to/from home, (4)study abroad programs (IQP/MQP/HUA), and (5)faculty WPI related trips. In the following subsections, we will be summarizing how the calculation process is done for each type of Scope 3 transportation-related sources.

5.1 Student Commuting

This includes emission of greenhouse gas that results from students commuting to WPI from their permanent address during the academic year. The definition of commuters for this particular situation is a person who commutes to WPI from his/her permanent address during the academic year. Students who rent an apartment near campus or lives on campus dorm are not considered as commuters. The student body is divided into four different groups, (1) undergraduate students with a permanent address located inside Massachusetts, (2) undergraduate students with a permanent address located outside Massachusetts, (3) graduate students with a permanent address located inside Massachusetts, (4) graduate students with a permanent address located outside Massachusetts. The reason for dividing the student body into four groups is that average roundtrips per week for each group is different. For example, according to survey responses, undergraduate students in Massachusetts tend to commute more frequently per week than those who live outside of Massachusetts.

For this kind of emission, non-US (or) international students can be omitted. Excel-based Carbon Calculator is used instead of web-based CCC because the former allows multiple input entries for student commuting. According to the Excel-based calculator, the following data inputs are required to estimate the greenhouse gas emission.

(1) Number of Student Commuters
(2) Total Trips/Week
(3) Weeks/Year[1]
(4) % trips by different modes of travel

[1] When assuming how many weeks the students commute per year, we choose 28 weeks as a default value since single academic year includes four 7-weeks terms.

(5) Trip Distance for each mode of travel (Miles)

After the data analysis of student survey responses, Table 5.1 is obtained. The following equation is used to find percentage distribution of each mode of travel.

% Commuter for each mode of travel = (number of responses for each mode of travel / total response) X 100

Table 5.1: Survey Data Analysis for Student Commuting

Type of Student	**Total number of Responses**	**Total Commuter (From Survey)**	**Commuter percentage**	**Car % (C)[2]**	**Train % (C)**	**Walk % (C)**	**Bus % (C)**	**Average round trips/week**
Undergrad Inside MA	29	5	17%	60%	0%	40%	0%	7
Undergrad Outside MA	32	1	3%	100%	0%	0%	0%	5
Grad Inside MA	48	22	46%	82%	5%	9%	5%	4
Grad Outside MA	22	3	14%	67%	0%	0%	0%	4

In order to get the distance traveled by each mode of travel in miles, Table A.1 and A.2 are implemented.

Commuter Miles = ***Summation one-way distance for a respective group of students*** (Table A.1) x ***Commuter percentage*** (Table 5.1, Column 4)

No. of Commuter (Table 5.2 Column 2) = ***Total No. of respective group of student*** x ***Commuter Percentage*** (Table 5.1, Column 4)

Commuter Miles for each mode of travel = ***Commuter Miles*** x ***Percentage Commuter for each mode of travel*** (Table 5.2, column 3)

[2] (C) = commuter percentage for each mode of travel

Table 5.2 Table showing number of commuters and distance traveled by each mode of travel

Type of Student	No. of Commuter	Commuter Miles	Commute Walk(Miles)	Commute Car (Miles)	Commute Bus(Passenger Miles)	Commute Train (Passenger Miles)
Undergraduate Inside MA	298	13,636	5455	8,182	0	0
Undergraduate Outside MA	68	37,228	0	37,228	0	0
Graduate Inside MA	409	11,096	1009	9,079	504	504
Graduate Outside MA	93	36,984	0	24,656	0	0

The following calculation procedures are carried out to acquire Table 5.2. First of all, the number of commuters (Table 5.2, Column 2) is calculated by multiplying a total number of respective groups of students (Table A.2) with the commuter percentage (Table 5.1, Column 4). Commuter miles for each group of students is calculated by multiplying the summation of one-way distance of student (Table A.1) with commuter percentage (Table 5.1, Column 4). Then, commuter miles for each mode of travel (Table 5.2, Column 4-7) is calculated by multiplying the total one-way distance (Table A.1) with percentage use of a respective mode of travel (Table 5.1). After all the required input for calculation is satisfied and plugged into the Excel-based carbon calculator, the estimated amount of eCO_2 is yielded as follows.

The Excel-based calculator performs the following calculation to get estimate eCO_2 emissions.

Commuter miles for each mode of travel ***(One-way)*** (Table 5.2) X 2 X ***Average roundtrips/week*** (Table 5.1, Column 8) X ***Weeks/year*** (28 weeks) = ***Total Distance travelled for each mode of travel***

Total Distance travelled for each mode of travel ***(Miles)*** X ***Emission Factor for each mode of travel*** ***(MT eCO_2 / miles)*** = ***Estimate Emission*** ***(MT eCO_2)***

Table 5.3 Table showing the estimated amount of eCO_2 due to student commuting

Type of Commuting Student	Estimate eCO_2 (MT)
Undergraduate Inside MA	351
Undergraduate Outside MA	1,902
Graduate Inside MA	304
Graduate Outside MA	675

5.2 Faculty/Staff Commuting

In this section, the emission results from faculties and staff commuting to WPI from their permanent address and vice versa is calculated. Excel-based Carbon Calculator is used for this calculation. The following data inputs are required to estimate the emissions

(1) Number of Faculty/Staff commuter
(2) Total Trips/Week
(3) Weeks/Year
(4) % trips by different modes of travel
(5) Trip Distance for each mode of travel (Miles)

One difference between student commuting and faculty/staff commuting is that their working weeks per year can be varied according to their job status (Full-time, Part-time, etc.). Unlike student commuting, the working week of them is more than 28 weeks. According to the survey responses, they make an average of 5 round trips to Campus per week and 45 weeks per year. The survey responses for faculty and staff are analyzed as follows.

The following equation is used to find percentage distribution of each mode of travel.

% Commuter for each mode of travel** = (**number of response for each mode of travel** x **total response**) **X 100

Table 5.4: Survey Data Analysis for Faculty/Staff Commuting

Total Survey Response = 107

	Car	Train	Walk	EV	Carpool	Average Round Trips/week	Average Weeks/year
Number of Response (Percentage)	76 (71%)	1 (1%)	7 (7%)	1 (1%)	21 (20%)	5	45

By implementing Table A.1 and A.3 from Appendix A, the total miles traveled by each mode of travel can be calculated.

Commuter Miles = ***Summation one-way distance for Faculty/Staff*** (Table A.1)

Commuter Miles for each mode of travel = ***Commuter Miles*** x ***Percentage Commuter for each mode of travel***

Table 5.5: Table showing distance traveled by each mode of travel

	Total	**Car**	**Train**	**Walk**	**EV**	**Carpool**
Commuter Miles (One-way)	51,050	36,260	477	3,340	477	10,019

The following calculation procedures are undergone to acquire Table 5.6. First of all, the distance for each mode of travel (Table 5.5, Row 2) is calculated by multiplying the total one-way distance of faculty/staff (Table A.1) with percentage use of a respective mode of travel (Table 5.4). After all the required input for calculation is satisfied and plugged into the Excel-based carbon calculator, the estimated amount of eCO_2 due to faculty/staff commuting is yielded to be 42.7 $MTeCO_2$.

The Excel-based calculator undergoes following calculation to get estimate eCO_2 emissions.

Commuter miles for each mode of travel ***(One-way)*** (Table 5.5) X 2 X ***Average roundtrips/week*** (Table 5.4, Column 7) X ***Weeks/year*** (Table 5.4, Column 8) = ***Total Distance travelled for each mode of travel***

Total Distance travelled for each mode of travel ***(Miles)*** X ***Emission Factor for each mode of travel*** ***(MT eCO_2 / miles)*** = ***Estimate Emission*** ***(MT eCO_2)***

5.3 Student Travel

In this section, the emission results from students traveling (1) to WPI from their permanent address at the beginning of the academic year (2) from WPI to their permanent address at the end of the

academic year or during breaks is estimated. The students are sorted into US students and non-US (International)students. The reason is that according to survey responses [Table 5.4], US students made at least 4 times more round trips than non-US students.

5.3.1 International Students Travel

Since air transportation is the only mode of travel for international students to travel to/from their permanent address, total one-way distance in miles [Table A.1]is calculated. In order to obtain total round trip distance in passenger miles, total one-way distance is multiplied by 2. From the survey responses, we learned that average round trips per year for undergraduate and graduate are 1.5 and 1.36 respectively. By multiplying the total round trip distance (passenger miles) with average round trips/ year, total air distance traveled/year is calculated. After plugging into Excel-based carbon calculator, the total air distance traveled per year is multiplied by "air emission factor" which is 0.00482417 $MTCO_2$ / passenger mile in order to get estimate eCO_2 emission.

Table 5.6: Survey data analysis for International Students Travel

Academic Year 17/18	**Undergraduate Int' Students**	**Graduate Int' Students**
Population	434	578
Total one-way distance (Miles)	2,561,828	4,036,650
Average round trips/year	1.5	1.36
Total distance traveled/year (Passenger Miles)	81,755	116,797

$$\textit{Estimate MT } eCO_2 = \textit{Total One-Way Distance} \times \textit{Average Round Trips/year} \times \textit{Emission Factor for Air} \times \textit{Estimate MT } eCO_2$$

(0.00482417 MT eCO_2)

Table 5.7: Table showing estimate amount of eCO_2 due to International Student Travel

Academic Year 17/18	**Undergraduate Int' Students**	**Graduate Int' Students**
Total distance traveled/year (Passenger Miles)	7,685,485	10,979,688
Air Emission Factor ($MTeCO_2$/passenger miles)	0.00482417	0.00482417
Estimate $MTeCO_2$	3707.5	5296.6

5.3.2 U.S Students Travel

Unlike international students travel, U.S students travel to/from their permanent address is associated not only with air transportation but also with other types of transportation. Although the calculation procedures are quite similar to international student travel, it also needs to take account of other types of transportation too. According to the survey responses, the following data can be analyzed.

Table 5.8: Table showing the survey data analysis of U.S student travel

Total Survey Responses = 110

Type of Students	**Student who travels back home (U.S travel)**	**Car %**	**Plane%**	**Train %**
Undergraduate	90%	73%	15%	4%
Graduate	47%	78%	17%	9%

After getting the information about the percentage use for each mode of travel, table A.1 and A.2 is implemented to calculate the total round trip distance(Table 5.9, column 4) which is multiplied with average round trips/year (Table 5.9, column 2) to obtain total travelling distance (Table 5.9, column 5).

One-Way Distance for each mode of travel ***(One-way)*** (Table 5.9)	X	2	X	***Average roundtrips/year*** (Table 5.10, Column 2)	=	***Total Distance travelled for each mode of travel***

Table 5.9: Table showing total distance traveled by different type of transportation

Type of Students	**Average round trips/year**	**Total One-Way Distance (Miles)**	**Total round trip Distance (Miles)**	**Total Distance Traveled (Miles)**	**Car (Miles)**	**Plane (Passenger Miles)**	**Train (Passenger Miles)**
Undergraduate	12	572,721	1,145,441	13,745,288	9,996,573	21,268	1,897
Graduate	1.7	69,315	138,629	235,670	184,437	436	78
Total					1,018,1010	21,704	1,975

After plugging the total distance traveled by each mode of travel into the Excel-based calculator as shown in Table 5.6, the estimate eCO_2 is yielded to be 3717 MT eCO2.

The Excel-based calculator undergoes following calculation to get estimate eCO_2 emissions.

Total Distance travelled for each mode of travel (Miles)	X	***Emission Factor for each mode of travel (MT eCO_2 / miles)***	=	***Estimate Emission (MT eCO_2)***

5.4 WPI-related travel (Faculty)

In this section, we will explain the calculation process to estimate the emission due to faculty business travel. In the survey, faculties are asked (1) if they go to WPI- related travel, (2)which transportation they use (ground or air), (3) how many WPI-related trips they go which is less than 50 miles and (4) the furthest WPI-related travel they went past year. The calculation process of ground and air transportation will be explained separately in following subsections.

5.4.1 Ground Transportation

In order to calculate the ground transportation, the total distance traveled is required. According to the survey responses, we obtain the following information.

Table 5.10 Table showing the survey data analysis of WPI-related travel (Ground Transportation)

Total Faculty Responses	**Those who travel WPI-related Trips with ground Transportation**	**% of faculty who travel with ground transportation**	**Average round trips per year (For trips less than 50 miles)**
107	58	54%	7

Although average round trips per year [Table 5.10, Column 4], is based on trips that are less than 50 miles, we made an assumption that each one-way distance is 50 miles. We also assumed with all of the trips were made by personal car. From Table A.3, the total faculty population is 586 for academic year 17/18. By using the linear extrapolation method, the total miles traveled by ground transportation can be calculated

Table 5.11 Table showing the total ground distance traveled for WPI-related trips

Total Faculty Population (17/18)	**% of faculty who use ground transportation (From Survey)**	**54% of total faculty population**	**Round Trip Distance per person (2 x 50 miles)**	**Average round trips per year**	**Total distance traveled per person (100 miles x 7)**	**Total ground distance traveled by faculty populations (700 miles x 316)**

586	54%	316	100	7	700	221,200

After getting the total ground distance traveled, it is multiplied by the emission factor of a car which is 0.0003647 MT eCO_2 / mile [Table A.4]. Therefore, the estimate emissions from faculty WPI-related travel (ground transportation) is yielded to be 80.67 MT eCO_2.

5.4.2 Air Transportation

In order to calculate the total distance traveled by air, the faculties were asked the furthest WPI-related trips they have traveled past year. The distance between each trip location and WPI is gathered. The distances are summed up and divided by "total number of responses who use air transportation" [Table 5.12, column 2] to get the average distances traveled per person [Table 5.12, column 6]. Since the survey did not ask how many round trips per year were made for WPI-related air travel, we will make an assumption that only one round trip per year was made for each person. By analyzing the survey responses, we obtain the following information.

Table 5.12: Table showing the survey analysis WPI-related travel (Air Transportation)

Total Faculty Responses	**Faculty who use air transportation**	**% of faculty who use air transportation**	**Total one-way distance traveled**	**Total roundtrip distance traveled (One-way distance x 2)**	**Total roundtrip distance traveled per person**
107	42	39%	139,731	279,462	6,654

Table 5.13 Table showing the total air distance traveled for WPI-related trips

Total Faculty Population (17/18)	**% of faculty who use air transportation (From Survey)**	**39% of faculty population**	**Total roundtrip distance traveled per person**	**Total air distance traveled by faculty population**
586	39%	228	6,654	1,517,112

The same linear extrapolation method used for ground transportation is applied for air transportation to obtain the total air distance traveled by total faculty population. After getting the total distance traveled by total faculty population, it is multiplied by air emission factor which is 0.00482417 MT eCO_2 to get estimate emission which is yielded to be 732 MT eCO_2.

5.5 Study Abroad Programs (IQP/MQP/HUA)

The emission due to study abroad program is completely associated with air transportation. For this type of emission, web-based Campus Carbon Calculator is used since it allows multiple data entries. In order to calculate the estimate eCO_2 emission, the following inputs are required.

(1) Number of students
(2) Total Miles per student
(3) Confidence Factor

First of all, a total number students who enrolled in each project center is gathered from WPI registrar office. All the information about student headcounts and project centers distances can be accessed by using the links mentioned in Appendix B. The total round trip distance from each project center to WPI is calculated.

After putting the number of students and total passenger miles per student, web-based calculator asks the user to choose confidence factor which can be either 0, 25, 50,75 or 100 depending on the level of uncertainties in the calculation. Due to the fact that some MQP student headcounts are missing and there is no information about the flight transits and type of aircraft that each student used to travel, we decided to choose 75 as confidence factor. Although the estimate eCO_2 emission is independent of the value of confidence factor, it can determine the margin of error for data accuracy. The estimate emission of the greenhouse gas due to IQP/MQP/HUA is yielded to be 7,433 MT eCO_2.

5.6 Data Summary

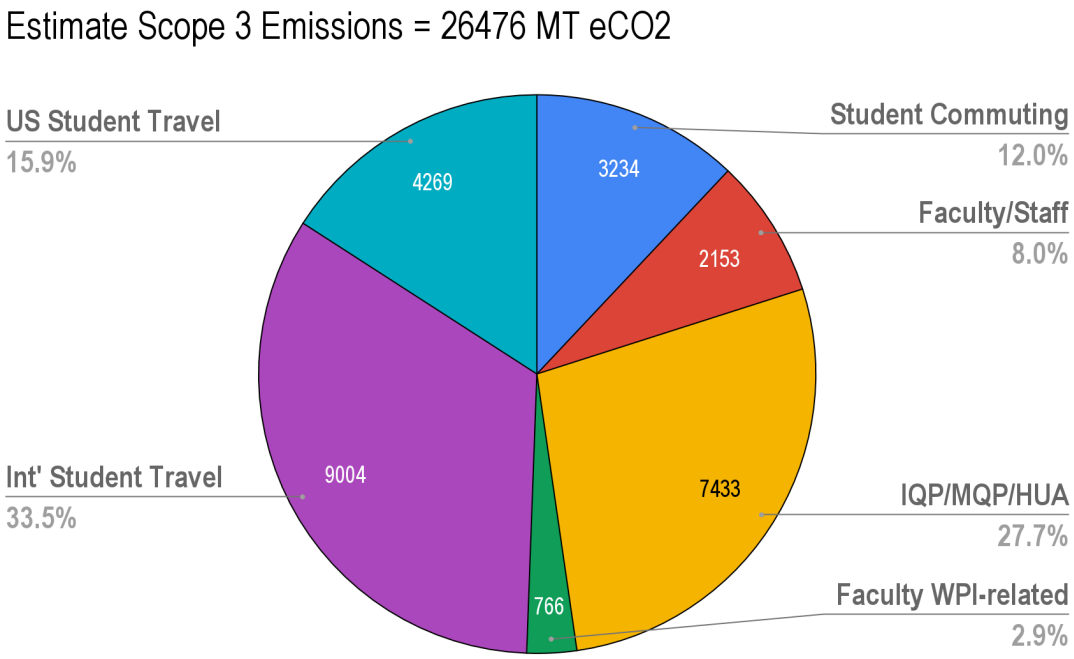

Figure 5.14 Pie Chart representing the value and percentage of different Scope 3 emissions

According to Figure 5.14, international students traveling to and from WPI is responsible for the largest contributor (33.5%) of the total Scope 3 emissions while study abroad programs (IQP/MQP/HUA) is the second largest contributor to Scope 3 (27.7%). This may be partly due to the fact that international student travel and study abroad programs consume more air miles compared to other Scope 3 sources. The smallest contributor to Scope 3 emissions in WPI is faculty WPI- related travel which is responsible for nearly 3% of the total emission. It is mentioned in the result section 5.4 that several assumptions have been made in calculating emissions from faculty WPI-related travel. Therefore, the estimated emission amount for this source is less accurate.

According to Figure 5.15, it is clear that Scope 3 emission from WPI covers over 60% of the total greenhouse gas emissions. While the amount of emissions for Scope 1 and Scope 2 account nearly 17500 MT eCO_2 in 2017, Scope 3 emission is almost 26500 MT eCO_2.

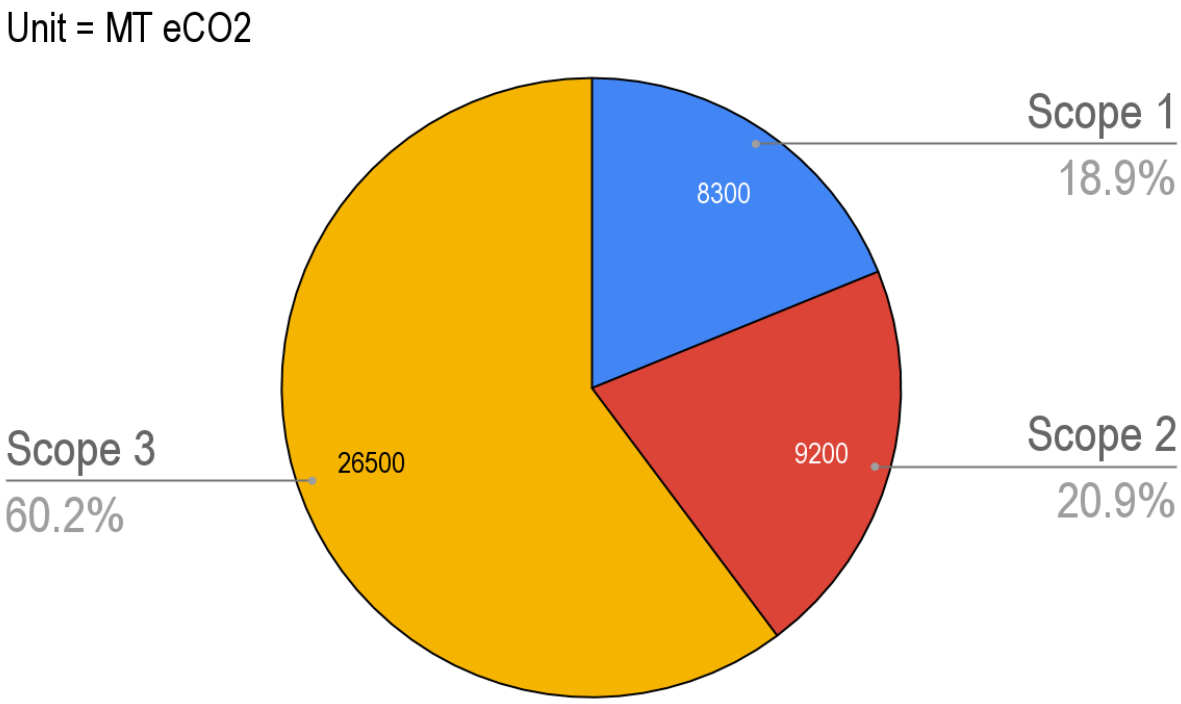

Figure 5.15 Pie Chart showing the value and percentage of different Scopes of Emissions [33]

5.7 Accuracy of Result

Apart from certain demographic questions, there can be an infinite degree of errors and inaccuracy in the survey. Some of the inaccuracy of the survey results from researchers' bias, survey respondents' interest in survey subject etc. It is important for the survey researchers to clearly identify their target population size, sample size and margin of error before they conduct the survey.

According to online survey tool "Survey Monkey", survey researchers can find the number of samples (survey respondents) required by using the sample size calculator [2]. The equation behind that

calculator is mentioned below.

$$\text{Sample Size} = \frac{\frac{z^2\, p(1-p)}{e^2}}{1+\frac{z^2\, p(1-p)}{e^2 N}}$$

Where N = population size
e = margin of error (as a decimal)
z = z-score
p = percentage value (as a decimal)

Population size is defined by the total number of people who represent in the survey. For example, if one wants to know if the campus food is preferable or not, his or her population size would include all the students and faculties who have meal plans. However, it is sometimes required to do some research to identify your population size.

Margin of error determines how large the uncertainty of result can have. It is inversely proportional to the number of the sample size (survey respondents). This means larger the sample size is, smaller the margin of error.

Confidence level is one way to measure how reliable the survey results are. It is represented by a percentage value. The most common standards of confidence level ranged from 80% to 99% depending on the type of survey subject. For example, if it is a clinical trial survey, one must need to get confidence level of 99% instead of 85%. However, for some surveys, the confidence level can be dependent on the number of survey respondents (sample size).

The percentage value is usually used to calculate the sample size for particular questions. If the certain survey is previously conducted, 75% of the people answered “yes” to a certain question, the percentage value of 0.75 should be used to find the sample size if the same survey is conducted again. However, the percentage value is usually 0.5 if the survey is conducted for the first time. This will produce the sample size value that is neither too high nor too low.

After utilizing the equation mentioned above, the accuracy of the results for students and faculties can be calculated since we have the data of total student and faculty population in WPI (population size) and total survey responses of students and faculties (sample size). It is found out that margin of error (or)the accuracy of the result for students is 9.57% and that of faculties is 12.4%. However, the margin of error for this calculation is only true for a survey with one question. Since the surveys we conducted to students and faculties include several questions, the margin of error can largely be increased and the accuracy of the results can be influenced.

6. Recommendations

6.1.Recommendations for more accurate data

Since WPI is pertaining to create an effective sustainability plan to reduce carbon emission, it is important that the data for each type of scope should be consistent with accuracy. The recommendations for more data accuracy in order to get a more accurate calculation include

- Surveys play a big role in getting the data that we cannot reach by WPI's given resources. Getting more surveys can give a more accurate data. In order to get more survey results, we can try to send out the survey email from WPI's emails, persuade all the WPI's sustainability enthusiastic Professors to send out the survey email to all their students, get a booth in Campus Center and exchange some food or candy treats with the surveys and go to the library and ask the students personally to take survey in order to get more surveys.
- A kind of unified system should be developed for recording and report WPI related business travel by the faculty and staff in order to get the more accurate data for business travels related Scope 3 carbon emissions.
- Monitor and report on student travel home by air during the breaks by getting the data from the WPI International House for getting the accurate data for international students whereas for the accuracy of the data for students going back home by air travel within the United States is to report on them to be developed WPI's system for travel reporting in order to get a more accurate data for students' air travel related Scope 3 carbon emissions.
- Encouraging the students, faculty, and staff to change and update their actual address zip codes where they commute to WPI every year with the information that changing and updating the address can actually benefit in more data accuracy for the WPI related projects using this more accurate data for commuting related Scope 3 carbon emissions.
- The next projects to measure Scope 3 emissions should just measure for the previous year of the year of the project time in order to avoid difficulties with getting data from unregistered study abroad IQPs and MQPs. For example, we faced a problem with getting the data from the student body of study abroad MQP centers being not registered yet for the students during C and D terms while we were doing our project in A and B terms.

6.2.Recommendations for reducing Scope 3 related carbon emissions

As WPI is creating a more eco-friendly community, reducing the carbon emissions by commuters can contribute a lot to create a more sustainable environment. Our recommendations to reduce carbon emissions include

- Encourage and educate the commuters to consider using electric cars which emit zero GHG emissions and chargeable on WPI campus' charging stations.
- Diesel-fueled cars can be more beneficial to the environment than gasoline-fueled cars in which diesel fuel is more efficient than gasoline in terms of GHG emissions by about 13% and diesel vehicles have better fuel economy as diesel vehicles get approximately 25% better gas mileage.

- The use of hybrid vehicles can reduce the carbon emission by a considerable amount of commuters because hybrid vehicles can more than double the gas mileage of conventional cars.
- Carpooling during the commute to WPI can also be a factor for reducing carbon emissions.

7. Conclusion

This report of WPI Scope 3 emissions is the building block of a larger process to profile the University's carbon footprint. This project is the first project to estimate WPI's Scope 3 carbon emissions. In this report, we estimated and calculated the carbon emissions caused by the transportation. Upon completion of our project, we believe that we can give WPI some visions to implement WPI's own Scope 3 related sustainability goals.

The total Scope 3 CO_2e emissions assessment for WPI amounts to 24,500 metric tons for the fiscal year 17. The total Scope 1 and 2 emissions assessment for the University amounts to 16,000 tonnes for the fiscal year 17. These results demonstrate that the Scope 3 emissions represent the largest source of CO_2e emissions for the University, making up around 60% of the total annual emission when combined with the figures for Scope 1 and Scope 2.

We suggest that the University conduct an all-inclusive University-wide (all departments and offices) assessment of GHG inventory on Scope 3 emissions such as the procurement, transmission and distribution losses, waste and water. This assessment would reveal opportunities to increase purchasing efficiencies. With this information, the University would be able to take a few different approaches to reduce supply chain emissions. The University should recognize offices and departments with the highest spending and implement a sustainable purchasing plan that outlines the low-impact products. Educating purchasers about supply chain emissions is an easy way to begin changing purchasing habits and raising awareness on the topic. Through taking proactive steps towards evaluating and reducing the University's Scope 3 emissions profile, the University could effectively mitigate climate change and become a leader among other institutions of higher education.

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Appendix A

Table A.1: Summation of one-way distances between each student's permanent location and WPI

Type of Student	**Total one-way distance(Miles)**
Undergraduates	3,832,226
Inside MA	79,092
Outside MA	1,191,306
Outside USA	2,561,828
Type of Student	**Total one-way distance (Miles)**
Graduates	4,331,991
Inside MA	24,123
Outside MA	271,218
Outside USA	4,036,650
Faculty/Staff	51,050

Table A.2: Student headcounts for academic year 2017/18 [WPI factbook 2017]

Type of Student	Undergraduate	Graduate
Inside MA	1,730	893
Outside MA	2,177	683
Outside US	434	578
Total	4,341	2,154

Table A.3: Faculty/Staff headcounts for academic year 2017/18

Academic Year (17/18)	Headcounts
Faculty	586[3]
Staff	745
Total	1,331[4]

[3] According to IPEDS database
[4] According to WPI's Registrar Office

Table A.4: eCO_2 Emission Factor used in Excel-based Calculator for 2016-2017 fiscal year [UNH]

Mode of Transportation	**Emission Factor $MTeCO_2$/mile**	**Emission Factor $MTeCO_2$/ passenger mile**
Automobile	0.0003647	
Bus	N/A	0.0003212
Light Rail	N/A	0.00021146
Commuter Rail	N/A	0.0001809
Air	N/A	0.000482417
Train	N/A	0.0001497
Alternative Fuel (Biofuel, EV)	0	0
Rental Car	0.000364668	N/A

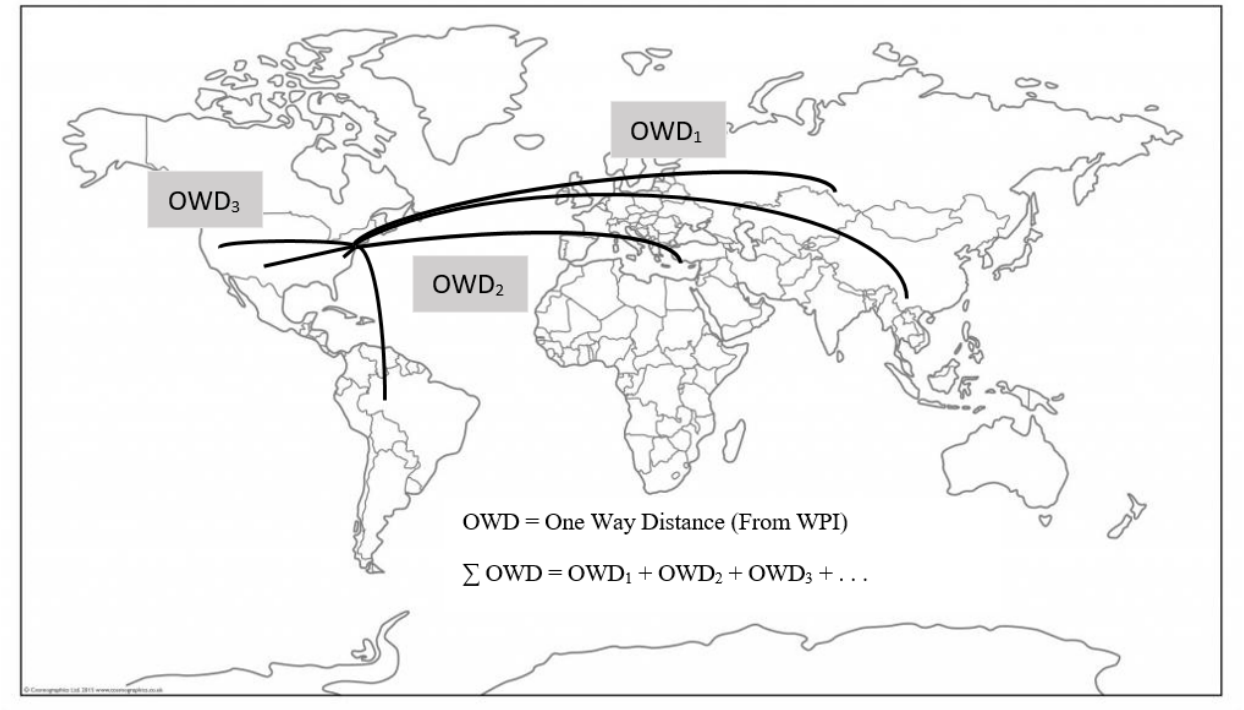

Figure A.5 Visual Explanation of how one-way distances from different permanent addresses are calculated

Appendix B

Table B.1: Spreadsheet showing part of the student survey responses

	Location of Permanent Address	Live on/near Campus	Commute from Permanent Address?	Country (Non-U	State/Region/Province	City/Town	Zip Code/Postal Code	Mode of Travel	Average Roudn Trips To PA per year	Country(Non-US)
2	In Massachusetts	Yes	No		MA	Sharon	2067	Car, Bus	7	0
3	In Massachusetts	Yes	No		MA	Boxford	1921	Car, Bus	10	
4	In Massachusetts	No	Yes		MA	Worcester	1609	Walk	2	
5	In Massachusetts	Yes	No		MA	Lynn	1904	Car, Bus	9	
6	In Massachusetts	No	Yes		MA	Worcester	1610	Car, Bus	0	
7	In Massachusetts	No	No		MA	Westfield		Car, Bus	16	
8	In Massachusetts	No	No		MA	West Boylston	1583	Car, Bus	30	
9	In Massachusetts	Yes	No		MA	Gloucester	1930	Car, Bus	3	
10	In Massachusetts	Yes	No		MA	Quincy	2169	Car, Bus	10	
11	In Massachusetts	Yes	No		MA	Agawam			10	
12	In Massachusetts	No	No		MA	Middlefield	1243	Car, Bus	9	
13	In Massachusetts	Yes	No		MA	Lincoln	1773	Car, Bus	10	

Table B.2: Spreadsheet showing part of the faculty/staff survey responses

	City	State	Zip Code	Mode of Travel	Car Sharing Number	Average Roundtrips Per Week	Average Number of Weeks per Year	WPI-Related Business Travel	Frequently Used Transportation	WPI related trips(<50miles) per ye	Farthest WPI related trip past year
2	Holden	MA	1520	Car	0	5	40	Yes	Air Transportation		
5	Dunstable	MA	1827	Car	0	10	47	Yes	Ground Transportation	25	Manchester NH
6	Holden	MA	1520	Car	1	5	52	Yes	Ground Transportation	0	Worcester
9	Attleboro	MA	2703	Car	0	5	47	Yes	Ground Transportation	4	Marlborough, MA
10	West Boylston	MA	1583	Car	0	4	47	Yes	Ground Transportation	6	Anaheim, California
11	Acton	MA	1720	Car	1	4	48	Yes	Ground Transportation	3	west coast
16	Spencer	MA	1562	Car	1	5	47	Yes	Air Transportation	4	Florida
18	Boston	MA	2111	Train		10	45	Yes	Air Transportation	10	Hangzhou, China
20	Worcester	MA	1602	Walk		0	0	Yes	Ground Transportation		
22	Springfield	MA	1108	Car	0	4	46	Yes	Air Transportation	12	Abuja, Nigeria; Lima, Peru
24	Worcester	MA	1602	Car	0	4	52	Yes	Air Transportation	3	Cardiff, United Kingdom
25	Worcester	MA	1605	Car	0	5	50	Yes	Ground Transportation	0	
27	North Providence	RI	2911	Car	0	5	50	Yes	Ground Transportation	0	5 miles
28		MA	1464	Car	0	4	50	Yes	Air Transportation	5	colorado

Link to MQP/HUA student headcounts and project centers' locations:
https://drive.google.com/open?id=1bb5uzfuNn-AlpuUBXikKeezoYbM1nYQUsXNa_nwwlxw
Link to IQP student headcounts and project centers' locations:
https://drive.google.com/open?id=1l4bN6UzQjvprAyKw7lCEe-JEScpsGUttSUgV29N3umk

Appendix C (Survey Questions)

Student Survey Form

WPI Scope 3 Greenhouse Gas Emissions

We are doing an IQP project which is to estimate the greenhouse gas emissions that results from the transportation/commuting of students, faculties and staffs. Your survey answers would be a great contribution to our project as well as to WPI sustainability plan.

PLEASE READ THIS BEFORE SURVEY
Permanent address is the state (For US students) or country (For Non-US students) where you come from and go back during long holidays or breaks.

* Required

1. **You are... ***
   Mark only one oval.
   - ◯ Undergraduate Student
   - ◯ Graduate Student
   - ◯ Exchange Student

2. **You have a permanent address which is located... ***
   Mark only one oval.
   - ◯ Outside of Massachusetts
   - ◯ In Massachusetts
   - ◯ Outside of US

3. **Do you live in Campus Dorm/ Campus Area Apartment?**
   Mark only one oval.
   - ◯ Yes *After the last question in this section, skip to question 5.*
   - ◯ No *After the last question in this section, skip to question 19.*

4. **Do you commute to Campus from your permanent address or do you live somewhere on or near campus during the academic year?**
   Mark only one oval.
   - ◯ Commute from permanent address *Skip to question 12.*
   - ◯ Live on or near campus *Skip to question 5.*

If you do not commute to WPI from your permanent address and live near Campus Area Apartment

5. **Which Country is your permanent address located? (Only for Non-US students)**

6. **Which State/Province/Region your permanent address is located?** *

7. **Which City/Town your permanent address is located?** *

8. **What is the zip code/ postal code of your permanent address?**

9. **What mode of travel do you use to visit/commute to your permanent address?**
Mark only one oval.

- ◯ Plane
- ◯ Car, Bus
- ◯ Train
- ◯ Walk
- ◯ Other: _____

10. **How frequent (average round-trips) do you visit your permanent address per year?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

11. **How frequent (average round-trips) do you visit your permanent address per year? (If more than 10)*****

Stop filling out this form.

If you commute to WPI from your permanent address

12. **Which Country is your permanent address located? (Only for Non-US students)**

13. **Which State your permanent address is located?** *

14. **Which City/Town your permanent address is located?** *

15. **What is the zip code/ postal code of your permanent address?**

16. **What mode of travel do you usually use to get to campus?**
Mark only one oval.

- ◯ Walking
- ◯ Bicycle
- ◯ Motorcycle
- ◯ Bus
- ◯ Car
- ◯ Other: _____

17. **If you come to campus in a car, how many WPI students or employees share the car? (excluding you)****
Mark only one oval.

0	1	2	3	4
◯	◯	◯	◯	◯

18. **How frequent (average round-trips) do you commute to WPI per week?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

If you do not live in Campus Dorm/ Campus Area Apartment

19. **Which State and City do you commute to WPI from?** *

20. **What is the zip code of your current address you are commuting from?**

21. **How frequent (average round-trips) do you commute to WPI per week?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

22. **What mode of travel do you use to commute to campus?**
Mark only one oval.

- ◯ Motorcycle
- ◯ Bus
- ◯ Car
- ◯ Other:

23. **If you come to campus in a car, how many other WPI students or employees share the car?**
Mark only one oval.

0	1	2	3	4
◯	◯	◯	◯	◯

24. **How frequent (average round-trips) do you commute to WPI per week?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

25. **What mode of travel do you use to visit/commute to your permanent address?**
Mark only one oval.

- ◯ Plane
- ◯ Car, Bus
- ◯ Train
- ◯ Other: _____

26. **How frequent (average round-trips) do you visit your permanent address per year?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

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A few answers from Student Survey

A	B	C	D	E	F	G	H
Timestamp	You are...	You have a permanent ad	Do you live in Campus D	Do you commute to Campus from your p	Which Country is your pe	Which State/Province/Re	Which City/T
11/8/2017 14:32:31	Graduate Student	In Massachusetts	No	Commute from permanent address			
11/8/2017 15:32:38	Graduate Student	In Massachusetts	No	Live on or near campus		MA	Billerica
11/8/2017 12:57:04	Undergraduate Student	Outside of Massachusetts	No	Live on or near campus			
11/8/2017 13:01:14	Undergraduate Student	Outside of US	Yes	Live on or near campus		Yangon	Yangon
11/8/2017 13:01:45	Undergraduate Student	Outside of US	No	Live on or near campus			Tirana
11/8/2017 13:02:46	Undergraduate Student	Outside of Massachusetts	Yes	Live on or near campus			
11/8/2017 13:10:15	Undergraduate Student	Outside of US	No	Live on or near campus		MA	Worcester
11/8/2017 13:18:54	Undergraduate Student	Outside of Massachusetts	Yes	Live on or near campus		NJ	Mendham
11/8/2017 13:25:49	Undergraduate Student	In Massachusetts	Yes	Live on or near campus		MA	Sharon

Faculty and Staff Survey Form

WPI Scope 3 Greenhouse Gas Emissions

We are doing an IQP project which is to estimate the greenhouse gas emissions that results from the transportation/commuting of students, faculties and staffs. Your survey answers would be a great contribution to our project as well as to WPI sustainability plan.

1. **Which State and City are you commuting from?**

_____

2. **What is the zip code of the address you are commuting from?**

_____

3. **What mode of travel do you usually use to get to campus?**
Mark only one oval.

- ◯ Car
- ◯ Motorcycle
- ◯ Train
- ◯ Bus
- ◯ Other: _____

4. **If you come to campus in a car, how many WPI employees share the car?**
Mark only one oval.

0	1	2	3	4
◯	◯	◯	◯	◯

5. **How frequently (average number of round-trips) do you commute to campus per week?**
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

6. **What is the average number of weeks per year to commute to WPI?**

_____

7. **Do you have to go any places for WPI-related business purposes?**
Mark only one oval.

- ◯ Yes *Skip to question 8.*
- ◯ No *Stop filling out this form.*

If you have to go WPI-related trips

8. **What type(s) of transportation do you most frequently use?**
Mark only one oval.

- ◯ Ground Transportation
- ◯ Air Transportation
- ◯ Other: _____

9. **How many WPI-related trips (at least 50 miles from campus) do you take each year?**

_____

10. **List the farthest destinations for WPI-related trips over the past year**

_____

_____

_____

_____

_____

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A few answers from Faculty and Staff Survey

A	B	C	D	E	F	G	H	I
Timestamp	Which State and City are	What is the zip code of th	What mode of travel do y	If you come to cam	How frequently (aver	What is the avera	Do you have to go	What type(s) of transp
11/10/2017 15:24:41	Holden, MA	1520	Car	0	5	40	Yes	Air Transportation
11/13/2017 9:05:27	Chatham, MA	2633	Car	0	1	30	No	
11/13/2017 9:05:50	Worcester, MA	1609	Walk	1	4	20	No	
11/13/2017 9:05:53	Dunstable MA	1827	Car	0	10	47	Yes	Ground Transportation
11/13/2017 9:05:55	Holden MA	1520	Car	1	5	52	Yes	Ground Transportation
11/13/2017 9:06:02	Worcester, MA	1603	Car	0	5	50	No	
11/13/2017 9:06:06	Worcester, MA	1602	Car	1	5	48	No	
11/13/2017 9:06:14	Attleboro, MA	2703	Car	0	5	47	Yes	Ground Transportation
11/13/2017 9:06:52	West Boylston, MA	1583	Car	0	4	47	Yes	Ground Transportation
11/13/2017 9:06:55	acton, ma	1720	Car	1	4	48	Yes	Ground Transportation